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Proceedings of the

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2024

Editors:

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Dr. Shelomi Krishnarajah

Sri Lanka Council for Agricultural Research Policy

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Enhancing Root Development in Poinsettia (*Euphorbia pulcherrima*) by Mitigating Latex-Induced Root Inhibition

Wijethunga B.A.N.A.[1]*, KumaraG.D.K.[1] and Senaratne M.M.D.J.[2]

[1] *Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka*
[2] *Floriculture Research and Development Unit, Royal Botanic Gardens, Peradeniya, Sri Lanka*

ABSTRACT

Euphorbia pulcherrima is in demand worldwide due to its stunning flower bracts with a retail value of just over one billion Euros annually. However, commercial nurseries struggle to meet the demand due to negative impact of latex secreted by laticifers on rooting of poinsettia stem cuttings. An experiment was conducted to find an effective method to treat against latex to enhance rooting ability of poinsettia stem cuttings. The experiment was setup in Completely Randomized Design with four treatments replicated five times. The effect of soaking stem cuttings in water for 24 hours, cold storage of cuttings at 8°C for 24 hours and cold storage of cuttings at 11°C for 8 hours before establishing the cuttings were tested in this study. Establishment of the cuttings without any treatments was used as the control. Number of roots, Mean length of the roots, length of the longest root and dry weight of the roots were used to evaluate the rooting performance. The rooting characteristics of poinsettia responded variably to different treatments. Cold storage at 8°C for 24 hours yielded a mean root length of 1.9 cm and a root dry weight of 35.3 mg, while a cold treatment at 11°C for 8 hours resulted in a median root number of 22.5, a maximum root length of 4.5 cm, and a dry weight of 39.1 mg—significantly enhancing all measured rooting parameters. Conversely, soaking stem cuttings in water for 24 hours led to notably lower rooting performance. These findings suggest that pre-establishment cold storage positively impacts rooting by mitigating latex-induced root inhibition in poinsettia.

Keywords: *Euphorbia pulcherrima*, latex, rooting, stem cuttings, treatments

INTRODUCTION

Ornamental plants are used to provide aesthetic purposes and to adorn open and enclosed spaces. And can be seen in public venues such as offices, schools, retail malls, and roadways (Cabahug *et al*., 2018).

Innovative concepts and new technologies are needed to be used in the cultivation and propagation of ornamental plants to support or expand current practices with increased benefits (Cardoso and Vendrame, 2022). Propagation is crucial for maintaining desirable traits in horticultural crops, particularly those that are vegetatively propagated (Ortiz *et al*., 2006).

Poinsettia, a member of the *Euphorbiaceae* family, is highly sensitive to both photoperiod and temperature (Karunananda and Peiris, 2011). This popular ornamental plant is in high demand, especially as a potted indoor plant during the Christmas season. Currently, there are approximately 300 commercial poinsettia varieties available on the market. (Lozoya-Gloria *et al*., 2023).

Propagation of poinsettia can be done vegetatively using cuttings, micropropagation and sexually through seeds. However, there are several limitations in conventional propagation of poinsettia by cuttings and seeds (Perera and Trader, 2010).

*nipuniwijethunga@gmail.com

Laticifers which are of the non-articulated type are found all over the poinsettia plant, primarily in specific parenchymatic and phloem tissues, and have a milky-white latex. The protoplast, which comprises a large continuous central vacuole filled with latex and a thin layer of cytoplasm, is still intact in the mature section of the cell. Numerous spherical inclusions or latex particles predominate in the latex (Madushani, 2022). In the case of *Sciadopitys verticillata*, minimizing the accumulation of latex-like sap at the cut ends of stems improved rooting success and root mass (Yates, 2006). Since poinsettia plant contains latex, the reported failures in propagation by stem cuttings may be due to negative impacts of latex on propagation.

It is crucial to investigate whether latex negatively impacts the rooting of poinsettia stem cuttings and to identify effective techniques to overcome this issue, ensuring improved rooting performance. Additionally, insights from this study could be applied to other plant species that contain latex, potentially enhancing propagation methods more broadly.

MATERIALS AND METHODS

The experiment was carried out in a misting room at Ceylon Foliage (Pvt) Limited, Boralanda, Sri Lanka. The experiment was setup in Completely Randomized Design with four treatments. Each treatment was replicated five times with two cuttings per each replicate.

Stem length was generally 2-2.5 inches (5-6 cm), and cuttings were taken from healthy, well grown poinsettia plants of the variety 'Ferrara' from Ceylon Foliage. Measuring of the length of the cutting was done from the base of the cutting to the growing tip and had approximately two mature leaves in that cutting. Bottom leaves were removed when it is within bottom half inch (Ecke III *et al*., 2004). Plug trays were cleaned properly and Jiffy® pellets were placed in plugs. Then, the Jiffy® pellets were wetted well. After that, wire mesh bench and the floor were washed with copper solution to prevent microbial infections. Finally, Jiffy® pellets were drenched using Homai® before establishing the cuttings. The ccuttings were treated as follows.

T1: As the control treatment, cuttings were planted without giving any treatment. T2: Cut ends of the cuttings were dipped in normal water for 24 hours. T3: Poinsettia cuttings were stored immediately under 8°C for 24 hours. T4: Poinsettia cuttings were stored under 11°C for 8 hours. Cuttings of T4 were collected with in-package gel ice and wetted newspapers to maintain cool condition (pre-cooling) between harvesting and storing in cold room.

In both treatments 3 and 4 cuttings were harvested and packed upside down in rigi foam cool boxes.

After giving the treatments, a root inducing hormone (0.3% IBA) was applied to every cutting before planting. Then, the poinsettia cuttings were planted in jiffy® pellets and labelled accordingly. Finally, plug trays of poinsettia were placed inside the misting room with regular misting.

Cuttings were uprooted five weeks after planting to obtain data. After uprooting each cutting, roots were washed thoroughly with tap water and allowed few minutes to dry. Then following root parameters of cuttings were measured carefully. Number of roots per cutting, Length of the roots (cm) per cutting, Length of the longest root (cm) of each cutting, Dry weight of the roots (g) was measured. Dry weight was obtained by oven drying each sample at 65°C for 3 days (Hu, Li and Jeong, 2020) and weighing the samples, using an analytical balance.

Data were statistically analysed using SAS (Statistical Analysis System) and one-way Analysis of Variance (ANOVA) was conducted, followed by mean separation to assess differences.

RESULTS AND DISCUSSION

Number of roots per cutting

Figure 1 indicates that the median number of roots of *Euphorbia pulcherrima* significantly varied (P<0.05) with the treatments. Cold treatment (11°C) for 8 hours showed the highest number of roots (22.5) while soaking the stem cuttings in water for 24 hours showing the lowest number of roots. Generally, number of roots counted provide a good impression of the rooting density in a soil profile (Bohm, 2012). Therefore, considering the number of roots as a parameter in the present study is very important. Additionally, cold storage can affect the availability of soluble carbohydrates in the cuttings, which is correlated with rooting in certain species (Agulló-Antón *et al*., 2011). And cold storage is commonly used to preserve the quality and extend the shelf life of cuttings of ornamental plants during transport (Vošnjak and Osterc, 2022).

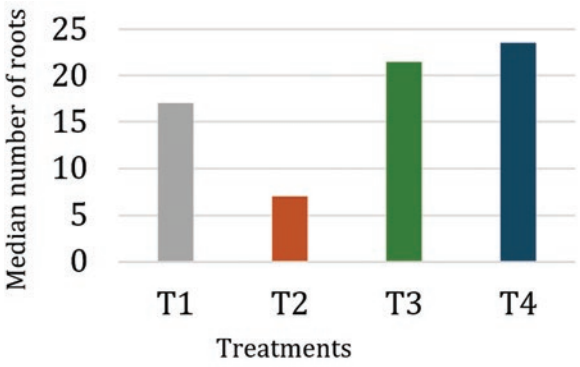

Figure 1: Variation of median number of roots of *Euphorbia pulcherrima* with treatments

Length of roots

According to *Figure 2*, the mean length of roots of *Euphorbia pulcherrima* significantly varied (P<0.05) with the treatments. The highest mean length of roots was given by both cold (8°C: 1.9 cm and 11°C) treatments while the lowest mean length of roots was being given by soaking the stem cuttings in water for 24 hours. Length of the root system is one of the most important parameters when considering the study of plant growth model (Gallot, 1984). According to Kiri (2023), the length of root system affects the root architecture and therefore absorption and anchorage. In the case of grapevines, cold storage at 1°C with high humidity has been found to maintain the quality of canes and improve rooting and shooting performance (Sabir and Sabir, 2018).

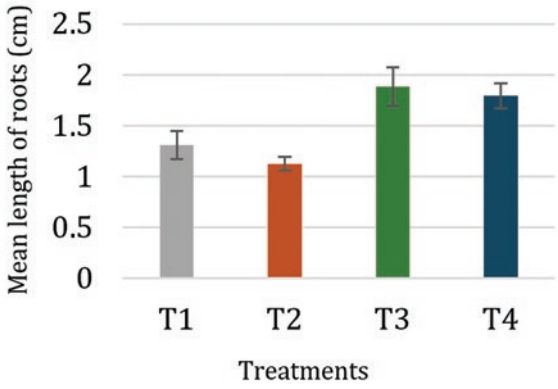

Figure 2: Variation of mean length of roots of *Euphorbia pulcherrima* with treatments

Length of the longest root

Figure 3 indicates that the mean length of the longest root of *Euphorbia pulcherrima* significantly varied (P<0.05) with the treatments. Cold treatment (11°C) for 8 hours has given the highest mean length of the longest root (4.5 cm) while water soaking for 24 hours has given the lowest mean length of the longest root. The size of root segments significantly affects their ability of regeneration and with longer root segments higher sprouting efficiency and more new roots can be observed (Verma *et al*., 2015). Therefore, when considering the propagation of poinsettia in the present study, the mean length of the longest root is an important parameter.

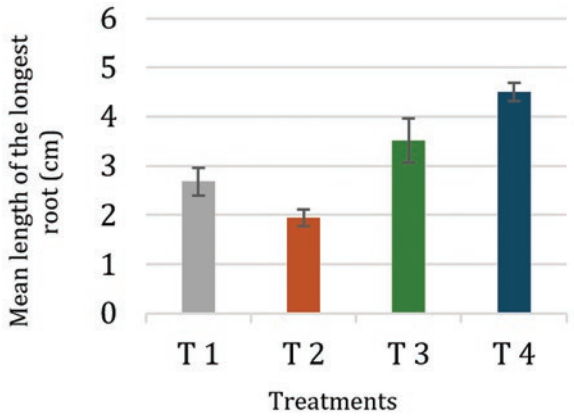

Figure 3: Variation of mean length of the longest root of *Euphorbia pulcherrima* with treatments

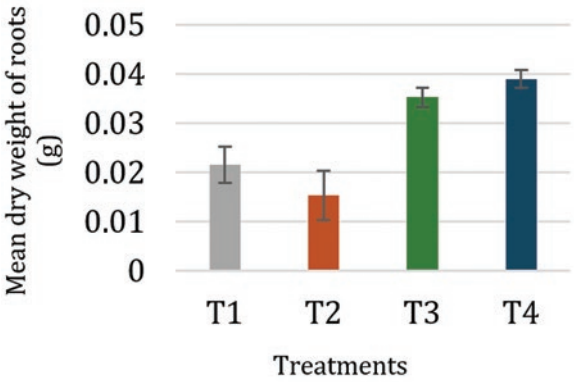

Figure 4: Variation of mean dry weight of roots of *Euphorbia pulcherrima* with treatments

Dry weight of roots

According to *Figure 4*, the mean dry weight of roots of *Euphorbia pulcherrima* significantly varied (P<0.05) with the treatments. Cold storage (8°C) for 24 hours and cold treatment (11°C) for 8 hours has significantly improved the mean dry weight of roots (0.0353 g and 0.0391 g, respectively) and there is no significant difference among those treatments. The lowest mean dry weight of roots resulted by the treatment, soaking the stem cuttings in water for 24 hours. There is no significant difference between control treatment and soaking stem cuttings in water for 24 hours. According to (Fageria and Moreira, 2011), the dry weight of roots is an important parameter for plant growth. Therefore, it is an important parameter when considering the propagation. It is reported that the latex from guayule plants remains stable and maintains its concentration and quality when stored at 4°C (Rodrigues *et al.*, 2009). Therefore, increment of dry weight of roots in cold storage (8°C) for 24 hours and cold treatment (11°C) for 8 hours in the present study may be due to cessation of latex flow under cold temperature.

CONCLUSION

Cold treatments (8°C for 24 hours and 11°C for 8 hours with pre-cooling) have proven effective in reducing the negative impact of latex on rooting, thereby enhancing rooting attributes in the propagation of *Euphorbia pulcherrima* stem cuttings.

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In-Vitro Seed Propagation Protocol for *Gastrochilus flabelliformis*: A Newly Recorded Orchid Species in Sri Lanka

Kularathne K.I.H.U.[1]*, Bandara M.M.L.I.W.[2], Jayalath J.M.S.M.[2] and Fonseka D.L.C.K.[1]

[1] *Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*
[2] *Department of National Botanic Gardens, Peradeniya, Sri Lanka*

ABSTRACT

Gastrochilus flabelliformis, commonly known as the Fan-Shaped Belly Lip Orchid, is an endangered species native to Sri Lanka and the Western Ghats of India. The orchid produces greenish-yellow flowers with red spots but exhibits low natural seed germination due to its dust-like seeds lacking endosperm. This limitation, coupled with restricted propagation, contributes to its endangered status. This study aimed to develop an efficient in vitro seed propagation protocol for conserving *Gastrochilus flabelliformis*. Seeds were harvested from healthy mother plants, surface sterilized, and cultured on three different basal media: ½ MS, MS, and KNC, supplemented with varying concentrations of coconut water, NAA, and GA3. Fourteen treatments were evaluated in a completely randomized design (CRD) with 10 replicates per treatment. Data collection began two weeks after seed inoculation and continued for 10 weeks. Results indicated that the MS medium supplemented with 30 g/L sucrose, 0.5 mg/L NAA, and 10% coconut water was optimal for germination. Similarly, the best results for ½ MS medium were achieved with 30 g/L sucrose, 1 mg/L NAA, and 10% coconut water. Notably, KNC medium without coconut water performed best, while KNC with coconut water had the highest contamination rate. This study successfully identified the most effective culture media combinations for in vitro propagation of *Gastrochilus flabelliformis*, offering a valuable conservation method for this endangered orchid.

Keywords: *Gastrochilus flabelliformis, in vitro* propagation, orchid conservation, seed germination, endangered species

INTRODUCTION

Gastrochilus flabelliformis, commonly known as the fan-shaped belly lip orchid, is recognized for its raceme-type inflorescence, with fan-like arranged sepals and petals (Amarasinghe *et al*., 2023). This orchid, native to Sri Lanka and the Western Ghats of India, produces greenish-yellow flowers with distinct red and yellow markings at the centre (Amarasinghe *et al*., 2023). The species is endangered, with its survival threatened by low seed germination rates due to lack of endosperm and limited success in vegetative propagation.

The Orchidaceae family, one of the largest angiosperm families, is found globally except in Antarctica, with the highest diversity in tropical regions like Madagascar, Borneo, and Indochina (Chase *et al*., 2015; Azizka *et al*., 2021). These habitat-specific plants have evolved unique adaptations for survival and reproduction. Orchids primarily disperse via small, wind-borne seeds, lacking endosperm, which makes germination challenging without symbiotic mycorrhizal fungi (Arditti *et al*., 1980).

Plant tissue culture techniques have been successfully employed in orchid conservation and propagation, although challenges remain with explant regeneration and genetic uniformity (Lal *et al*., 2020). Natural additives

*kularathne83at@ags.ruh.ac.lk

like coconut water have been shown to enhance seed germination and overcome dormancy barriers in orchid culture (Pradhan, Sahoo, & Parida, 2014).

The main objectives of this research are, to increase the germination rate of *Gastrochilus flabelliformis* seeds and assist in conservation efforts, this study attempts to create an ideal in vitro seed propagation strategy. This goal entails assessing how different medium compositions—including natural additives—affect seed germination.

MATERIALS AND METHODS

Seed pods of the *G. flabelliformis* orchid were used as explants, and three culture media (detailed below) were employed as treatments, each containing varying concentrations and combinations of growth hormones and coconut water.

T1- ½ Murashige & Skoog media

Identification of the best hormonal and additive combination with ½ MS medium for seed culture of *G. flabelliformis*

Table 1: best hormonal and additive combination with ½ MS medium for seed culture of *G. flabelliformis*.

Treatment	Medium Composition	NAA (mg/l)	Coconut Water (%)	GA_3 (mg/l)
$T1_1$	½ MS Media + 30g of Sucrose	1.0	0	0
$T1_2$	½ MS Media + 30g of Sucrose	1.0	0	1.5
$T1_3$	½ MS Media + 30g of Sucrose	1.0	10	0
$T1_4$	½ MS Media + 30g of Sucrose	1.0	10	1.5

T2- Murashige and Skoog media

Identification of the best hormonal and additive combination with full MS medium for seed culture of *G. flabelliformis*. To keep things consistent, I utilised the same sample of coconut water for each media treatment. I am aware that the variety, maturity, and age of coconut water can all affect its nutrient content, which may have an impact on germination. The goal was to reduce these differences across treatments by using a single, reliable source.

Table 2: best hormonal and additive combination with MS medium for seed culture of *G. flabelliformis*.

Treatment	Medium Composition	NAA (mg/l)	Coconut Water (%)
$T2_1$	MS Media + 30g of Sucrose	0.5	0
$T2_2$	MS Media + 30g of Sucrose	1.25	0
$T2_3$	MS Media + 30g of Sucrose	3.0	0
$T2_4$	MS Media + 30g of Sucrose	0	0
$T2_5$	MS Media + 30g of Sucrose	0.5	10
$T2_6$	MS Media + 30g of Sucrose	1.25	10
$T2_7$	MS Media + 30g of Sucrose	3.0	10
$T2_8$	MS Media + 30g of Sucrose	0	10

T3 – Knudson C medium

Identification of the impact of incorporating coconut water to the KNC medium for seed culture of *G. flabelliformis*.

Table 3: best additive combination with KNC medium for seed culture of *G. flabelliformis*

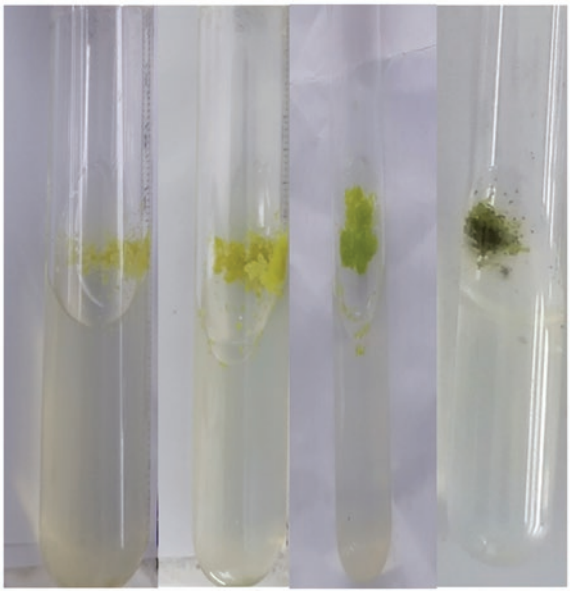
Treatment	Medium Composition	Coconut Water (%)
$T3_1$	KNC Media + 30g of Sucrose	0
$T3_2$	KNC Media + 30g of Sucrose	10

Seeds of *G. flabelliformis* were collected from mature seed capsules. The capsules were first sterilized under running tap water for 30 minutes. Afterward, the explants were surface sterilized by immersion in 70% ethanol for 1 minute, and the sterilization process was performed near a Bunsen burner for aseptic conditions. This sterilization step was repeated three times. The experiment was designed

using a Completely Randomized Design (CRD) with 14 different media treatments to assess their effects on seed germination. Each treatment had 10 replicates. The culture media used in the experiment included three main types. Data was collected every two weeks (at 14-day intervals). Given the distribution of the germination rate data, nonparametric statistical methods were employed for analysis. The Kruskal-Wallis test was used to compare differences among the treatments, followed by the Mann-Whitney U test for pairwise comparisons where applicable.

Table 4: different germination rates with germination scale

Seed colour	Germination state	scale
Original seed colour (light yellow)	Not germinated	1
Light green	Low germination	2
Green	Moderate germination	3
Dark green	Hight germination	4



Scale1 Scale2 Scale3 Scale4

Figure 1: germination scales

RESULT AND DISCUSSION

In this study, Treatment 01 involved the use of ½ MS medium supplemented with different concentrations of NAA and GA_3, both in the presence and absence of coconut water, to evaluate their effects on the germination of *G. flabelliformis* seeds. The germination rate was monitored and recorded biweekly to determine the optimal combination for seed germination.

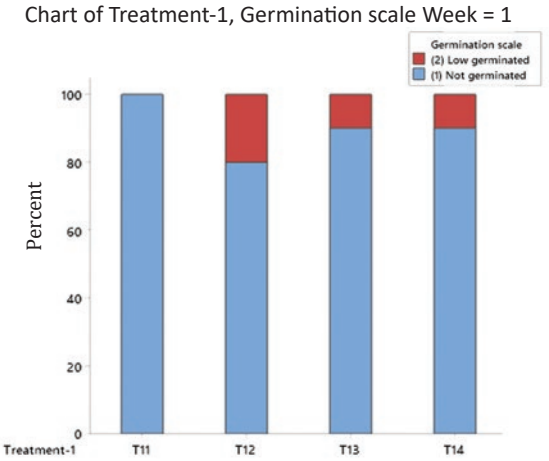


Figure 2: germination scale of ½ MS Media in fist two week.

During the first two weeks of the study, the germination rates across treatments showed significant variation. Treatment $T1_2$ achieved the highest germination rate, attributed to the combination of ½ MS medium, 30g of sucrose, 1 mg/l NAA, and 1.5 mg/l GA_3, without the addition of coconut water. Treatments $T1_3$ and $T1_4$ showed comparable germination rates, whereas $T1_1$, in contrast, did not produce any germination within the first two weeks.

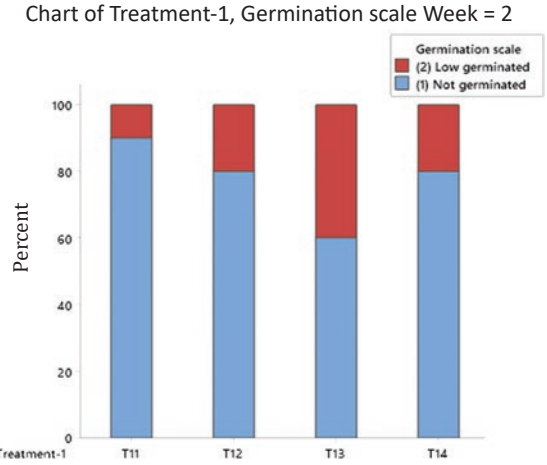


Figure 3: germination scale of ½ MS Media in fourth week.

In the first four weeks of the study, T13 demonstrated the highest germination rate overall. This treatment, which used ½ MS medium with 30g sucrose, 1 mg/l NAA, and 10% coconut water, effectively harnessed the synergistic effects of coconut water and growth regulators. The NAA likely provided the necessary hormonal stimulus for seed germination, while the coconut water contributed essential nutrients and growth factors. Additionally, $T1_1$ began showing signs of seed germination during this period.

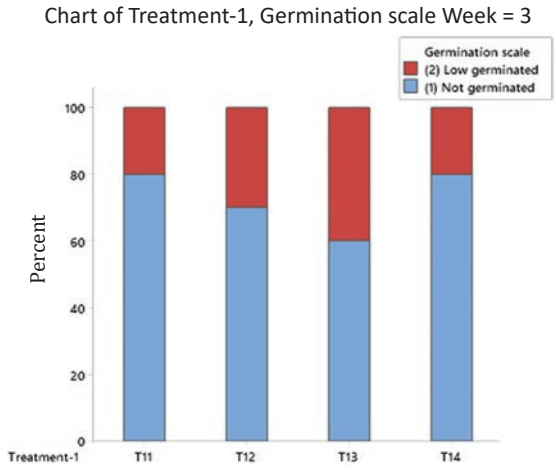


Figure 4: germination scale of ½ MS Media in sixth week.

In the first six weeks of the study, $T1_3$ emerged as the top performer, achieving the highest overall germination rate. This treatment, which utilized ½ MS medium supplemented with 30g sucrose, 1 mg/l NAA, and 10% coconut water, effectively combined the beneficial properties of both coconut water and growth regulators. The presence of NAA likely provided the hormonal stimulus needed for seed germination, while the coconut water contributed essential nutrients and growth factors. In comparison, the remaining treatments$T1_1$, $T1_2$, and $T1_4$ showed moderate germination rates.

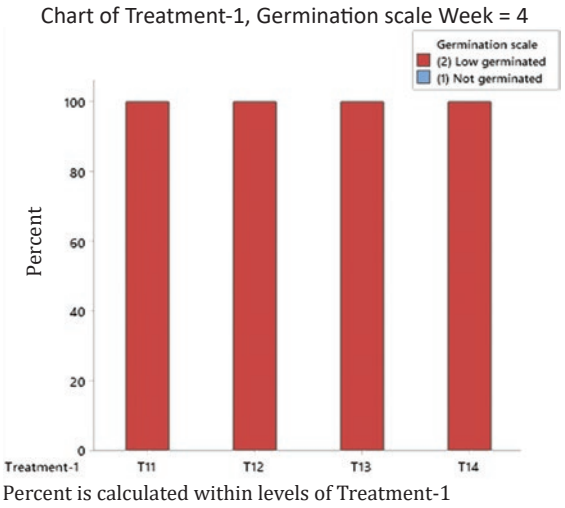


Figure 5: germination scale of ½ MS Media in eighth week.

In the first eight weeks of the study, seed germination was observed across all treatments: $T1_1$, $T1_2$, $T1_3$, and $T1_4$. In this study.

Treatment 02 involved the use of MS medium supplemented with different concentrations of NAA, both in the presence and absence of coconut water, to evaluate their effects on the germination of *G. flabelliformis* seeds. The germination rate was monitored and recorded biweekly to determine the optimal combination for seed germination.

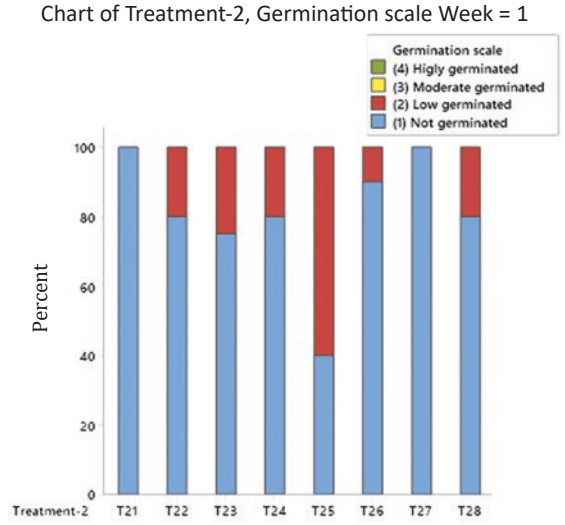


Figure 6: germination scale of MS Media in first two week.

In the first two weeks of the study, $T2_5$ yielded the highest seed germination, making it the most effective medium for the initial phase of germination. $T2_5$ appears to provide an optimal balance of the growth regulator NAA and additional nutrients, such as coconut water, which may aid in breaking seed dormancy. This treatment consisted of MS medium, 30g sucrose, 0.5 mg/l NAA, and 10% coconut water. However, no seed germination was observed in $T2_1$ and $T2_7$ during this period, suggesting that their compositions may have been insufficient to break dormancy or promote early germination. The observed delay in seed activation could potentially be attributed to an imbalance or deficiency in essential growth regulators, such as Naphthaleneacetic Acid (NAA), or other critical components in the media formulation. This hypothesis aligns with findings in other orchid species, where specific auxins and supplements, like coconut water, play a role in overcoming dormancy and promoting germination (Pradhan, Sahoo, & Parida, 2014). Further investigation into the precise concentrations and combinations of these regulators may provide clarity on their role in enhancing germination efficiency in *G. flabelliformis*. The absence of germination in $T2_1$ and $T2_7$ highlights the need to reconsider their formulations and identify the limiting factors. The remaining treatments, $T2_2$, $T2_3$, and $T2_4$, also showed varied responses.

$T2_6$ and $T2_8$ exhibited a moderate germination rate during the first two weeks. While not as successful as $T2_5$, these media still provided a favourable environment for seed germination, albeit at a slower pace. The observed germination suggests that the nutrient and growth regulator levels in these treatments were adequate for some seed development, though less efficient than $T2_5$. Although further optimization would be needed to enhance their effectiveness, these treatments may still hold potential for seed propagation

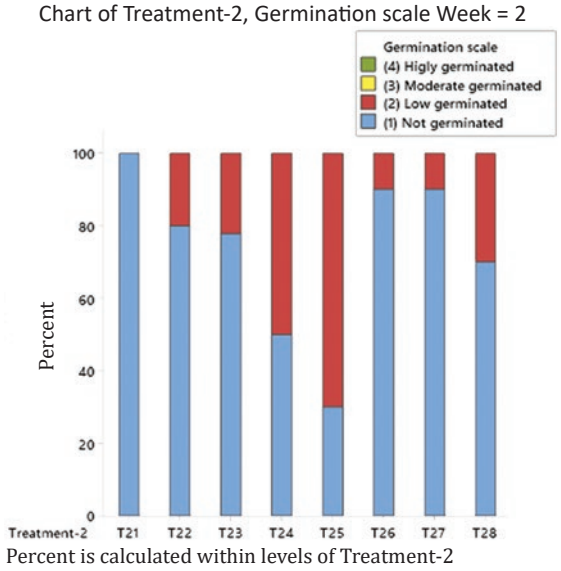


Figure 7: germination scale of MS Media in fourth week.

In initial four weeks of study, $T2_5$ media yielded the most seed germination within 4 weeks after which it became a superior medium for initial phase of seed germination. $T2_5$ seems to provide an ideal balance of growth regulator NAA, and potentially additional nutrients such as coconut water which is conducive for seed germination breaking dormancy. $T2_5$ combination of MS media + 30g sucrose + 0.5mg/l NAA + 10% coconut water. However, during the first two weeks, no seed germination occurred in $T2_1$ media. The lack of germination in these medium raises the possibility that the conditions in their compositions were insufficient to break dormancy or encourage early germination. A delay in seed activation may have resulted from either insufficient or poorly balanced quantities of growth regulators, such as NAA, or other essential components, in these treatments. The necessity to reconsider these medium compositions and identify the elements that in the first four weeks of the study, $T2_5$ produced the highest rate of seed germination, establishing itself as the most effective medium for the initial phase of germination. $T2_5$ appears to offer an optimal balance of the growth regulator NAA and additional nutrients, such as coconut water,

which may help break seed dormancy. This medium consisted of MS medium, 30g sucrose, 0.5 mg/l NAA, and 10% coconut water.

Meanwhile, treatments $T2_2$, $T2_3$, $T2_4$, $T2_6$, $T2_7$, and $T2_8$ demonstrated moderate germination rates in the first two weeks. Although they were not as successful as $T2_5$, these media still created a favourable environment for seed germination, albeit at a slower pace. The moderate germination observed indicates that the nutrient and growth regulator levels in these treatments were adequate for some seed development but fell short of $T2_5$'s efficiency. Further optimization may be required to enhance their performance, but these treatments still hold potential for seed propagation.

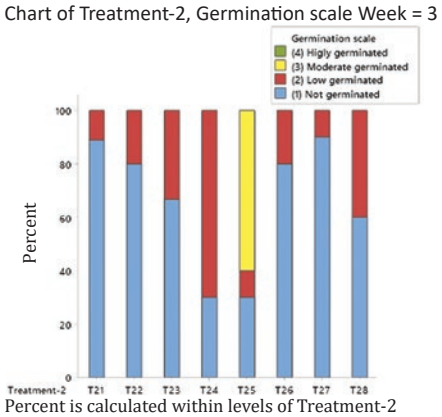


Figure 8: germination scale of MS Media in sixth week.

In the first six weeks of the study, $T2_5$ demonstrated the highest rate of seed germination, establishing itself as the most effective medium for the initial phase of germination. $T2_5$ appears to provide an optimal balance of the growth regulator NAA along with additional nutrients, such as coconut water, which facilitate the breaking of seed dormancy (Pradhan, Sahoo, & Parida, 2014). This treatment consisted of MS medium, 30g sucrose, 0.5 mg/l NAA, and 10% coconut water

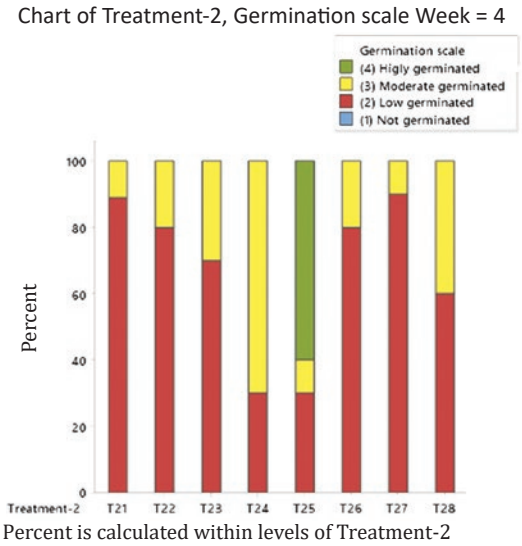


Figure 9: germination scale of MS Media in eighth week.

In the first eight weeks of the study, $T2_5$ achieved the highest seed germination rate, solidifying its status as the most effective medium for the initial phase of germination. $T2_5$ appears to offer an ideal balance of the growth regulator NAA and additional nutrients, such as coconut water, which support the breaking of seed dormancy. This treatment consisted of MS medium, 30g sucrose, 0.5 mg/l NAA, and 10% coconut water.

Treatment 03 involved the use of KNC medium supplemented with both in the presence and absence of coconut water, to evaluate their effects on the germination of *G. flabelliformis* seeds. The germination rate was monitored and recorded biweekly to determine the optimal combination for seed germination.

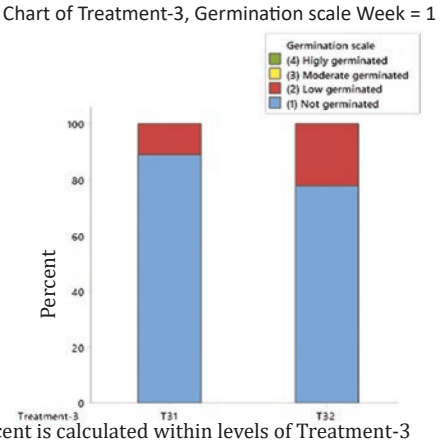


Figure 10: germination scale of KNC Media in first two weeks.

In the first two weeks of the study, Treatment $T3_2$ produced the highest seed germination rate, establishing itself as the most effective medium for the initial phase of germination. $T3_2$ consisted of KNC medium, 30g sucrose, and 0% coconut water.

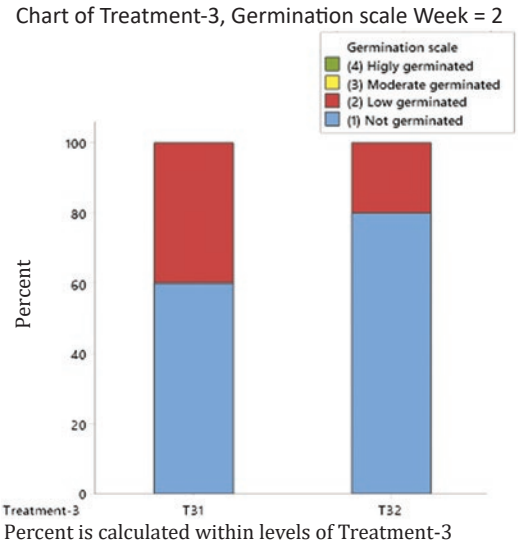


Figure 11: germination scale of KNC Media in fourth week.

In initial four weeks of study, $T3_1$ treatment yield the most seed germination within two weeks after which become superior medium for initial phase of seed germination. $T3_1$ combination of KNC media +30g sucrose + 10% coconut water.

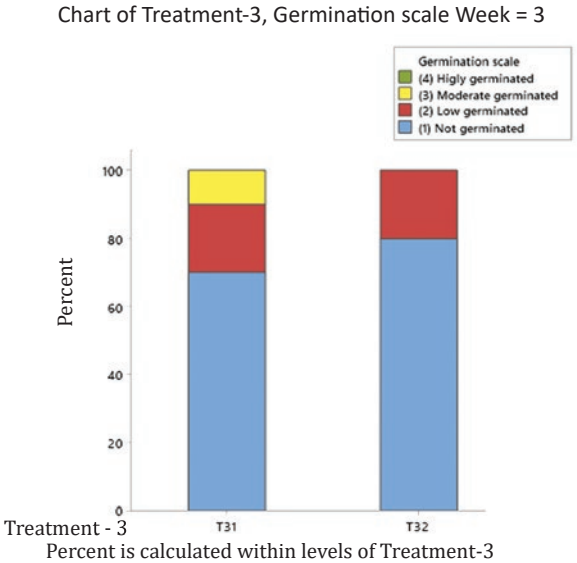


Figure12: germination scale of KNC Media in Sixth week.

In the sixth weeks of the study, Treatment $T3_1$ yielded the highest seed germination rate, establishing it as the most effective medium for the initial phase of germination. $T3_1$ was composed of KNC medium, 30g sucrose, and 10% coconut water.

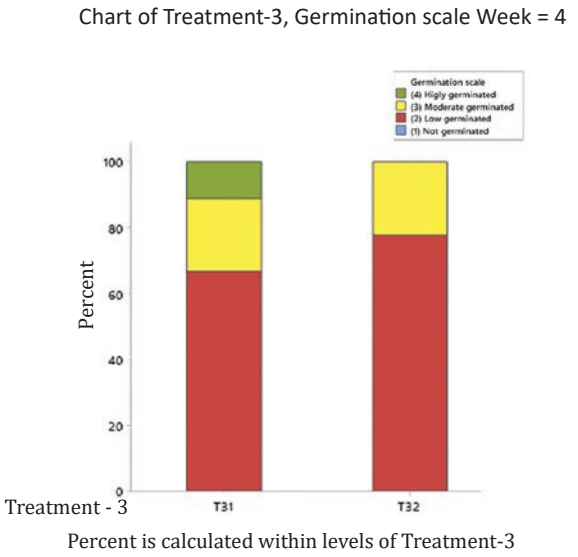


Figure 13: germination scale of KNC Media in eighth week.

In the eight weeks of the study, Treatment $T3_1$ achieved the highest seed germination rate, making it the most effective medium for the initial phase of germination. $T3_1$ consisted of KNC medium, 30g sucrose, and 10% coconut water.

CONCLUSION

The primary objective of this research was to develop an efficient *in vitro* seed propagation method for the conservation of the endangered orchid species *G. flabelliformis* in Sri Lanka.

Based on the results, the optimal media combinations for seed germination were as follows:

- For ½ MS medium: 30g sucrose + 1 mg/L NAA + 0 mg/L GA3 + 10% coconut water.
- For full-strength MS medium: 30g sucrose + 0.5 mg/L NAA + 10% coconut water.
- For KNC medium: 30g sucrose (without coconut water).

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Improvement of ½ MS Media Using Cassava as a Gelling Agent for *Anthurium andraeanum*

Pramodya K.T.J.[1], Nanayakkara A.N.[2], Kirthisinghe J.P.[1] and Wijethunga H.S.[2]

[1] *Department of Crop Management, Faculty of Agriculture, Aquinas College of Higher Studies, Colombo 08, Sri Lanka.*
[2] *Department of National Botanic Gardens, Sri Lanka.*

ABSTRACT

Agar is a relatively more expensive material used as a gelling agents for the MS medium.Various alternative gelling agents have been used to substitute the needs of Agar for *in vitro* micropropagation. This study aimed to develop an improved, cost-effective MSmedia using cassava starch as a gelling agent and to establish the gelling properties andrequired amount of locally extracted cassava as an alternative to agar for *in vitro* micropropagation of *Anthurium andraeanum*. *In vitro* grown 1.5cm nodal cuttings extracted from previously cultured plants were used as explants. Dry pure cassava flourwas used for media preparation. The experimental design was CRD with five treatment groups corresponding to the different cassava starch concentrations combined with agar. 50g/l : 3g/l, 60g/l : 2g/l, 70g/l : 1g/l Cassava : Agar combinations, 80g/l ofcassava starch without agar and 8g/l agar without cassava flour were used. Four replicates per treatment were prepared. Data were collected within five days up to 8 weeks. The height of the first shoot, Number of shoots, and Number of roots were measured. A combination of 70g/l cassava starch and 1g/l agarproduced a significantly different number of new shoots of anthurium compared to othercombinations. The treatment 8g/l agar reported the highest number of roots and height of the first shoot compared to other treatments. Adding small amounts of agar to cassava starch greatly improved gelling ability. The medium consisting of 70g/l cassava starch combined with 1g/l agar significantly enhanced multiplication within two months.

Keywords: MS medium, Agar, Gelling agent, Anthurium, Cassava

INTRODUCTION

MS medium is a basal salt medium that gives plants all the necessary nutrients to develop in a regulated environment, including vitamins, amino acids, and macro- and micronutrients. In plant tissue culture, gelling agents are crucial for solidifying the culture medium and providing a stable environment for plant growth. A gelling agent is one of the most essential ingredient in any culture medium. It is used to make the culture medium more viscous and enable plant tissues or organ parts to stay above the surface of the nutrient medium. Agar is the most frequently used solidifying agent in plant tissue culture media. It is commercially extracted from a species of red algae. (McLachlan 1985).

Agar is a relatively more expensive material used as a gelling agent of the MS medium. However, the high cost of agar prevents it from being used widely, particularly in countries that are developing. Some characteristics must be considered before choosing a gelling agent. Those are clarity, texture, and toxicity. (Ebile, P.A., Opata, J. and Hegele, S., 2002.) Various alternative gelling agents have been used to substitute the needs of Agar for *in vitro* micropropagation. However, extractions of these alternate gelling agents are costly and require expertise (Ssamula A and Mukasa S B2015). .

Cassava has potential as a gelling agent in tissue culture. Using cassava flour as a gelling agent in MS media has several possible

*janithipramodya@gmail.com

benefits. It is easily available in nations that produce cassava, which may considerably lower the cost of preparing tissue culture media (Maliro and Lameck, 2004). Cassava flour is rich in carbohydrates, particularly starch, which can serve as an additional energy source for growing explants (Kumar *et al*., 2019). Cassava flour typically contains 74-75% carbohydrates, 8-9% protein, and low fat (around 4-5%). Cassava qualities that make a variety popular are a function of starch physicochemical properties. Cassava starch does not dissolve in water at room temperature (25-27°C) so solubility temperature was reported (Nuwamanya *et al*., 2009).

The physicochemical characteristics of cassava starch make it suitable as a gelling agent. According to Moorthy (2002), the amylose content of cassava starch granules ranges from 13.6-23.8%, and their diameters range from 5 to 35 µm. These characteristics help it gel and stay stable, which makes it a viable agar replacement in tissue culture media. Therefore, this study was conducted to determine the amount and gelling characteristics of locally derived cassava that would be needed in place of agar for the in vitro micropropagation of Anthurium.

MATERIALS AND METHODS

Medium preparation using cassava starch powder

Original Tapioca flour was used for media preparation. Media were prepared with varying concentrations of cassava starch and agar. Five treatment groups corresponding to the different cassava starch concentrations with agar as 50g/l: 3g/l, 60g/l: 2g/l, 70g/l: 1g/l Cassava: Agar combinations, 80g/l of cassava starch without agar, and 8g/l agar without cassava flour were used.

Gelling of culture medium using cassava starch 2L of MS media were prepared with different combinations of cassava starch, and agar was melted and dispensed into culture vessels. 20ml of Murashige and Skoog's media were used for one culture vessel. A total of 100 culture vessels were used. The pH level of the medium was adjusted to 5.8 using 1N NaOH or 1N HCl before adding the gelling agent. Media was sterilized by autoclaving at 121°C temperature and 1.05 kg/cm^2 pressure (103.4 KPa), for 20 min. The media was allowed to cool in a sterile environment provided by a laminar air flow hood. Agar at 8 g/l without cassava starch was used as a control.

Preparation, initiation, and subculturing of explants

Nodal cuttings (without tips) from previously cultured plants were used as explants. Diseases-free and healthy cultured plants were selected for subculturing. Nodal cuttings were cut at approximately a height of 1.5 cm. Nodal cuttings (without tip) were inoculated into a culture vessel containing 20 ml of MS medium using sterile forceps. Twenty glass culture vessels per treatment per explant were inoculated and incubated under 12 hr photo period and light intensity of 30-40 µM M- 2 S-1 supplied by white fluorescent tubes. Temperature was maintained at 25-27 °C in the growth room by air conditioning units.

Experimental design and data analysis

The experiment was laid out in a completely randomized block design in which four replicates per treatment were evaluated on each of the different treatments of MS media supplemented with cassava starch at varying concentrations.Data were collected during 8 weeks. Growth of Anthurium explants in different combinations of gelling concentrations was examined for the height of the first shoot, Number of shoots per explant,and Number of roots per explant.

RESULT AND DISCUSSION

Optimization of the cassava starch concentration for anthurium growth.

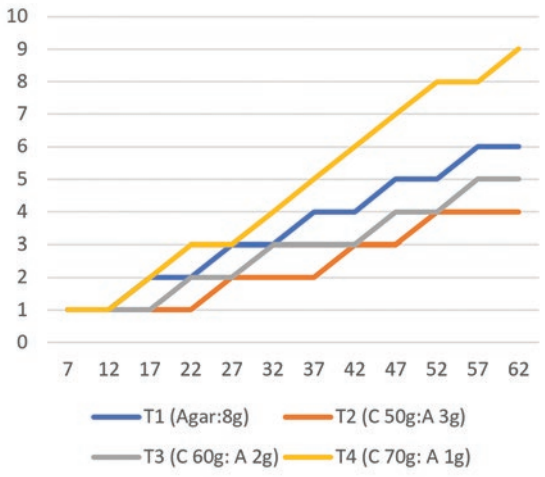
The experiment investigates the effect of five treatments (T1 to T5) over 62 days. 80g/l of cassava starch without agar could not be used for the subculture process. The main reason was that the medium did not set properly. In addition, it was a liquidity medium.

Number of shoots per ex-plant

Table 01: Effect of cassava starch and agar combination on the number of shoots per ex-plant.

Treatments	Number of shoots per explant
T1 (Agar:8g)	3.500^{ab}
T2 (C.50g: A.3g)	2.333^{b}
T3 (C.60g: A.2g)	2.833^{ab}
T4 (C.70g: A.1g)	4.750^{a}

Treatment T4 has the highest number of shoots per explant (4.750), significantly different from T2, which has a lower value. Treatments T1 and T3 are statistically similar, and there is no significant difference between these two treatments.



Graph 1: Number of shoots per explant on MS media supplemented with combinations of cassava starch and agar.

T1 shows the shoot number increases steadily but remains lower than T4. T4 shows the highest number of shoots, demonstrating that the 70:1 ratio of C to A provides an optimal balance, promoting active shoot regeneration. T3 shows consistent growth, though slightly lower than T1. T2 shows the lowest shoot count during this research period (62 days).

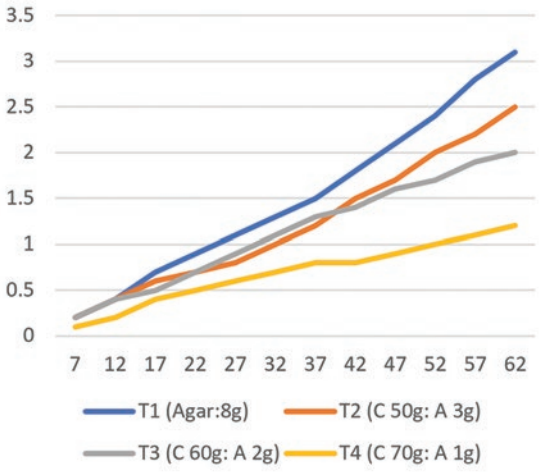
According to this graph, the highest number of new shoots was reported from T4 treatment compared to agar only. T4 (70g C: 1g A) shows the highest shoot growth, reaching 9 shoots per plant by day 62. This treatment proves optimal for shoot development.

Height of the first shoot (cm)

Table 02: Effect of cassava starch and agar combination on height of the first shoot.

Treatments	Height of the first shoot (cm)
T1 (Agar:8g)	1.525^{a}
T2 (C.50g: A.3g)	1.233^{ab}
T3 (C.60g: A.2g)	1.142^{ab}
T4 (C.70g: A.1g)	0.6917^{b}

T1 shows the highest height and is significantly different from T4(0.6917 cm). T4 (0.6917 cm) has a significantly lower height compared to the other treatments (T1, T2, and T3).



Graph 2: Height of the first shoot on MS media supplemented with combinations of cassava starch and agar.

T1 exhibits the best growth overall, with the tallest explants at the final observation. Growth was relatively slow in T4 and ended with the shortest explants among the four groups. The higher concentration of C (70g) and lower agar (1g) may not have provided optimal support. T1 (8g agar) supports the highest explant growth, demonstrating that a moderate concentration of the solidifying agent promotes better growth outcomes.

Number of roots per ex-plant

Table 03: Effect of cassava starch and agar combination on number of roots per ex-plant.

Treatments	Number of roots per ex-plant
T1 (Agar:8g)	1.667[a]
T2 (C.50g: A.3g)	1.083[a]
T3 (C.60g: A.2g)	1.000[a]
T4 (C.70g: A.1g)	0.667[a]

Among all treatments (T1, T2, T3, and T4), there is no statistically significant difference between them in the number of roots per explant.This measures new root growth over the same 62-day period.T1 has a more rapid increase in root formation compared to other treatments. T1 (8g agar) shows the best performance in root development, suggesting that the medium with agar only optimally supports new root development in MS media.

Cost Analysis

The cost of gelling materials was recorded. The cost was calculated per liter of medium for each treatment. Cost-effectiveness was compared for each treatment based on gelling material costs and the quality of plantlets produced.

T1 - 8 g/l of agar without cassava starch (control treatment).

Table 04: Total cost of gelling material per liter of T1

Gelling material	Required quantity per liter	Cost of gelling materials Rs
Agar	8g	144.00
Total cost of gelling material per liter		144.00

T2 - 50g/l of cassava starch with 3g/l agar.

Table 05: Total cost of gelling material per liter of T2

Gelling material	Required quantity per liter	Cost of gelling materials Rs
Agar	3g	54.00
Cassava flour	50g	35.00
Total cost of gelling material per liter		89.00

T3 - 60 g/l of cassava starch with 2g/l agar

Table 06: Total cost of gelling material per liter of T3

Gelling material	Required quantity per liter	Cost of gelling materials Rs
Agar	2g	36.00
Cassava flour	60g	42.00
Total cost of gelling material per liter		78.00

T4 - 70 g/l of cassava starch with 1g/l agar

Table 07: Total cost of gelling material per liter of T4

Gelling material	Required quantity per liter	Cost of gelling materials Rs
Agar	1g	18.00
Cassava flour	70g	49.00
Total cost of gelling material per liter		67.00

The total cost for 1L MS medium using only agar as a gelling agent was about Rs 144.00. However, the total cost of treatments with combinations of agar and cassava starch was considerably reduced than agar only.

CONCLUSION

Tissue culture grade agar can be replaced with a variety of other gelling agents that have been researched. This study evaluated the amount and gelling characteristics of locally derived cassava that would be needed in place of agar for the *in vitro* micropropagation of Anthurium. The physicochemical characteristics of cassava starch make it suitable as a gelling agent.These characteristics help it gel and stay stable, which makes it a viable agar replacement in tissue culture media.

Among the four treatments, 50g/l: 3g/l, 60g/l: 2g/l, 70g/l: 1g/l cassava and agar combination evaluated A combination of 70g/l cassava starch and 1g/l agar medium significantly enhanced multiplication of shoots within two months. The treatment with 8g/l agar reported the highest number of roots and height of the first shoot compared to other treatments. According to cost analysis, it may be concluded that combining small amounts of agar with cassava starch leads to a cost-effective gelling agent of the MS medium for *in-vitro* propagation of anthurium.

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Development of A Novel *in vitro* Protocol for *Nymphaea* Leaf Culture

Sahana M.N.F.[1], Mubarak A.N.M.[2] and Nanayakkara A.N.[3]

[1,2] *Department of Biosystems Technology, Faculty of Technology, South Eastern university of Sri Lanka*
[1,2] *Henarathgoda Botanic Gardens, Gampaha*

ABSTRACT

Nymphaea is commercially important aquatic plants propagated through cross pollinated seeds cause trait variations in the offsprings, the morphological features of flowers are different from one plant to another and cause major problem by commercial producers and vendors. Therefore, multiplication through micropropagation is a viable option. Hence, this research focused on establishing a robust in vitro protocol for *Nymphaea* leaf culture. The young leaves of *Nymphaea* were excised from a single mother plant and cut into (5mm × 5mm) pieces were used as explants. Then five sterilization methods (Factor 1) viz: 0.2% of $HgCl_2$ (T1), 0.1% of $HgCl_2$ (T2), 5% NaOCl (T3), 10% NaOCl with Tween20 (T4), 10% NaOCl (T5) were employed. Then two types of media (Factor 2), namely 1/2MS (M1), comprising 50 ml of A stock, 2.5 ml of B stock, 5 ml of C stock, along with glycine, pyridoxine, nicotinic acid, thiamine, BAP, 2.4-D, Myo-inositol, and sugar, consistent and favorable results were observed across various sterilization techniques. Conversely, media 2 (M2), with a similar composition but supplemented with BA, NAA, and kinetin were employed. The data collected over the course of 12 weeks, the results indicate that T4 consistently exhibits the lowest contamination percentage of leaf across both media formulations, while T3 consistently demonstrates higher contamination rates. Furthermore, Media 1 consistently yields superior results in terms of tissue culture initiation compared to media 2. By identifying optimal sterilization techniques and media formulations, this study provides valuable insights for enhancing mass propagation.

Keywords: *Invitro* protocol, Surface sterilization, *Tween20*, *NaOCl*

INTRODUCTION

Nymphaea, commonly known as water lilies. Water lilies belong to the family Nymphaeaceae and order Nymphaeales and are known for their unique adaptations to aquatic environment. These are normally called as the water lily. Due to the dominant character of all these species have very beautiful flowers and leaves (Le *et al*., 2016)

Water lilies are the most popular water garden plants but are expensive to propagate. Traditional vegetative propagation techniques are inefficient, and losses to disease also contribute to the high costs. *In vitro* propagation of disease-free stock may be an effective method for combating disease losses, reducing propagati on costs, and facilitating long-term germplasm storage.

Nymphaea is commercially important aquatic plants but they are cross pollinated. So, they are difficult to propagate same as the mother plant. The flowers are different from one plant to another plant. It is the major problem faced by commercial producers and vendors. Therefore, this research integrating two distinct media formulations and five different sterilization techniques to increase the ornamental value of plant. By identifying optimal sterilization techniques and media formulations, this study provides valuable insights for enhancing

**fathimashahana57@gmail.com*

mass propagation, conservation, and genetic manipulation of *Nymphaea* species, thereby contributing to both plant biotechnology and the preservation of aquatic ecosystems.

MATERIALS AND METHODS

This research focuses on establishing a robust *in vitro* protocol for *Nymphaea* leaf culture, by integrating five different sterilization techniques (treatments) [factor 1] and two distinct media [factor 2] formulations.

The study meticulously explores the impact of these sterilization methods 0.2% of $HgCl_2$ (T1), 0.1% of $HgCl_2$ (T2), 5% NaOCl (T3), 10% NaOCl with Tween20 (T4), 10% NaOCl (T5) on two types of media, namely 1/2MS and an alternative formulation. For media 1(1/2MS), comprising 50 ml of A stock, 2.5 ml of B stock, 5 ml of C stock, along with glycine, pyridoxine, nicotinic acid, thiamine, BAP, 2.4-D, Myo-inositol, and sugar, consistent and favorable results were observed across various sterilization techniques. Conversely, media 2, with a similar composition but supplemented with BA, NAA, and kinetin, showed varied outcomes influenced by the chosen sterilization method.

The young leaves of *Nymphaea* were excised from a single mother plant and cut into (5mm × 5mm) pieces were used as explants. Two pieces of explant were cultured inside the culture media. There were 40 replicates taken for each treatment. Then the culture bottles were labeled and kept inside the culture room and covered by black in color polythene for a week to increase the humidity.

The cultures were kept inside the culture room and it was grown at 16-18 °C under 12/12 (light/dark) hours photoperiod supplied by cool white two bulbs.

RESULTS AND DISCUSSION

Analyzing the contamination percentages and the factors influencing microbial growth and contamination in *Nymphaea* tissue cultures, aiding in the optimization of culture conditions. Analysis of the contamination data revealed significant differences between the two types of media, M1 and M2, as well as the contamination percentages resulting from five different sterilization methods (T1, T2, T3, T4, T5) employed for *Nymphaea* tissue culture were analyzed. Then two factor factorial design was used for the analysis of the data and SAS software was used for the analysis.

A Comparative Analysis of Contamination Levels Between Different Growth Media

Media	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
M1	0.00± 0.44^{b}	0.22± 0.58^{a}	1.00± 0.80^{a}	2.25± 0.97^{a}	4.25± 1.31^{a}	8.25± 1.45^{a}	14.25± 1.55^{a}	20.05± 1.66^{a}	27.32± 1.91^{a}	27.32± 1.91^{a}	30.77± 2.31^{a}	36.02± 2.62^{a}
M2	1.75± 0.44^{a}	3.25± 0.577^{a}	5.25± 0.80^{a}	7.75± 0.96^{a}	16.25± 1.31^{a}	23.50± 1.45^{a}	30.878± 1.56^{a}	37.02± 1.68^{a}	41.35± 1.99^{a}	41.35± 1.99^{a}	43.17± 2.69^{a}	44.28± 3.19^{a}

The above table displays the contamination percentages observed in *Nymphaea* tissue cultures across two different types of media, indicating varying levels of susceptibility to contamination. The data analysis over the course of 12 weeks, the contamination percentages in *Nymphaea* tissue cultures were reveals that the contamination percentage in *Nymphaea* tissue cultures grown in M1 media is significantly lower than that in cultures grown in M2 media. Beginning from Week 1, the contamination percentage in M1 media was notably lower than that in M2 media.

This trend persisted throughout the experiment, with M1 consistently exhibiting

lower contamination percentages across all subsequent weeks. By Week 12, the contamination percentage in M1 media remained significantly lower than that in M2 media, indicating the sustained effectiveness of M1 in minimizing contamination levels over time. So, suggesting that M1 is more effective in maintaining sterile conditions during *Nymphaea* tissue culture growth.

A Comparative Analysis of Contamination Levels Between Different Sterilization Techniques (Treatments)

Treatments	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
T1	0.00± 0.69^{b}	0.00± 0.91^{b}	0.62± 1.26^{b}	1.25± 1.53^{b}	7.50± 2.06^{b}	10.62± 2.30^{b}	16.57± 2.4^{b}	25.74± 2.68^{bc}	30.91± 3.21^{bc}	30.91± 3.21^{bc}	33.28± 4.13^{b}	37.44± 4.67^{bc}
T2	0.62± 0.69^{b}	1.25± 0.91^{b}	1.87± 1.26^{b}	1.87± 1.53^{b}	5.00± 2.06^{b}	9.37± 2.30^{b}	16.25± 2.46^{b}	21.37± 2.65^{c}	23.66± 3.07^{c}	23.66± 3.07^{c}	23.02± 3.65^{b}	22.89± 4.07^{c}
T3	3.75± 0.69^{a}	6.25± 0.91^{a}	9.37± 1.26^{a}	15.62± 1.53^{a}	21.25± 2.06^{a}	31.25± 2.30^{a}	36.87± 2.46^{a}	43.05± 2.66^{a}	47.41± 3.16^{a}	47.41± 3.16^{a}	53.07± 4.54^{a}	68.86± 5.62^{a}
T4	0.332± 0.69^{b}	0.44± 0.91^{b}	0.62± 1.26^{b}	1.87± 1.53^{b}	5.62± 2.06^{b}	10.62± 2.30^{b}	15.62± 2.46^{b}	20.00± 2.63^{c}	29.70± 3.01^{bc}	29.70± 3.01^{c}	24.84± 3.71^{b}	21.37± 4.15^{c}
T5	0.22± 0.69^{b}	0.62± 0.91^{b}	3.12± 1.26^{b}	4.37± 1.53^{b}	11.87± 2.06^{b}	17.50± 2.31b	27.50± 2.46^{a}	32.50± 2.63^{b}	40.00± 2.97^{ab}	40.00± 2.97^{ab}	50.62± 3.71^{a}	50.19± 4.43^{b}

Analyzing the contamination percentages for each week across the five sterilization methods employed for *Nymphaea* tissue culture, notable trends emerged. Initially, during Week 1, T1 exhibited the lowest contamination percentage, suggesting its efficacy in minimizing contamination at the onset of the experiment. However, as the experiment progressed, T4 consistently maintained the lowest contamination percentages from Week 2 through Week 12, indicating its superior performance in maintaining sterile conditions over an extended period.

Conversely, T3 consistently showed the highest contamination percentages throughout the 12-week duration, highlighting its limited effectiveness in controlling contamination. Methods 1 and 2 demonstrated intermediate contamination percentages and T5 exhibited 50% of contamination across the weeks, suggesting moderate success in sterilization.

Overall, these findings emphasize the importance of selecting an appropriate sterilization method to ensure the successful propagation of *Nymphaea* tissue cultures while minimizing contamination risks.

A Comparative Analysis of Contamination Levels Between M1 Media and Different Sterilization Techniques (Treatments)

Sterilization	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
T1	0.00± 0.98	0.00± 1.28	0.00± 1.79	0.77± 2.16	1.25± 2.92	1.25± 3.26	7.50± 3.48	15.0± 3.72	24.32± 4.37	28.33± 5.24	24.07± 5.39	30.76± 5.88
T 2	0.00± 0.98	0.44± 1.28	1.25± 1.79	1.25± 2.16	1.25± 2.92	2.50± 3.26	6.25± 3.48	10.26± 3.77	15.38± 4.26	18.91± 4.72	19.11± 4.81	19.69± 5.22
T3	0.88± 0.98	1.77± 1.29	2.50± 1.79	8.75± 2.16	12.50± 2.92	23.75± 3.26	31.25± 3.48	38.75± 3.72	41.89± 4.38	41.67± 5.24	46.1± 5.49	65.0± 6.70
T4	0.00± 0.98	0.00± 1.28	0.00± 1.79	1.33± 2.16	3.55± 2.92	5.00± 3.26	10.00± 3.48	12.50± 3.72	21.25± 4.21	24.32± 4.72	19.69± 4.87	16.67± 5.47
T5	0.22± 0.98	0.44± 1.289	1.25± 1.79	1.25± 2.17	6.25± 2.92	8.75± 3.26	16.25± 3.48	23.75± 3.72	33.75± 4.21	44.59± 4.72	44.83± 5.2	48.00± 5.99

The above tables offers that the contamination percentage in M1 medium associated with the different sterilization techniques. The analysis of contamination levels in media 1 across the various treatment groups provides critical insights into the efficacy of each treatment method in mitigating microbial growth. Upon examination, T4 emerges as the most effective in maintaining the lowest contamination levels. This finding suggests that T4 exhibits superior contamination control compared to the other treatments evaluated in this study. Conversely, T3 demonstrates the highest contamination level among the tested treatments throughout the 12-week period.

T1 also showed relatively low contamination levels, especially in the early weeks. And T1, T3, and T5 resulted in higher contamination percentages compared to T2 and T4. This notable disparity in contamination levels underscores the importance of carefully selecting and implementing treatment protocols to minimize microbial proliferation within media 1.

A Comparative Analysis of Contamination Levels Between M2 Media and Different Sterilization Techniques (Treatments).

Sterilization	1 WAP	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
T1	0.00± 0.98	0.00± 1.29	1.25± 1.79	2.50± 2.16	13.75± 2.92	20.00± 3.26	25.64± 3.52	36.486± 3.871	37.50± 4.70	42.85± 5.42	42.50± 6.26	44.11± 7.27
T2	1.25± 0.98	2.50± 1.28	2.50± 1.79	2.50± 2.16	8.75± 2.92	16.250± 3.260	26.25± 3.48	32.50± 3.72	31.94± 4.43	34.84± 4.99	26.92± 5.49	26.08± 6.25
T3	7.5± 0.98	12.50± 1.28	16.25± 1.79	22.50± 2.17	30.00± 2.92	38.75± 3.26	42.50± 3.48	47.36± 3.82	52.94± 4.57	61.53± 5.63	60.00± 7.23	72.72± 9.04
T4	0.33± 0.98	0.88± 1.28	1.25± 1.79	3.75± 2.16	11.25± 2.92	16.25± 3.26	21.25± 3.48	27.50± 3.72	38.15± 4.32	32.75± 5.33	30.00± 5.60	26.08± 6.25
T5	0.22± 0.98	1.25± 1.29	5.00± 1.79	7.50± 2.16	17.50± 2.92	26.25± 3.26	38.75± 3.48	41.25± 3.72	46.25± 4.21	51.35± 4.72	56.42± 5.29	52.38± 6.54

In this table, the comparison of contamination levels in media 2 highlights nuanced variations that warrant further exploration. Contamination levels varied among the sterilization methods, with T2, T4 generally showing the lowest contamination percentages. T3 consistently resulted in the highest contamination levels, indicating its limited effectiveness in sterilizing cultures grown in M2 media. While T4 demonstrates the lowest average contamination level, it is essential to consider the context in which these results were obtained. For instance, T3, despite having a slightly higher contamination level than other Treatments.

Media Comparison:

Overall, M1(1/2 MS,comprising 50 ml of A stock, 2.5 ml of B stock, 5 ml of C stock, along with glycine, pyridoxine, nicotinic acid, thiamine, BAP, 2.4-D, Myo-inositol, and sugar) media consistently exhibited lower contamination percentages compared to M2 media (supplemented with BA, NAA, and kinetin) across all weeks. This suggests that M1 may provide better conditions for maintaining sterile cultures of *Nymphaea* tissue.

M1 Media (1/2 MS) with Treatments:

Among the five sterilization methods tested, T4(10% NaOCl with Tween20) consistently resulted in the lowest contamination percentages throughout the 12-week period. Method 1 also showed relatively low contamination levels, especially in the early weeks. T1(0.2% of $HgCl_2$), T3 (5% NaOCl),

and T5 (10% NaOCl) resulted in higher contamination percentages compared to T2 and T4.

M2 Media (Supplemented with BA, NAA, And Kinetin) with Treatments:

Contamination levels varied among the sterilization methods, with T2, T4 generally showing the lowest contamination percentages. T3 consistently resulted in the highest contamination levels, indicating its limited effectiveness in sterilizing cultures grown in M2 media.

Identified Trends:

Across both media types, T4 (10% NaOCl with Tween20)appeared to be the most effective sterilization method, consistently yielding the lowest contamination percentages. Conversely, T3(5% NaOCl) consistently showed the highest contamination percentages, regardless of the media type.

CONCLUSION

Cold treatments (8°C for 24 hours and 11°C for 8 hours with pre-cooling) have proven effective in reducing the negative impact of latex on rooting, thereby enhancing rooting attributes in the propagation of *Euphorbia pulcherrima* stem cuttings.This report investigated the impact of two distinct types of media and five sterilization methods on *nymphaea* culture. Through this experimentation and analysis, it becomes evident that the combination of M1 medium(1/2MS, comprising 50 ml of A stock, 2.5 ml of B stock, 5 ml of C stock, along with glycine, pyridoxine, nicotinic acid, thiamine, BAP, 2.4-D, Myo-inositol, and sugar) in T4 (10% NaOCl with Tween20) is the most effective strategy for fostering robust growth and development in *nymphaea* leaf culture.

The findings suggest that the choice of both media type and sterilization method significantly influences contamination levels in *Nymphaea* tissue cultures. Opting for M1 (1/2MS) media and employing T4(10% NaOCl with Tween20) for sterilization could help minimize contamination risks and improve culture success rates. The callus formation was occurred in M1medium which was sterilized by T4.

This highlights the critical importance of media selection and sterilization techniques in achieving optimal outcomes in aquatic plant cultivation.

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Study on Germination Dynamics and Optimization of Early Seedling Growth of *Acmella oleracea* (Acmella)

Nakandalage N.[1], Madushani W.G.I.[1], Dissanayake D.M.D.I.[1] and Fonseka D.L.C.K. [1]

[1] *Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Matara, Sri Lanka*

ABSTRACT

Ornamental plants, made up of diverse species and cultivars, enrich our lives by providing aesthetic appeal and environmental advantages. The current study aimed to enhance seed germination and promote early vegetative growth of *Acmella oleracea* (Synonym: *Spilanthes acmella* var. *oleracea*). Different seed treatments were applied, including water soaking for 12, 18, and 24 hours, alternating wet and dry conditions, and different concentrations of GA3 (200, 400, and 500 ppm). Data on Number of sprouted or germinated seeds and number of days taken for germination were collected. Experiments were laid out in Completed Randomized Design with four replicates. Data on plant height (cm), stem diameter (mm), were collected weekly and fresh and dry weight of above ground growth (g) and roots were collected. In addition, sturdiness and quality indices were calculated. Data were analyzed using SAS software. The findings revealed that GA3 at a concentration of 500 ppm produced the highest seed germination rate, reaching 74%. The most favorable growth and yield metrics, such as plant height (24 cm), sturdiness index (12.5), and quality index (0.09) were obtained using a soil blend of topsoil, sand, and compost in a 1:1:2 ratio, combined with Maxicrop liquid fertilizer, indicating optimal conditions for growth and development of *A. oleracea*. Seedlings irrigated in 3-day interval reported the highest plant height (27.8cm), sturdiness index (11.2) and quality index (0.35).In this Study, the most promising seed treatment for higher seed germination of *A. oleracea* was GA3 500ppm solution. A mixture of topsoil, sand and compost in the ratio of 1:1:2, along with Maxicrop liquid fertilizer, proved to be the most effective growth medium and fertilizer for promoting early vegetative growth of *A. oleracea*. Furthermore, an irrigation interval of three days emerged as the optimal watering frequency at this growth stage.

Keywords: Early vegetative growth, fertilizer, irrigation frequency, potting media, seed germination

INTRODUCTION

Ornamental plants, made up of diverse species and cultivars, enrich our lives by providing aesthetic appeal and environmental advantages (Van *et al*., 2015). These plants offer a feeling of tranquility and comfort, often being utilized in home gardens, landscaping, and as cut flowers or potted plants. The growing demand for aesthetically attractive plants has transformed their production into a booming industry, with the ornamental plant sector seeing significant growth driven by the expansion of global trade (Milstein, 2005).

Although ornamental plants are grown primarily for their aesthetic value, many are also grown for their therapeutic qualities since they contain various bioactive substances such essential oils, carotenoids, phenolic, and other secondary metabolites. These plants not only enhance our surroundings more visually pleasing, but also, they offer natural cures that are frequently more affordable and lack the negative consequences of pharmaceuticals(Kennedy and Wightman, 2011).

*niluka@crop.ruh.ac.lk

A significant member of the Asteraceae family, *Acmella oleracea* (Synonym: *Spilanthes acmella* var. *oleracea*)is mostly endemic to tropical and subtropical climates, having a notable presence in South America and India (Sana and Rani, 2017). Known by most as the "Toothache plant," it is prized for its decorative qualities as well as its medicinal qualities (Pandey and Agrawal, 2009). The plant has an impressive range of morphological variation, ranging from 1 cm tiny plants to 30 m towering trees (Rolnik *et al*., 2021). According to Purushothaman *et al*. (2018), *A. oleracea* flower heads and leaves are traditionally used to cure mouth infections and ease toothaches.

Garden spaces gain significant aesthetic value from *A. oleracea*'s eye-catching, daisy-like blooms. The compact growth habit of the plant makes it a desirable choice for ornamental and herb gardens; it is frequently used in borders, rock gardens, and as a ground cover. Stunning button-shaped flowers and rich green foliage of *A. oleracea* enhance its allure. Because *A. oleracea* is a versatile plant that grows well in a range of environments, it is often used as a decorative plant. *A. oleracea* is a species of plant that grows in many different temperatures. These are especially sensitive to woodland surroundings, yet in warmer climates it acts like a perennial. This plant grows well in full sun to light shade and requires rich, moist, well-drained soil with a pH of 6.1 to 6.5. Optimal seed germination occurs at temperatures between 20–24°C (68–75°F) (Hare Krishna *et al*., 2019).

However, Sri Lanka's ornamental and medicinal plant industry faces several significant challenges, including plant decline, high cost, export market difficulties, substandard quality, and high levels of waste and climate and environmental issues. In addition, lack of standardized cultivation and processing protocols as well as inconsistent and inadequate supply further hampers the growth of the industry (Kankanamalage *et al*., 2013). Systematic cultivation of important plant species is essential to meet these challenges faced by the ornamental and medicinal plant industries. Fostering the growth and utilization of *A. oleracea* can improve Sri Lanka's standing in the international market and diversify agricultural revenue streams. However, information on seed germination as well as cultivation and management practices for *A. oleracea* is scarce.

This study aimed to identify the optimal seed treatment methods for *A. oleracea* germination, along with the most effective growing media, fertilizer applications, and irrigation frequency. Also it explores the broader medicinal and economic potential of select ornamental plants, highlighting how floriculture can expand market opportunities by increasing the availability of plants that offer both aesthetic and therapeutic benefits.

MATERIALS AND METHODS

All experiments were conducted at Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya during June to September 2023. The present study was conducted with a series of sub-experiments.

Experiment 1: Selection of suitable seed treatments for the germination of *Acmella oleracea*

The objective was to identify the most effective seed treatments to enhance germination of *A. oleracea*. Twenty seeds were placed on moistened filter paper in Petri dishes. Seven treatments (Table 2.1) were applied in a completely randomized design with four replicates. Under constant temperature and moisture, observations were made daily for 14 days. Radicle emergence was considered as a criterion of seed germination (Sana and Rani,

2017). Number of sprouted or germinated seeds and the number of days taken for germination were recorded.

Table 2.1: Treatment combination to enhance the germination of *A. oleracea* seeds

Treatment	Description
T_1	12 hours water soaking
T_2	18 hours water soaking
T_3	24 hours water soaking
T_4	Alternative wet and dry (1st day) for 12 hours wet and 12 hours dry, (2nd day) for 6 hours wet and 6 hours dry, (3rd day) for 3 hours wet and 3hours dry
T_5	GA_3 (200ppm) for 14 hours soaking
T_6	GA_3 (400ppm) for 14 hours soaking
T_7	GA_3 (500ppm) for 14 hours soaking

Experiment 02: Selection of the most suitable growing media and fertilizer combinations for higher seedling survival and growth

Seeds were soaked in 500 ppm Gibberellic Acid solution (0.5g/L) for 24 hours and then drained using filter paper. Afterward, seeds were sown in nursery trays, and after 14 days, the seedlings were transplanted into polybags filled with different combinations of growing media and fertilizers.For the preparation of pots, black polythene with a gauge of 300 was used to make poly bags, each measuring 20 cm × 7 cm. Water drainage holes were made at the bottom of each bag, which were then filled with potting mixtures. Rooted *A. oleracea* plant lets were transplanted into pots and irrigated daily for four weeks to ensure optimal establishment of them for the experiment. After this period, fertilizer was applied according to the specified treatment plan. (Table 2.2)

A two-factor factorial completely randomized design (CRD) with six treatments and five replicates were used for the experiment. Six different treatment combinations were prepared using two types of growing media and three types of fertilizer applications, as follows.

Factor 1- Potting Media
C1- Top soil: Sand: Compost (1:1:1)
C2 - Top soil: Sand: Compost (1:1:2)

Factor 2- Fertilizer
F1 - No fertilizer application
F2 - Maxi cropfoliar application
F3 - Albert solution application

Table 2.2: Different treatment combinations used to select the most suitable growing media and fertilizer combinations for higher seedling survival and growth of *A. oleracea*

Treatments	Description
C_1F_1	Top soil 1: sand 1: Compost 1, No fertilizer application
C_1F_2	Top soil 1: sand 1: Compost 1, Recommended Level of Maxicrop fertilizer
C_1F_3	Top soil 1: sand 1: Compost 1, Recommended level of Albert solution
C_2F_1	Top soil 1: sand 1: Compost 2, No fertilizer application
C_2F_2	Top soil 1: sand 1: Compost 2, Recommended Level of Maxicrop fertilizer
C_2F_3	Top soil 1: sand 1: Compost 2, Recommended level of Albert solution

Albert's solution is recommended at 10g per 4.5 liters, requiring 2.2g per liter and 10-12 mL per plant. Maxicrop liquid fertilizer is recommended at 30mL per 15 liters, requiring 2mL per liter and 10-12 mL per plant.

Experiment 03: Selection of suitable irrigation frequency for higher seeding survival and growth of *A. oleracea*

Seeds were soaked in a 500 ppm Gibberellic Acid solution (0.5g per liter) for 24 hours and then drained using filter paper. Afterward, the seeds were sown in nursery trays, and 14 days later, the *A. oleracea* seedlings were transplanted into poly bags.

For the preparation of pots, black polythene with a gauge of 300 was used to make poly bags, each measuring 20 cm × 7 cm. Water drainage holes were made at the bottom of each bag. They were filled with potting mixture of top soil: sand: compost, 1:1:1 and randomly placed inside the protected house.

Rooted plantlets of *A. oleracea* were planted in pots. All plantlets were irrigated frequently for 4 weeks for the better establishment of plants for the experiment. After 4 weeks irrigation was practiced according to the designed treatments. Completely Randomize Design (CRD) with five treatments and 3 replicates were used for the experiment as follows.

T_1: Daily watering, T_2: 2 days interval, T_3: 3 days interval, T_4: 5 days interval, T_5: 7 days interval

Soil samples from each medium were taken and watered to saturate. Then samples were kept for 72 hours (drained by gravity) to reach the field capacity. Moisture content was determined by gravimetric method. Moisture needs to reach the field capacity was determined. Initial moisture content of each media was also determined by gravimetric method.

Water needs for the plants to reach field capacity = (Moisture amount in field capacity level – Initial moisture in soil)

Parameters and Data Collection

As different parameters; Plant height (cm), Number of leaves, Number of branches, Stem diameter (mm), Chlorophyll content, Fresh weight of above ground growth/ Shoot (g), Dry weight of above ground growth/ Shoot (g), Fresh weight of root (g) and Dry weight of root (g) were collected. In both experiments with seedlings, data on plant height (cm), number of leaves, and number of branches were taken in weekly intervals. Stem diameter (mm), shoot dry weight (g), root dry weight (g), chlorophyll content was collected at four weeks after treatment application.

Sturdiness index (Roller, 1977)

$$SQ = \frac{\text{Seedling height (cm)}}{\text{Collar diameter of root (mm)}}$$

Quality index (Dickson *et al*., 1960)

$$QI = \frac{sdw}{(h/d) + (t/r)}$$

Where,

Sdw- Seedling dry weight (g), h- Seedling height (cm), d- Collar diameter (mm), t- Shoot dry weight (g), r- Root dry weight (g)

Statistical analysis

The data were analyzed using ANOVA with the Statistical Analysis System (SAS) software, version (9.2). Means were separated using Duncan multiple range test (DMRT) at a significant level of $P<0.05$.

RESULT AND DISCUSSION

Experiment – 01. Selection of suitable seeds treatment/s for seed germination of *Acmella oleracea*

Germination and seedling establishment are critical stages which affect both quality and quantity of crop yields (Subedi and Ma, 2005. According to Farooq *et al*., 2006, the treatment of seeds increased the germination. Also, it was reported earlier that GA participated in regulation of many growth and developmental processes in plants (Hedden *et al*., 2000). In the present study, the highest seed germination rate (74%) was observed with GA_3 treatment at 500 ppm (T_7), closely followed by GA_3 at 400 ppm (T_5). These results aligned with previous research findings highlighting the effectiveness of Gibberellic acid (GA_3) in promoting seed germination by stimulating the synthesis of hydrolytic enzymes, which break down stored food reserves in seeds, thus enhancing germination rates (Gulzar *et al*., 2001; Miransari and Smith, 2014). GA_3 is particularly effective in overcoming seed dormancy by promoting endosperm weakening and embryo expansion, leading to a higher germination percentage in *A. oleracea*. Conversely, seeds subjected to 12 hours of

water soaking showed the lowest germination rate (24.2%), suggesting that simple hydration is insufficient to break dormancy or enhance seed viability in this species.

Experiment 02: Selection of optimal growing media and fertilizer for enhanced seedling survival and growth of *A. oleracea*

The interaction effect between potting media and fertilizer type was found to be statistically not significant ($P > 0.05$) for several growth parameters, including plant height, number of leaves, stem diameter, chlorophyll content, root dry weight, and shoot dry weight.

In this experiment, the C2 potting medium (Topsoil, Sand, and Compost in a 1:1:2 ratio) and Maxicrop liquid fertilizer (F_2 Fertilizer) consistently produced the highest values for plant height, stem diameter, chlorophyll content, root dry weight, (Figure 3.1). This compost-enriched media provides superior nutrient availability and water retention, supporting more vigorous plant growth. This may also strengthen the soil structure, maintaining cell turgidity, boosting nutrient content, and maintaining soil humidity, along with, which can promote healthy seed sprouting (Unal, 2013).

The interaction effect between potting media and fertilizer type was also not significant for the sturdiness quotient ($P > 0.05$), a measure of seedling robustness. However, the highest sturdiness quotient was recorded in the C_2 potting medium, plants treated with Albert solution (F_3 fertilizer) had a higher sturdiness quotient compared to other fertilizer treatments (Figure 3.2). These findings underscore the importance of selecting an appropriate potting medium and fertilizer independently for maximizing *A. oleracea* growth and survival.

Experiment 03: Selection of suitable irrigation frequency for higher seeding survival and growth of *A. oleracea*

In our study, Irrigation frequency with 2-day intervals (T2) produced the tallest plant height (36.4 cm), while the weekly irrigation treatment (T5) recorded the lowest height (20.1 cm). This suggests that frequent irrigation favors greater vertical growth, possibly because stagnant water promotes nutrient uptake and photosynthesis, thereby enhancing cell expansion and elongation (Ismail *et al*., 2007). Additionally, reduced water supply during the weekly irrigation treatment limited the physiological processes required for optimal plant growth.Maximum number of leaves (11.3) and the highest number of branches (11.33) showed a similar pattern at a 5-days irrigation interval (T_4). Frequent irrigation has been shown to positively alter stem diameter; the maximum value (0.43 cm) was reported at a 2-day interval (T_2). At 7 days interval (T_5), the highest shoot dry weight (1.80 g) was recorded and these results imply that longer irrigation intervals can cause the plant to adopt water-saving mechanisms that prioritize shoot growth over root development. Hardness value, an indicator of seedling stability, was highest (11.57) at 3-day interval (T_3) and lowest (9.23) at 5-day interval (T_4). While this frequency encouraged leaf and branch growth, it compromised the structural integrity of the plants as indicated by the low sturdiness quotient observed at the 5-day interval.

CONCLUSION

The present research was able to identify the most effective techniques for promoting seed germination and early seedling growth of *A. oleracea*. The use of GA_3 (Gibberellic acid) at 500 *A. oleracea* ppm is a notable discovery for enhancing germination rates of *A. oleracea*. The growth media composition of sand,

compost, and topsoil in a 1:1:2 ratio provides an optimal balance for early stages of seedling growth. The application of Maxicrop, a commercially available liquid fertilizer, during the early growth phase resulted in increased seedling vigor. Optimal irrigation frequency that promoting healthy growth of *A. oleracea* is found to be every three days. These findings provide valuable insights for enhancing seed germination and production of healthy and vigorous genetic materials of *A. oleracea* for commercial scale farming practices.

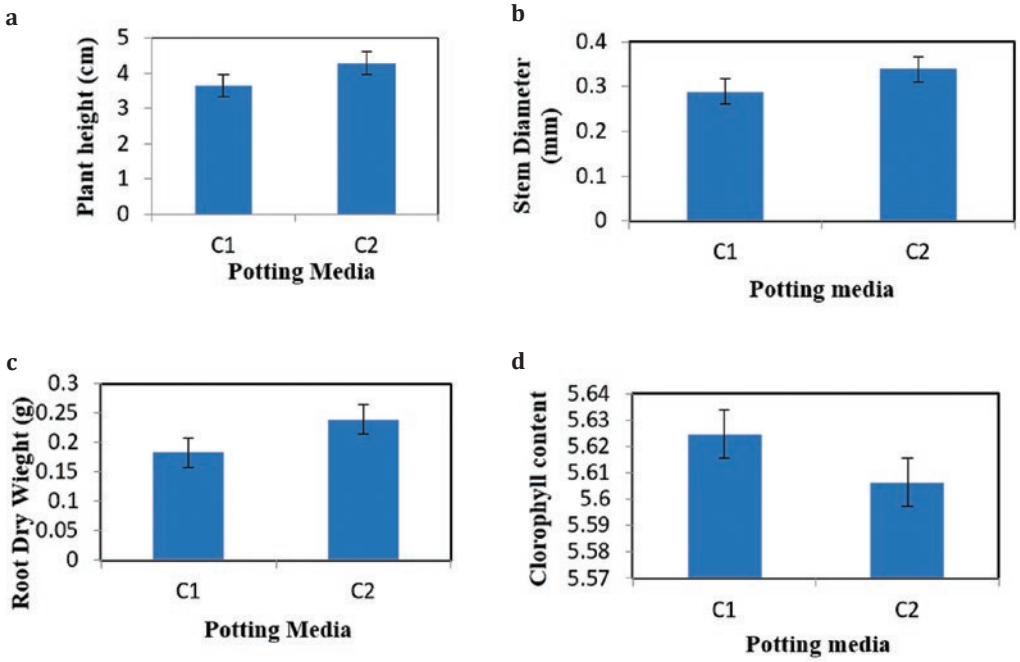

Figure 3.1: Changes in (a) plant height (cm), (b) stem diameter (mm),(c) root dry weight (d) chlorophyll contentof *A. oleracea* grown in different potting media. (C_1: Top soil: Sand: Compost (1:1:1), C_2: Top soil: Sand: Compost (1:1:2)

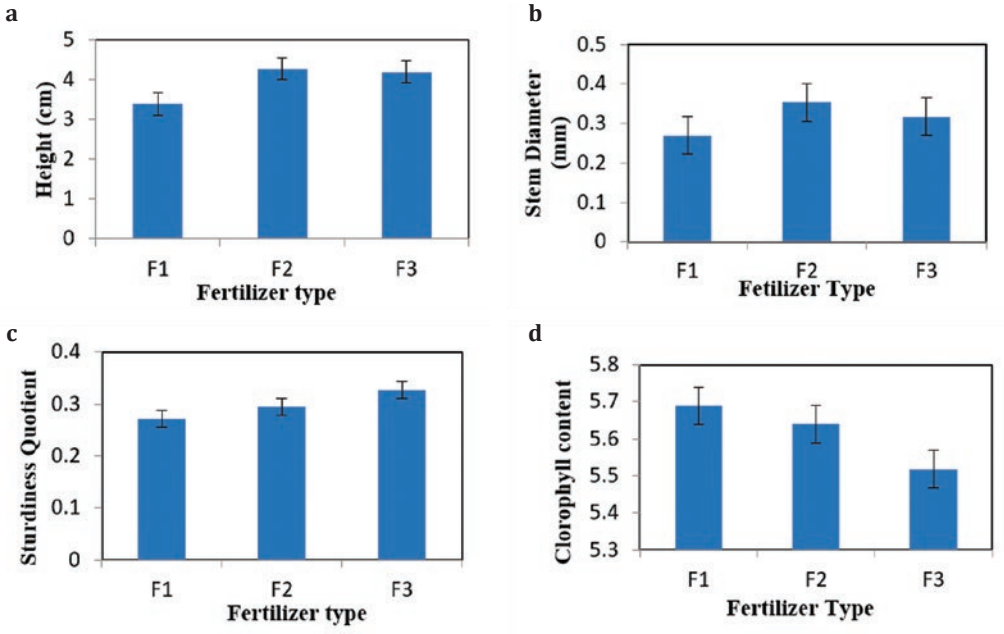

Figure 3.2: Changes in (a) plant height (cm), (b) stem diameter (mm), (c) sturdiness quotient, (d) chlorophyll content of *A. oleracea* grown in different potting media. (F_1: No fertilizer application, F_2: Maxi crop foliar application, F_3: Albert solution application)

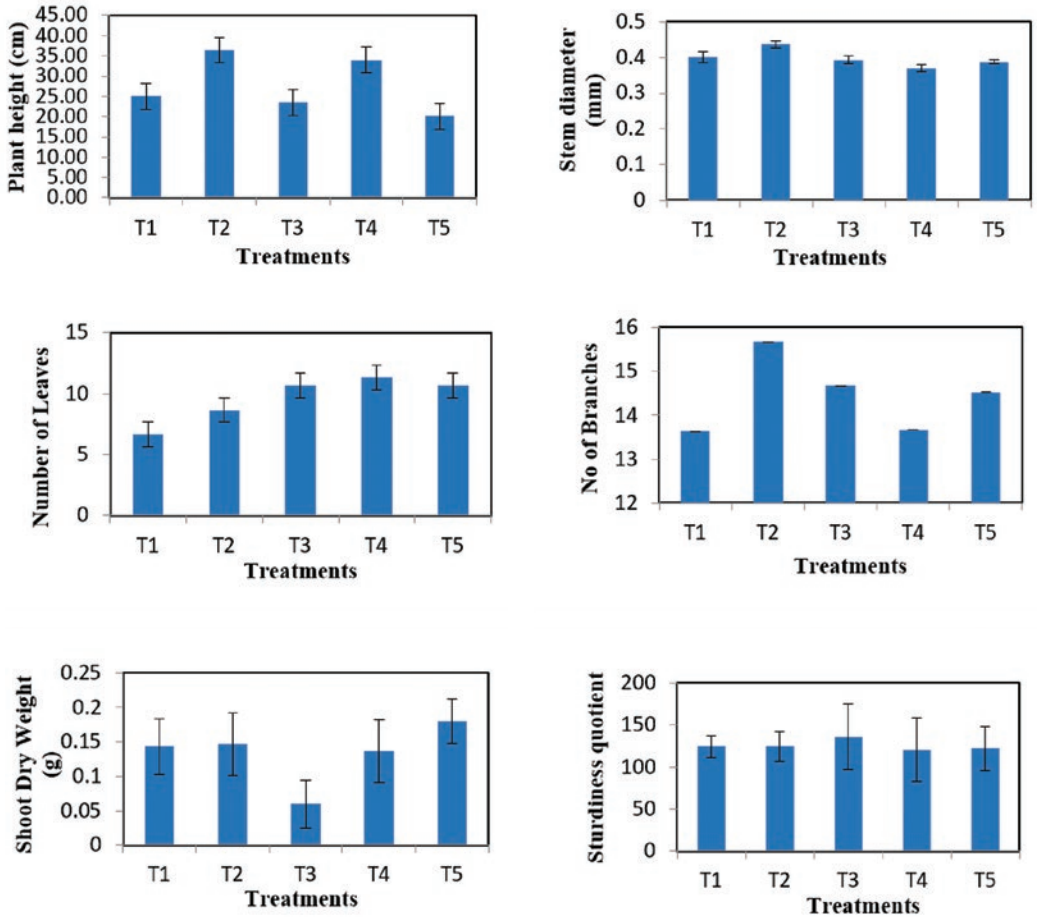

Figure 3.3: Changes in (a) Plant Height (cm), (b) stem diameter (mm), (c) number of leaves, d) number of branches, (e) shoot dry weight, (f) sturdiness quotient of *A. oleracea* plants with different irrigation frequencies. (T_1: Daily watering, T_2: 2 days interval, T_3: 3 days interval, T_4: 5 days interval, T_5: 7 days interval)

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Morphological Study of Some Conserved Orchids in Royal Botanic Gardens, Peradeniya

Wijerathna H.M.J.C[1], Bandara M.M.L.I.W.[2], Fonseka, D.L.C.[1], Jayalath J.S.M. [2]

[1] *Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka.*
[2] *Department of National Botanic Gardens, Peradeniya, Sri Lanka*

ABSTRACT

This study investigates the ecological traits and conservation status of naturally occurring and cultivated orchids found in the conservatory of Royal Botanic Gardens, Peradeniya, with a focus on their implications for biodiversity preservation. The primary objectives include morphologically identifying the orchid species, their natural range, conservation status of each species, and exploring conservation strategies to protect vulnerable species. Through detailed morphological analysis and photographic documentation, the study identified 10 orchid species, all are native species .The findings reveal that species distributions are strongly associated with specific microhabitats, highlighting the ecological importance of habitat conservation. Conservation strategies recommended in the National Red List 2020, such as habitat protection, seed banking, host tree conservation, and microhabitat simulation, are critical for native species. These measures ensure the survival and ecological integrity of native orchids within their specific microhabitats. The main challenge in identifying certain species is the lack of flowers and pods, which are crucial for accurate identification. By documenting the unique characteristics and ecological preferences of these orchids, this research provides valuable insights for targeted conservation efforts. The study underscores the role of the Royal Botanic Gardens in ensuring the protection of Sri Lanka's orchid biodiversity while supporting global conservation goals.

Keywords: Orchid, morphological identification, microhabitats, conservation strategies

INTRODUCTION

Orchids, belonging to the family Orchidaceae, are renowned for their extraordinary diversity and intricate floral structures. Comprising approximately 25,000 species globally (Dressler, 1993), they represent one of the largest families of flowering plants. Beyond their aesthetic appeal, orchids play pivotal ecological roles, serving as critical pollinators and indicators of environmental health. Their complex relationships with a variety of pollinators underscore their significance in maintaining biodiversity and ecological balance. However, many orchid species face serious threats due to habitat loss, climate change, and illegal trade, which necessitate urgent conservation, measures (Cribb & Brown, 2007).

Sri Lanka is home to approximately 189 orchid species, with 55 being endemic to the island, and around 71% of these species are classified as threatened, highlighting the critical need for targeted conservation strategies (National Red List 2020). This unique biodiversity not only contributes to the ecological tapestry of the region but also holds cultural significance, as orchids have been integral to local traditions and practices.

Botanical gardens play an indispensable role in the ex-situ conservation of plant diversity (Mace and Purvis 2008) emphasize that these gardens function as living archives

**jananiwijerathna3@gmail.com*

for threatened species, facilitating scientific research, education, and public outreach.

The Royal Botanic Gardens, Peradeniya, established in 1821, is one of Sri Lanka's foremost botanical institutions. It spans 147 acres and houses an extensive collection of endemic, native, and exotic orchids. The garden plays a vital role in conserving the genetic diversity of orchids, which are particularly vulnerable to environmental fluctuations. Additionally, some of these orchids are cultivated in nurseries, further emphasizing the gardens' critical contribution to the preservation of rare and endangered species and the broader conservation of botanical diversity.

This study focuses on evaluating the diversity, ecological traits, and conservation status of some naturally occurring orchids in the field and cultivated orchids found in conservatory of the Royal Botanic Gardens, Peradeniya

The research objectives include the morphological identification of various orchid species, evaluation of their conservation status, and to explore and implement conservation strategies for protecting those orchid species.

By documenting these orchids, the study seeks to address existing knowledge gaps regarding their distribution and conservation requirements.

Furthermore, this research aims to emphasize the ecological and aesthetic importance of orchids and their contribution to rich biodiversity in Sri Lanka.

MATERIALS AND METHODS

Study Area: Royal Botanic Gardens, Peradeniya,

Section Division: The garden was subdivided into four zones (figure 1) Two zones were examined for identification of orchid species.

Figure 1: Study Area

Field Surveys: The field survey was conducted over two sections (section 1 and 2) of the Royal Botanic Gardens, Peradeniya.

Orchid Observation: Naturally occurring orchids in the field and cultivated orchids in the conservatory except orchid nurseries were observed and photographed using high-resolution cameras with specialized lenses to capture detailed floral and vegetative characteristics.

Identification: Observed orchid species were morphologically identified and documented their conservation status, habitats, floral characteristics, host plants, and leaf characteristics.

Size of Leaf, flowers and inflorescence were measured and categorized as follows:

- Small: 1–5 cm
- Medium: 5–10 cm
- Large: Above 10 cm

Confirmation: Orchid species were identified and confirmed using herbarium specimens and with the guidance of the Flora of Ceylon and relevant scientific literature

RESULT AND DISCUSSION

Through detailed morphological analysis and photographic documentation, 10 orchid species were identified in the study, including six naturally occurring species from the field and four cultivated species in the conservatory of the Royal Botanic Gardens.

The identified field species includes *Aerangis hologlottis*, *Vanda testacea*, *Dendrobium macrostachyum*, *Luisia tenuifolia, Rhynchostylis retusa*, and *Polystachya concreta*, while the cultivated species in the conservatory are *Arundina graminifolia*, *Cymbidium haematodes*,*Liparis viridiflora*, and *Acampe ochracea*.

Orchids in the field *Aerangis hologlottis*

Aerangis hologlottis is a stemless, non-pseudobulbous epiphytic orchid with cylindrical, vermiform roots that firmly adhere to its host. This orchid was found on the branch lets of its host plants, which are *Phyllanthus myrtifolius* and *Pittosporum tenuifolium*. These plants provide structural support, shade the microenvironment, and thereby, increase the humidity needed for this orchid to grow and survive on its host (Benzing, 2000).

Leaves are oblong-lanceolate, falcate and coriaceous, measuring 4.5–9 cm (medium) in length and 1.1–1.7 cm in width of medium size, 4.5–9 cm long and 1.1–1.7 cm wide. They are dark green and glossy on the above surface, paler underneath, with a prominent midrib and conspicuously reticulated lateral veins. The apex is unequally bilobed, an adaptation that minimizes transpiration, aiding the orchid's survival in its epiphytic environment (Gentry,1982). The inflorescence is a prominently bracteated, semierect raceme, categorized as large (measuring 13.5–16.5 cm in length). The flowers are white, small (1.1–1.4 cm in diameter), and arranged irregularly along the raceme, opening at either the base or the middle. The floral bracts are ovate and almost enclosing the rachis and split open as the flower buds emerge.

The irregular flowering pattern observed in this species promotes its reproductive success by extending the period during which blooms are available to pollinators (Stebbins, 1974). Flowering was recorded during April and June, providing insights into the seasonal patterns of this species. Additionally, the reticulated venation of the leaves optimizes light absorption and enhances photosynthesis, allowing the plant to thrive under shaded conditions provided by the dense canopy of its host plants (Benzing, 2000). The cylindrical spur on the lip is a specialized adapt efficient facilitates specific pollinator interactions, ensuring the efficient pollination and subsequent seed production (Faegri & van der Pijl, 1979).

These distinctive morphological features, particularly the medium-sized leaves with reticulated venation, the large inflorescence, and the irregular flowering pattern along the raceme, clearly distinguish *Aerangis hologlottis* from other species within the genus. Additionally, its association with *Phyllanthus myrtifolius* and *Pittosporum tenuifoliumas* host plants further emphasizes its ecological preference for shaded and humid microhabitats.

Conservation Status

Aerangis hologlottis is listed as an Endangered species in the IUCN Red List of Threatened Species, 2020 edition (IUCN, 2020) and it is considered native to Sri Lanka.

A B

Figure 2: A- *Aerangis hologlottis* plant, B-Flower

Vanda testacea

Vanda testacea is a robust epiphytic orchid with a short, non-pseudobulbous stem measuring 10–15 cm covered at the base by remnants of old brown leaf sheaths. The leaves are large strap-like and coriaceous, displaying mid-green, measuring approximately 15 cm in length and 1.3–1.9 cm in width. The leaves arranged oppositely at an angle from the central stem, with unequally lobed or toothed apices, characterized by a central tooth formed by the midrib. This feature distinguishes it from species like *Vanda tessellata* (which has praemorse apices) and *Vanda spathulata* (with keeled, emarginate apices). *Vanda testaceawas* observed growing at approximately about 1 meter above ground level, associated with Bougainvillea as the host plants indicating its preference for shaded, humid habitats, as described in the Flora of *Ceylon* Vol.II.

The flowering of *Vanda testacea* is reported to occur predominantly in February, March, and September, as documented in the Flora of Ceylon Vol. II. This restricted flowering period limited the opportunity to observe blooms during the research period.

According to the literature, *Vanda testacea* is characterized by cream-yellow flowers (1.8 cm broad), cream-yellow with a white, purple, or reddish-pink lip, borne on erect racemes measuring 6–15 cm (Dassanayake & Fosberg, 1980). The flowers are notably smaller than those of *Vanda tessellata* (5 cm broad) and feature a distinct three -lobed lip with a narrow, funnel-shaped spur (3.1 mm). This differentiating it from species like *Vanda spathulata*, which produces larger racemes and flowers (Dressler, 1993). The combination of *Vanda testacea*'scompact stature, medium-sized leaves, smaller inflorescence, and ecological adaptations make it a distinctive species within the genus (Benzing, 2000).

Conservation Status

The national conservation status of *Vanda testacea* in Sri Lanka is classified as "Least Concern" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native in Sri Lanka.

Figure 3: *Vanda testacea*

Dendrobium macrostachyum

Dendrobium macrostachyum is an epiphytic orchid species characterized by slender, drooping, *pseudobulbous* stems, typically measuring 30 -70 cm in length, classifying it as large. It was observed growing on *Mangifera indica* trees, utilizing the structural support provided by its hosts. The dense canopy of these trees creates a shaded, humid micro environment that offers optimal conditions for the orchid's growth (Benzing, 2000). The roots are cylindrical and vermiform, firmly adhering to the host trees and ensuring stability and anchorage in the epiphytic habitat.

The leaves of *D.macrostachyum* are oblong-lanceolate, with a distinctive acute apex and a

prominent venation. The leaves, classified as medium-sized (4–6 cm in length and 0.9–2.3 cm in width), are sessile and distichous, displaying a coriaceous texture. Their arrangement maximizes the surface area for photosynthesis, crucial for survival in the shaded microhabitat of its host trees. The basal sheaths envelop the stems and extend from one node to the next, contributing to the structural integrity of the plant (Gentry, 1982).

The inflorescence of *D. macrostachyum* consists of a short, multi-flowered cluster that emerging from the nodes of leafless pseudo bulbs. The greenish yellow-colored flowers, measure 2–2.3 cm across, are small, and arranged in clusters of 2–4-flowerswith short peduncles. Floral bracts are oblong-ovate, acute, and 3-veined, almost sheathing the rachis before splitting as the flowers open.

The flowers display the typical morphological features of the genus, including oblong-lanceolate dorsal and lateral sepals, lanceolate petals, and a 5-veined lip with small lateral lobes that embrace the column. The midlobe of the lip is quadrately ovate, apiculate, and recurved, with a crenulate, ciliate margin. This distinctive feature helps differentiate Dendrobiummacrostachyum from other species within the genus (Dressler, 1993).

The flowering of *Dendrobium macrostachyumis* reported to occur predominantly in March, June and July, as documented in the Flora of Ceylon Vol. II. This seasonal flowering pattern may correlate with the availability of specific pollinators during these months, enhancing reproductive success (Stebbins, 1974). The greenish-yellow flowers likely attract pollinators that are adapted to this orchid's ecological niche, ensuring effective pollination. The morphological features, such as the elongated lip with a cylindrical spur and the distinct floral arrangement, reflect adaptations for pollinator interactions (Faegri & van der Pijl, 1979).

Conservation status

The national conservation status of *D. macrostachyum* in Sri Lanka is classified as "Least Concern" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native to Sri Lanka.

a b

Figure4: a-*Dendrobium macrostachyum* plant , b-Flower

Luisia tenuifolia

Luisia tenuifolia is a unique epiphytic orchid species known for its slender, drooping stems and distinct leaf and flower morphology.

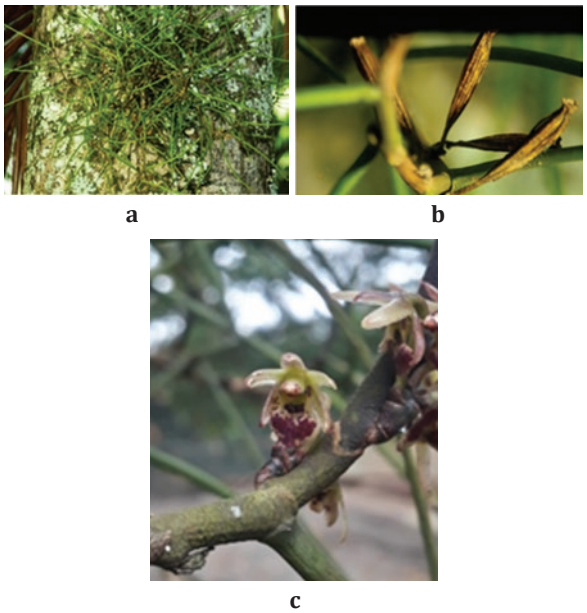
Luisia tenuifolia was found growing on the trunk of a *Rostonea oleracea* tree, approximately 4 meters above ground level, in a partially shaded environment beneath the tree canopy. This habitat preference for semi-shade, combined with its location and height on the tree, aligns with the species' ecological requirements for high humidity and filtered light, conditions typical of epiphytic orchids

The species features non-pseudobulbous, terete, and slender stems ranging from 17–75 cm in length, with vermiform roots and internodes measuring approximately 3.2 cm long. The leaves are dark green, slender, and arranged in a basal rosette pattern, measuring between 8–28 cm in length and 0.4–0.7 cm in width. The leaves are terete and flexuous, with a pointed apex that forms a nail-like beak. A characteristic feature that differentiates *L. tenuifolia* from other *Luisia* species, such as *L. teretifolia*, which has more rigid and thicker

stems and distinct leaf morphology (Benzing, 2000).

Flowering was observed in June, consistent with the flowering period reported in the Flora of Ceylon Vol. II. The flowers of *L. tenuifolia* are medium-sized, measuring approximately 1.1 cm in diameter, and are exhibit pale yellowish-purple with a white-patched dark purple lip. This specific color pattern sets *L. tenuifolia* apart from other species in the genus, such as *L. teretifolia*, which feature purplish green flowers. The flowers are sparsely arranged along close spiciform racemes, with individual blooms opening subsequently. The racemes emerge from axillary peduncles about 6 mm length distinguishing characteristic of this species. Unlike the denser flower clusters observed in *L. teretifolia* or *L. spathulata*, the inflorescence of *L. tenuifolia* is more loosely arranged, further highlighting its uniqueness within the genus.

Conservation status-The national conservation status of *Luisia tenuifolia* is classified as "Near Threatened" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native to Sri Lanka.



a **b**

c

Figure 5: a- *Luisia tenuifolia* plant b- Seed pods, c- Flower

Rhynchostylis retusa

Rhynchostylis retusa is a robust epiphytic orchid with a non-pseudobulbous stem and long, robust aerial roots. The stems, classified as small to medium measuring5–25 cm in length, are leafless at the base, often sheathed with remnants of old leaves. The leaves are strap-shaped, linear, and coriaceous, measuring 15–37 cm in length and 1.6–2 cm in width. The upper surface of the leaves is grooved, and the apex is recurved with an asymmetrically lobed, a ''bitten-off" appearance ((Dassanayake & Fosberg, 1980).

The inflorescence consists of stout, compact, and drooping axillary racemes, categorized as large measuring 20–30 cm in length and 3.5–5 cm in diameter. The flowers, 1.2–2 cm in diameter, are white with violet-pink tinges and are borne on a robust peduncle measuring 9–10 cm in length with sterile bracts at its base. Floral bracts are small cordate, and acute measuring (2.5 mm length) The floral morphology is characteristic of the genus, with ovate sepals, oblong-ovate petals, and a distinctive 3-lobed lip. The lip features a deflexed claw, a deeply saccate or spurred midlobe, and a 2-lobed disc with a rounded, puberulous tip. The column is short, supporting a 2-loculed anther with waxy, globosepollinia attached via a slender strap to small glands (Dressler, 1993).

This species was observed growing on *Mangifera indica* as its host plant, thriving in shaded, humid microhabitats that provide structural support and a favorable environment. Flowering was recorded in August, complementing its known seasonal blooming pattern in January, April, July, and November (Benzing, 2000).The combination of robust aerial roots, compact drooping racemes, and distinct floral morphology highlights its ecological adaptations and taxonomic significance.

Conservation status

The national conservation status of *Rhynchostylis retusa* in Sri Lanka is classified as "Endangered " according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native in Sri Lanka.

Figure 6: *Rhynchostylis retusa*

Polystachya concreta

Polystachya concreta is an epiphytic orchid with a robust pseudobulbous stem, clothed with old leaf sheaths and bearing vermiform roots. The stems are small to medium-sized (15–25 cm length), tufted, and associated with shaded habitats on tree branches. The leaves, classified as medium-sized (10–20 cm in length and 1.2–3 cm in width), are light green, arranged alternately in a distichous fan-like pattern, and are linear-oblong or oblanceolate with an obtuse apex featuring a minute incurved tooth. The leaves are coriaceous, glossy, and slightly wavy along the margin, with a distinct median vein and many lateral veins ((Dassanayake & Fosberg, 1980).)

Although no flowers were observed during the research period, the Flora of Ceylon describes its flowers as pale yellow, 1 cm broad, and resupinate, arranged in terminal panicles up to 42 cm long with faintly tomentose rachises. Floral structures include ovate floral bracts, oblong-ovate sepals, and linear-oblong petals. The lip is cuneate-obovate, fimbriate, and joined to the column foot, with a scurfy disc and trifurcate lateral veins supporting the lobes. The column is short (1.9 mm in lenght), bearing a terminal 2-loculed anther with subglobose pollinia (Dressler, 1993).

This species was observed growing on *Samanea seaman* (Mara) and *Swietenia macrophylla* (Mahogany), which provide structural support and suitable micro environments. These findings align with its ecological preference for shaded, humid habitats. The lack of observed flowering offers insights into its seasonal phenology, highlighting the importance of further monitoring for reproductive studies.

Conservation status

The national conservation status of *Polystachya concreta* in Sri Lanka is classified as "least concern" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native in Sri Lanka.

Figure 7: *Polystachya concreta*

Cultivated orchids in conservatory

Arundina graminifolia

The *Arundina graminifolia* orchid is a tufted herb with grass-like stems and leaves, adapted to its conserved habitat within a conservatory. The stems are tall, measuring approximately 130 cm in length, and the leaves are long and narrow, linear-lanceolate, and acuminate, ranging from medium to large in size (20–28 cm length and 1.5–2.3 cm width). The leaves are sheathing at the base and exhibit 5–9 prominent veins, which enhance their structural support and photosynthetic

efficiency ((Dassanayake & Fosberg, 1980). Flora Of Ceylon Volume II)

The flowers, distinctively white and approximately 5 cm broad, are arranged in terminal racemes, emerging prominently from the stem apex. Floral bracts are broadly ovate, persistent, and acute, while sepals are linear-lanceolate and spreading, displaying a highly veined structure. Petals are oblong-lanceolate, marked by three prominent veins with branched lateral veins at the base. The lip, measuring 5 x 3.7 cm when spread, is characterized by rounded lateral lobes that embrace the column and a subrotund midlobe with curled margins. The disc features three fimbriated ridges, each with a basal callus on the lateral ridges that extends to the midlobe, a morphological trait aiding in species differentiation within the genus (Dressler, 1993).

This species' large, showy flowers and structural adaptations, particularly its prominent fimbriated ridges and callused disc, distinguish it from other varieties in its genus. Observed flowering in June and the white flower coloration provide critical phenological and morphological data, diverging from the rose-purple flowers((Dassanayake & Fosberg, 1980).

Conservation status

The national conservation status of *Arundina graminifolia* in Sri Lanka is classified as "Data Deficient" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native in Sri Lanka.

a

b

Figure 8: a- *Arundina graminifolia* plant, b-Flower

Cymbidium haematodes

Cymbidium haematodes is a tufted epiphytic orchid with very short, non-pseudobulbous stems clothed with brown, ovate-lanceolate sheaths. The roots are thick, vermiform, and provide strong anchorage to the substrate. The leaves are dark green, long, and narrow, classified as large (approximately 50–70 cm in length and about 5 cm in width). The leaves are linear-ensiform, acute, and 3–5-veined beneath, with scabrous margins, making them well-suited for minimizing moisture loss in their epiphytic habitat (Benzing, 2000).

The flowers are sweetly scented, dull yellow with pink veins, and a pale-yellow lip spotted and stained with dark pink. The flowers are large (6.5 cm broad) and arranged along a suberect, many-flowered raceme categorized as large (approximately 30 cm in length). The flowering period was observed in June, coinciding with its seasonal blooming pattern described in the Flora of Ceylon Volume II.

This species was observed in a partially shaded environment within a conservatory, which mimics its natural habitat by providing optimal light and humidity conditions. The sweetly scented flowers and colorful lip markings are adaptations to attract specific pollinators, contributing to reproductive success (Faegri & van der Pijl, 1979). The plant's dense arrangement of leaves and sturdy root system enhances its ability to capture

light and retain moisture, key adaptations for thriving in shaded, epiphytic habitats. The observed morphological traits, including the large leaves, large inflorescence, and distinctive floral characteristics, align closely with the taxonomic description of *Cymbidium haematodes*. These features clearly distinguish it from other species in the genus *Cymbidium* and *underscore* its ecological preferences and adaptations.

Conservation status

The national conservation status of *Cymbidium haematodes* in Sri Lanka is classified as "Vulnerable" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native in Sri Lanka.

Figure9: a- *Cymbidium haematodes* plant, b-Flower

Liparis viridiflora

Liparis viridiflora is a tufted epiphytic orchid distinguished by its ovoid to conical pseudobulbs, which measure 1–9 cm in length and are clothed in papery sheaths. The plant bears 2–3 sessile, coriaceous leaves clustered at the base of the pseudobulbs. These leaves are linear-lanceolate, broader toward the apex, and measure 3–24.5 cm in length, offering efficient water retention and light absorption, critical for its epiphytic lifestyle (Benzing, 2000).

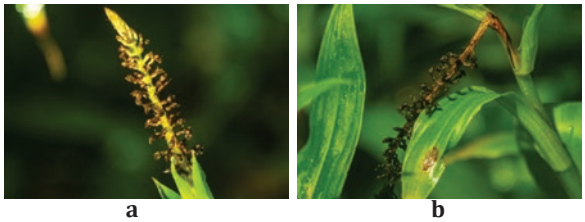
The flowers are small, green, and arranged in long, pendulous racemes measuring 17–18 cm in length. These racemes emerge from a green, terete peduncle (5–8 cm long) that carries sterile bracts toward the end. Each flower is 2.8–3.5 mm across, with an orbicular-ovate lip that is obscurely 3-lobed and fleshy.The column is arched, standing 1.8–2 mm high, and the pollinia are waxy, presented in two pairs. This floral morphology is distinct, with the pendulous racemes and small green flowers differentiating *L. viridiflora* from other species in the genus, such as *L. walkeriae* (with purple flowers) or *L. gibbosa* (with short racemes) (Flora Of Ceylon Volume II)

Ecologically, *L. viridiflora* thrives in humid environments with filtered light. The plant was found within a conservatory, growing under controlled conditions that mimic its natural habitat. The flowers, pale yellow and approximately 7 cm in lenghth , were borne on a central spike, and flowering was recorded in June. These findings align with the seasonal blooming patterns noted for epiphytic orchids, where flowering often coincides with high humidity and optimal pollinator availability (Arditti, 1992).

The long, pendulous racemes and clustered, coriaceous leaves are adaptations that enhance the orchid's ability to attract specific pollinators and conserve water. Traits such as coriaceous leaves and pendulous inflorescences are typical of epiphytic orchids, as they optimize survival in shaded, humid environments (Benzing, 2000). Additionally, the ecological specialization of *Liparis* species highlights their adaptability to epiphytic niches (Flora Of Ceylon Volume II). These features make *L. viridiflora* a clearly identifiable species within its genus, particularly when compared to terrestrial relatives like *L. wightiana* or *L. barbata*.

Conservation status

The national conservation status of *Liparis viridiflora* in Sri Lanka is classified as "Nerly Threatened" according to the IUCN Red List 2020 (IUCN, 2020) and it is considered as native in Sri Lanka.



a b

Figure 10: a –*Liparis viridiflora* plant, b-Flower

Acampe ochracea

Acampe ochracea is an epiphytic orchid with simple, non-pseudobulbous stems, ranging from 30 to 76 cm in length. The roots are vermiform and branched, providing strong anchorage and efficient nutrient absorption in its epiphytic habitat. The leaves are dark green, thick, fleshy and strap-like, arranged in two opposite rows along the stem, classified as large (14.5–19.3 cm in length and 1.8–2.3 cm in width). The leaves are lorate, distichous, and keeled, with two rounded lobes at the apex. Each leaf articulates into short petiolar sheaths that ensheath the internodes above. This structural arrangement optimizes light capture and minimizes water loss, which is critical for epiphytic survival in environments with fluctuating moisture availability (Benzing, 2000).

The plant was observed in a conservatory under controlled conditions that mimic its natural habitat, with optimal humidity and indirect light. No flowers were observed during the study, consistent with its seasonal flowering cycle, where blooms typically emerge from axillary racemose panicles. The flowers are described in the literature as small (1 cm across), yellow with red transverse striae, and borne on panicles that are as long as or longer than the leaves. The observed vegetative traits, particularly the large strap-like leaves and distinct articulation on petiolar sheaths, align closely with the taxonomic description of *Acampe ochracea* in the Flora Of Ceylon Volume II. These features clearly distinguish it from other species in the genus and underscore its adaptation to epiphytic habitats.

Conservation status

The national conservation status of *Acampeo chraceaea* in Sri Lanka is classified as "Near Threatened" according to the IUCN Red List 2020 (IUCN,2020) and it is considered as native in Sri Lanka.

Figure 11 : *Acampe ochracea*

DISCUSSION

This study identified 10 native orchid species from the Royal Botanic Gardens, Peradeniya, categorized based on conservation status and ecological requirements. The two native species, *Dendrobium macrostachyum* (Least Concern) and *Luisia tenuifolia* (Near Threatened), underscore the importance of conservation through host tree preservation, seed banking, and controlled propagation. Microhabitat protection is particularly critical for *Luisia tenuifolia* due to its vulnerability Among the other native species, *Rhynchosty lisretusa* and *Aerangish ologlottis*, both classified as Endangered, necessitate targeted habitat restoration, pollination support, and the establishment of controlled environments to enhance survival. *Polystachya concreta* and *Vanda testacea*, categorized as Least Concern, require periodic monitoring and in-situ conservation efforts to maintain stable populations. *Arundina graminifolia*, identified as Data Deficient, underscores the need for further research and incorporation

into conservation monitoring program. Additionally, three native species found in conservatory in the garden, *Cymbidium haematodes* (Vulnerable), *Liparis viridiflora* (Near Threatened), and *Acampe ochracea* (Near Threatened) highlights their contribution to the biodiversity of the gardens. Conservation strategies for these species emphasize propagation to prevent over-collection, regular population assessments, and their use in educational and awareness programs to promote community engagement.

Overall, the conservation of these orchids requires a multifaceted approach, including habitat preservation, propagation techniques, research-driven initiatives, and public involvement. These tailored measures, addressing the unique ecological needs of each species, will ensure the long-term sustainability and biodiversity of these native orchids within the Royal Botanic Gardens.

CONCLUSION

This study documented 10 orchid species from the Royal Botanic Gardens, Peradeniya, observed in both the field and the conservatory. So all are considered as native species in Sri Lanka. According to the National Red List 2020, these orchids exhibit varying national conservation statuses: three species are listed as Least Concern, three as Near Threatened, two as Endangered, and one as Data Deficient.

According to the findings, conservation strategies must be tailored to the needs of each category. For Least Concern species, habitat monitoring is recommended to maintain their stable status. Near Threatened species require proactive measures, such as habitat restoration and ensuring adequate pollination. Endangered species demand urgent conservation interventions, including microhabitat protection, propagation, and seed banking.

The Royal Botanic Gardens play a critical role in orchid conservation, providing ex-situ conservation for a diverse range of native orchid species. Its efforts in propagation, habitat simulation, and public education are essential for safeguarding Sri Lanka's rich orchid heritage. By addressing challenges such as habitat loss, climate change, and over-collection, the gardens contribute significantly to the preservation of native biodiversity and support broader conservation initiatives at both national and global levels.

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Improvement of The Growth and Ornamental Quality of *Henckelia* Hybrid ii Plants in Different Shade Levels

Abeysinghe K.M.N.S.[1]*, Jayalath J.M.S.M.[2], Karunarathne A.D.R.[2], Senarathne M.M.D.J.[2] and Geretharan T.[1]

[1] *Department of Crop Science, Faculty of Agriculture, Eastern University, Sri Lanka*
[2] *Floriculture Research and Extension Unit, Royal Botanic Gardens, Peradeniya, Sri Lanka*

ABSTRACT

Henckelia hybrid II is a perennial flowering plant produced by wild crossing and raring at Royal Botanic Gardens, Peradeniya. The present study was conducted with the objective of introducing *Henckelia* hybrid II as a potted flowering plant to the floriculture industry in Sri Lanka. The best stem cutting part for propagation and the effect of different shade levels on growth for the *Henckelia* hybrid II were investigated. This was carried out with two experimental studies and the experiments were arranged in Complete Randomized Design (CRD). In experiment 01, inclined with 3 treatments with 10 replicates and experiment 02 inclined with 5 treatments with 5 replications. Plant height was increased significantly (P<0.000) in 80% shaded condition. The lowest plant height was recorded under the 0% shade condition (under full sunlight). Number of leaves (P<0.000) and average root length (P<0.000), chlorophyll content of the plant and fresh mass of the plant also significantly increased the plants that were under 80% shade condition. Number of lateral shoots were not showed significant difference (P<0.708) between the treatments.

Keywords: *Henckelia* hybrid ii, propagation, shade levels, stem cuttings

INTRODUCTION

Henckelia hybrid ii is a wild plant which belongs to family of Gesneriaceae in the major group Angiosperms. *Henckelia* species can be propagate sexually using seeds and vegetative by leaves and stem cuttings (Rubasinghe *et al*., 2009). Genus *Henckelia* has approximately 140 species those widely distributed among western Himalaya and southern China to Southern India, Sri Lanka, and western Malesia. (Y. Z. Wang *et al*., 2011). The synonym of *Henckelia* is Chirita. *Henckelia* (Chirita) is a wild caulescent herb or shrub. It has opposite or whorled leaves and petiolate. Inflorescence axillary, 1-flowered, or compound dichasium. Calyx is large, deeply 5- parted or divided. Corolla large, tubular-funnel form, ventricose. Five lobes. Anthers connate, app;anate, with a tuft or hairs on back. Disk annular or lobed, surrounding base of ovary. Fruit a capsule, linear, loculicidally 2-valved, seed numerous. (flora of Ceylon) Many crops are impacted by climate variables at various stages of their development and growth, so it is crucial to consider how climate affect agricultural productivity(Baraka *et al*., 2019).

The plant growth is affected by environmental factors. Light, temperature, and water (precipitation) are the three environmental variables that have the most biological impact on rangeland plant growth. Internal regulators that are altered in response to external factors manage the growth. The most significant ecological factor influencing plant growth is light. Light is necessary for photosynthesis, and changes in the length of the day (photoperiod) regulate the phenological development of rangeland plants. Physiological mechanisms that start development and flowering as well as the process of hardening for resistance to

*nuwanthiabesinghe@gmail.com

low temperatures in the fall and winter are activated or stopped by changes in the length of the day(The University of Arizona, 1998)

Compared to wild plants, the technology available for cultivating endemic plant species, such as *Henckelia* (Chirita), is very limited. Also, the big issue is wild *Henckelia* (Chirita) species are threatened to be rare plants because of urbanization and deforestation. Unknown *Henckelia* hybrid varieties are essential for propagation and enhance population to minimize the risk of rare and lost (Rubasinghe *et al*., 2009). Also, when it comes to the foreign exchange earning sector of the floriculture industry, developing rare plants like *Henckelia* as pot ornamentals will increase popularity and distribution among the public. Also there is no study conducted in the past in Sri Lanka to assess the shade tolerance limit of *Henckelia*. Therefore, this study aimed to find out the best wood cutting for propagation and determine the effect of different shade levels and best shade levels for the development of *Henckelia* as pot ornament plant.

This study conducted to identify the effect of shade levels on number of leaves, number of flowers and chlorophyll content of *Henckelia* hybrid ii plant. Also, the plant is stunted by pinching of shoot tips and maintaining height of a plant between 15 cm – 20cm, using 50%, 60%, 70% and 80% shade levels. This research was carried out under two experimental studies. From experiment 1, the best wood part will be selected, and experiment 2 will find the suitable shade level to increase the number of flowers and quality leaves. For the selection of best wood part as measurements number of leaves, death percentage and visual healthiness will take. Selected best plant wood parts are repotting and place under 50%, 60%, 70%, 80% shade levels and open sun light (control) and their growth and flowering will observe.

MATERIALS AND METHODS

The experiment was performed from December 2022 to March 2023 at the Floriculture Research and Development Unit, Royal Botanic Gardens, Peradeniya; at central province of Sri Lanka, belongs to agro-ecological zone 2b mid country wet zone, coordinates 7°16'N 80°35'E. The mean annual rainfall ranges 1900-2500mm and annual temperature variation ranges 18°C -30°C. The experiment was arranged in a completely randomized design (CRD). Graded levels of shade were defined as treatments.

This study was conducted under two experiments. Experiment 01 conducted for identified best cutting part for vegetative propagation. It was inclined with 3 treatments ((soft wood, semi hard wood and hard wood) with 10 replicates and used sterilized Leaf mold: Coir dust (1:1 ratio)as growing medium sieving by 2mm net and treatments kept under propagator in one month. In experiment 2 conducted to identify optimum shade level for the selected best cutting part from the experiment one. In this experiment 02 used Sand: Leaf mold (1:1 ratio) growing medium. It inclined with 5 treatments (50%, 60%, 70%, 80% shade condition and full sunlight for control) with 5 replications. In experiment 02, number of leaves, number of lateral branches and height of the plant were measured from three weeks after repotting in one-week intervals. Chlorophyll content, fresh mass of the plant, average root length and number of roots were measured after 6th week from repotting.

RESULT AND DISCUSSION

The study was carried out to study the best cutting part and optimum shade level of the *Henckelia* hybrid ii to induce the growth performance as well as improve the quality of the plant production. According

to the experiment one the following table 01 illustrates that the survival percentages of different wood cuttings after one-month propagation period. There is a significant difference between soft wood cuttings and hard wood cuttings while p>0. 034. The highest survival percentage was reported from the soft wood cuttings and hard wood cuttings were reported the lowest survival percentage. This result might be the highest rooting potential of soft wood cuttings and similar results were reported Likwise, Gvasaliya *et al*. (not in the reference list) (1990) that top cuttings of fresh stems and shoots were used to successfully propagate stevia.

Table 01: The survival percentage of *Heckelia* hybrid ii wood cuttings

Treatments	Survival percentage (%)
T1 (soft wood)	0.900 ± 0.100^{a}
T2 (semi-hard wood)	0.800 ± 0.133^{ab}
T3 (hard wood)	0.400 ± 0.163^{b}

The experiment 02 showed that the effect of different shade levels (Table 02) on the height of *Henckelia* hybrid ii plant after 6th week from repotting date. Among these different shade levels, the highest plant height was recorded in T1 (6.52cm). The lowest height was recorded in T0 (2.6cm).These results reflect those of Cermeno *et al*. (2001) who also found that reduction of radiation increased stem length in chrysanthemums (Hlatshwayo, 2010).

Table 02: The effect of different shade levels on the height of *Heckelia* hybrid ii plant after 6th week from repotting date.

Treatments	Height of the plant (cm)
T0(0% shade)	2.620 ± 0.136^{d}
T1(80% shade)	6.520 ± 0.116^{a}
T2(70% shade)	4.080 ± 0.037^{b}
T3(60% shade)	3.500 ± 0.270^{bc}
T4(50% shade)	3.120 ± 0.252^{cd}

The table 03 explained the effect of different shade levels on number of leaves of *Henckelia* hybrid ii plant after 6th week from repotting date. The number of leaves were significantly (P<0.05) concealed when compared with the 0% (control). It was revealed that the highest number of leaves are in T1 (16) at the p >0.000 level. The lowest number of leaves was observed in T4 (7) compared with other treatments. And T0 (control) plants obtained more leaves than the treatment 04 plants. These results reflect those of Abhay *et al*. (1992) not in the reference list who also found that Dracaena plants under shady condition (50%) showed higher number of leaves than full sunlight condition. The number of leaves increase in the succulent plants under cool climatic conditions (https://www.sciencedirect.com/science/article/abs/pii/S1537511017300880).

Table 03: The effect of different shade levels on number of leaves of Heckelia hybrid ii plant after 6th week from repotting date.

Treatments	Number of leaves
T0(0% shade)	8.000 ± 0.548^{c}
T1(80% shade)	16.400 ± 0.245^{a}
T2(70% shade)	11.400 ± 0.510^{b}
T3(60% shade)	9.400 ± 0.540^{bc}
T4(50% shade)	7.800 ± 0.860^{c}

The table 04 indicated the effect of different shade levels on number of lateral shoots per plant of *Henckelia* hybrid ii. This result is significant at the p <0.708 level. According to the results there are no significant differences between the treatments. According to Rylski, I., & Spigelman, M. (1986) was found that the shading inhibits the development of lateral shoots of sweet pepper.

Table 04:The effect of different shade levels on number of lateral shoots per plant of *Heckelia* hybrid ii plant after 6th week from repotting date.

Treatments	Number of lateral shoots
T0(0% shade)	2.800 ± 2.060[a]
T1(80% shade)	2.000 ± 0.000[a]
T2(70% shade)	1.400 ± 0.510[b]
T3(60% shade)	1.000 ± 0.000[a]
T4(50% shade)	1.400 ± 0.245[a]

Furthermore, the following table 05 showed the effect of different shade levels on fresh mass of *Henckelia* hybrid ii plant after 6th week from repotting date. The fresh mass was significantly (P<0.05) swallowed when compared with the 0% (control). According to the results the highest weight was observed from the T1 (15.790g). The lowest weight was reported in T0 (control).Because of that the plant growth improves under the shade condition of the shade loving plants.

Table 05: The effect of different shade levels on fresh mass of *Heckelia* hybrid ii plant after 6th week from repotting date.

Treatments	Fresh mass (g)
T0(0% shade)	5.435 ± 0.117[c]
T1(80% shade)	15.790 ± 1.500[a]
T2(70% shade)	9.389 ± 0.477[b]
T3(60% shade)	6.504 ± 0.639[bc]
T4(50% shade)	6.173 ± 0.629[bc]

The effect of different shade levels on chlorophyll content of *Henckelia* hybrid ii plant after 6th week from repotting date are presented in table 06. The chlorophyll content was significantly (P<0.05) suppressed when compared with the 0% (control). The results revealed that T1 showed highest (32.614) chlorophyll content compared to the other treatments. The decrease in light intensity under 80% shade condition might be the reason for highest chlorophyll content in the plants. Furthermore, Muhidin *et al*., 2018 concluded that shade had a significant effect on the chlorophyll and anthocyanin content of plant leaves.

Table 06: The effect of different shade levels on chlorophyll content of *Heckelia* hybrid ii plant after 6th week from repotting date (µmol m-2).

Treatments	Chlorophyll content (µmol m-2)
T0(0% shade)	21.39 ± 2.140[b]
T1(80% shade)	32.614 ± 0.753[a]
T2(70% shade)	26.384 ± 0.264[b]
T3(60% shade)	24.078 ± 0.839[b]
T4(50% shade)	21.840 ± 1.110[b]

Table 07 below shows the effect of different shade levels on average root length of *Henckelia* hybrid ii plant after 6th week from repotting date. The best results were obtained at T1 plants (9.6cm). A possible explanation for this might be due to better microclimate in terms of reduction in temperature, relative humidity, wind speed and light intensity under 80% shade.

Table 07: The effect of different shade levels on average root length of *Heckelia* hybrid ii plant after 6th week from repotting date (cm).

Treatments	Average root length (cm)
T0(0% shade)	1.720 ± 0.242[c]
T1(80% shade)	9.600 ± 0.551[a]
T2(70% shade)	6.280 ± 0.224[b]
T3(60% shade)	5.200 ± 0.336[b]
T4(50% shade)	2.960 ± 0.477[c]

CONCLUSION

The main objective of this study was to determine the best shade level to develop *Henckelia* hybrid II plant as pot ornamental. The second aim of this study was to investigate the best wood cutting for propagation of *Henckelia* hybrid II. This study has identified the best wood cutting t for propagation as soft wood cutting, which had 90% survival percentage. The best shade level for growth of *Henckelia* hybrid II plant is 80% shade

condition. *Henckelia* hybrid II plants grown under 80% shade level with better growth performance such as plant height, number of leaves, average root length, chlorophyll content and fresh weight of the plants the findings of this study revealed that the height of the plant, number of leaves. On the other hand, *Henckelia* hybrid II grows less when it is shaded. The plants under full sun light (0% shade level) showed lesser growth performance.

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Influence of Temperature, Indole-3-Butyric Acid and Node Count on Root Development of *Nerium oleander* 'White' in Low Country Dry Zone of Sri Lanka

Devinie M.D.[1]*, Aththanayake M.C.L.[2] and Fonseka D.L.C.K.[1]

[1] *Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Sri Lanka*
[2] *Floriculture and Research unit, Dry Zone Botanic gardens, Mirijjawila, Hambantota, Sri Lanka*

ABSTRACT

Nerium oleander L., a member of the family Apocynaceae, is commonly found in the low-country dry zone of Sri Lanka but is challenging to propagate due to its high latex content under normal growing conditions. Current propagation methods are insufficient to meet the demand for large-scale plant production, necessitating the development of a more efficient propagation technique. This study aimed to identify the most suitable propagation methods for *N. oleander* 'White' under low-country dry zone conditions. Stem cuttings with three and four nodes were treated with Indole-3-butyric acid (IBA) and subjected to two temperature levels to assess their effect on rooting. Data on shoot count, root length, root volume, and shoot number were recorded 45 days post-planting. Results revealed significant effects of the treatments (temperature, node number, and IBA) on root number ($p = 0.0043$), root volume ($p = 0.0108$), and shoot count ($p = 0.0121$). The highest mean values were observed in three-node semi-hardwood cuttings treated with IBA and grown at 27°C, offering a viable propagation strategy for this commercially important plant in the low-country dry zone.

Keywords: Dry zone, Indole – 3- butyric acid, Node, Root volume

INTRODUCTION

When considering the Sri Lankan context, there is a huge potential to develop the floriculture sector as a business. The floriculture sector is facing challenges in meeting the growing demand due to inadequate supply. To address this problem, implementing improved techniques & practices is essential to enhance productivity & quality. This can also position the sector to tap into foreign markets, opening new opportunities for growth & competitiveness on a global scale.

The present floriculture industry is recognized as a profitable industry since it can generate higher profit per unit area than some of the field crops, even horticultural crops both for the domestic and export market. (www.dailynews.lk) in addition to that coming about the higher salary era, the floriculture sector too appeared for creating new business openings for rustic populations, especially ladies and youth. (www.dailynews.lk)

Nerium oleander, a member of the family Apocynaceae, is an evergreen shrub characterized by linear, dark green, glossy leaves (Mitchel *et al*., 2000). Known for its ability to tolerate saline conditions and thrive in areas with poor drainage, such as dry zones, this plant is predominantly found in Mediterranean countries. It naturally occurs along watercourses, gravelly terrains, and damp slopes. Widely cultivated for ornamental and landscaping purposes, N. oleander is prized for its abundant, long-lasting flowers, moderate hardiness, low maintenance requirements, and manageable size (Ezioportis *et al*., 2004).

Propagation of *N. oleander* through normal hardwood cuttings is challenging due to the

*dinithidevini0@gmail.com

high latex content, resulting in a low rooting percentage. In the dry zone, propagation has traditionally been done through air layering of hardwood branches. However, this method has significant limitations for commercial purposes, such as landscaping, as it produces a limited number of plants at a time, is time-consuming, and less efficient. Additionally, after each air layering cycle, the mother plants require a recovery period before the next cycle, further delaying production. This issue is particularly problematic for the Dry Zone Botanical Gardens in Mirijjawila, Hambantota. Air-layered plants are also larger and more expensive to produce, resulting in higher costs per plant and reduced demand at sales outlets

Research on rooting methods for *N. oleander* 'White' is limited, highlighting the need to develop an efficient technique to produce plants in greater numbers and the desired size for commercial demand. This study aimed to establish a practical propagation method for *N. oleander* with the following.

The primary objective is to develop an effective and feasible vegetative propagation method for *N. oleander* using stem cuttings. Specific Objectives are:

- To determine the optimal temperature for rooting induction in *N. oleander*.
- To identify effective treatments for enhancing the rooting percentage.
- To assess the impact of node count on the rooting success of *N. oleander*.
- To evaluate the effect of different IBA concentrations on the rooting performance of *N. oleander*

MATERIALS AND METHODS

Location of the Study

- The research was conducted in Floriculture Unit in Dry Zone Botanical Gardens, Mirijjawila, Hambantota from July to October 2023.

Media preparation

- Top soil (sieved by 1/8 inches sieve) and partially burned paddy husk were used in 3 to 1 ratio. These two media components were mixed thoroughly and used to fill the in all experiments.

Preparation of propagator

- The bottom layer of the propagator was lined with polythene, followed by a layer of sand to prevent excessive root growth. A 350 to 400-gauge polythene sheet was used to cover the propagator, which was then secured with soil. The covering process began with the longer sides of the propagator and concluded with the shorter sides. This design allows for multiple openings, facilitating efficient watering and management practices.

Figure 1: Preparation of propagator

Treatments

Table 01: Application of different treatments

Treatment	Temperature	Node	IBA
T1	6°C	3	Without
T2	6°C	3	With
T3	6°C	4	Without
T4	6°C	4	With
T5	27°C	3	Without
T6	27°C	3	With
T7	27°C	4	Without
T8	27°C	4	With

Planting material preparation

- *N. oleander* single petal white variety was used for the experiment. Semi-hardwood cuttings were used for the study and the cutting preparation was done in the morning (before 9 am), to reduce the transpiration. Three and four nodal cuttings were prepared, and after taking the cuttings the cut end immediately dipped in water for avoiding the air bubbles entering to the vascular regions.

Cuttings preparation for 6°C temperature to restore the carbohydrate.

- The three and four nodal cuttings were taken and 20 cuttings per one nodal type was used for the study, 40 cuttings were prepared for storing under 6°C temperature. Prior to cooling the cuttings were sprayed with water and cutting were wrapped in papers. After wrapping sprayed the water again and stored 6°C temperature. Cuttings were stored in refrigerator overnight at 6°C temperature and were taken out.

Rooting hormone preparation

- IBA was used as the root inducer and the main active ingredient of this chemical is Indole-30 butyric acid (Concentration of IBA - 0.35%). Captan 50% (w/w) was used for preventing fungal attacks. These two chemicals were mixed together and applied few drops of water and made as a pulp.

Polythene bag preparation

- Polythene bag was used for the study and, 50 to 60 gauge for polythene bags (five inches height and five inches width). Polythene bags were filled with the media.

Establishment of cuttings

- The media filled polythene bag was taken and made a hole in the middle; one cutting per one polythene bag was established. To reduce the risk of fungal attacks & rots, avoid burying the cuttings too deeply & the base should be just below the surface to allow proper air circulation.

Management Practices

Table 02: Fungicide application schedule

Fungicide	Concentration (g/l)	Time of application
Captan	5g/4l	Before sealing the propagator
Captan	5g/4l	After 21 days

- Watering was done before sealing the propagator to maintain the moisture content in the soil.

Experimental design and layout

Factorial Completely Randomized Design was applied with ten replicates. Factors and levels are as follows:

- The level of Temperature
- The concentration of IBA
- The number of nodes

Data Collection

Vegetative data were collected; number of roots per cutting, highest root length, root volume per cutting, and number of shoots were recorded within 4 days period. When taken the root length, the longest root length was measured in cm. Root volume was measured in ml by using measuring cylinder. When considering the root volume, for getting the actual value of the roots, cut the root system from the cutting and it was bind together by using thread and after measure the root volume. Data were recorded 45 days after establishment.

Data Analysis

The data were analyzed by Statistica 10 computer package following ANOVA procedure. Mean separation was done with kruskhalwallis test.

RESULT AND DISCUSSION

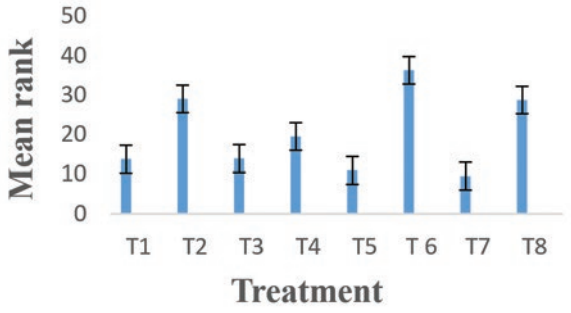

Figure 02: Influence of different treatments on number for roots of *N. oleander*

(Refer Table 01: Application of different treatments)

Figure 02 is shown the variation of the number of roots in *N. oleander* white variety among eight different types of treatments during experimental period. There was a significant difference (p value = 0.0043) among the eight different types of treatments on number of roots of *N. oleander* after 45 days. The sixth treatment (three nodal under 27°C and with IBA semi hardwood cutting) has highest mean value. Also, seventh treatment has the lowest mean value and it is four nodal cutting. Semi hardwood and softwood cuttings are more likely to develop roots and easily develop as independent plant than hardwood cuttings. (https://www.purdue.edu)

The application of IBA significantly increases the root number per cutting, particularly in three nodal cutting, after a 45 day period. This suggests that the use of IBA as a rooting hormone promote root development in three - nodal cuttings compared to four - nodal cuttings.

The enhanced root development observed in three-nodal cuttings compared to four-nodal cuttings can be attributed to the efficient distribution of auxin, greater allocation of nutrients (including energy and resources essential for root development), and a balanced interaction of auxin with other hormones such as cytokinins and gibberellins. Additionally, favorable environmental conditions contributed to creating an optimal environment for root initiation and growth (Adugna *et al*., 2015).

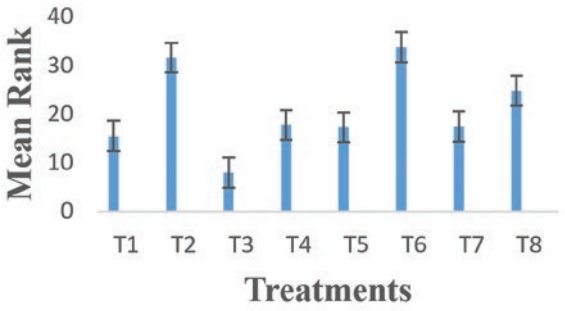

Figure 03: Influence of different treatments for highest root length in *Nerium oleander*

Figure 03 shows the highest root length of *N. oleander* among the eight different treatments during experimental period. According to figure 03 there is no significant difference (p value = 0.0721)among the eight treatments on highest root length of *N. oleander* after 45 days of planting of plant.

As shown in the figure, the sixth treatment (27°C, three-nodal cuttings, and 0.35% IBA) produced the highest mean root length (33.8 cm), significantly outperforming other treatments. The second treatment (three-nodal cuttings with IBA at 6°C) showed a comparatively higher mean root length than the rest. This suggests that the treatment conditions might influence rooting success. The greater root length observed at low temperatures could be attributed to carbohydrate storage in the cuttings during cold storage, which serves as an energy reserve for root development. The initial carbohydrate content in the cuttings is often sufficient to supply energy throughout the rooting period, (https://www.sciencedirect.com)

Figure 04: Measure the root length

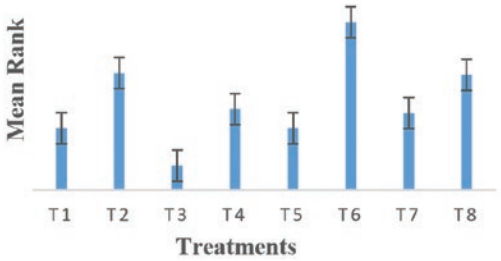

Figure 05: Influence of different treatments for Root volume of *Nerium oleander*

As shown in Figure 05, there was a significant difference (p = 0.0108) in root volume among the eight treatments for *N. oleander* after 45 days. The highest root volume was observed in the three-nodal cuttings. Root volume was measured using a 10 ml graduated cylinder. Additionally, the third treatment resulted in the lowest mean root volume, measuring 5.5 ml.

For the increasing of root volume the level of hormones, the level of temperature, the availability of water, the ability to respond to the stress conditions, the intensity of light and other environmental factors are affecting. (Guess *et al*.,2009) According to the results of the experiment, the sixth treatment, which applied 0.35% IBA and treated the cuttings at 27°C, resulted in a higher root volume compared to the cuttings treated at 6°C. N. oleander is also known to tolerate stress and harsh conditions better than other stem cuttings, which likely contributed to the increased root volume observed in the sixth treatment.

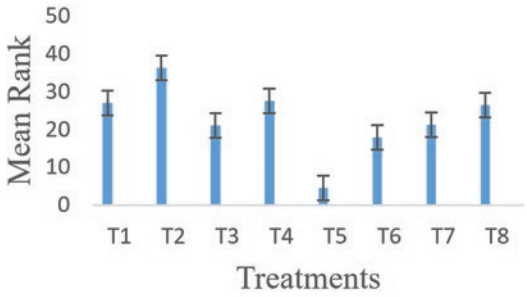

Figure 06: Influence of different treatments for Number of shoots of *Nerium oleander*

Figure 06 illustrates the shoot parameters, specifically the number of shoots. According to the figure, there was a significant difference (p = 0.0121) among the eight treatments regarding the number of shoots in *N. oleander* after 45 days.

According to the results, the second treatment, which involved three-nodal cuttings treated with IBA at 6°C, produced the highest number of shoots (36.375). In contrast, the lowest value (4.5) was observed in the fifth treatment, which involved three-nodal cuttings treated at 27°C.When comparing the results of three- and four-nodal cuttings, those treated at 6°C consistently showed higher values for the number of shoots than those treated at 27°C.

After 45 days, significant effects of auxin treatment and their interactions were observed on the rooting and shoot growth of the cuttings (Leo Sabatino *et al*., 2019), which aligns with the experimental results. The higher levels of auxin in the cuttings and the subsequent stem tissue regeneration at the top of the cuttings led to an increase in the number of shoots in the propagated stem cuttings (https://smujo.id). IBA, a type of auxin, combined with lower temperatures, helped maintain hormone stability under minimal stress conditions. In contrast, temperatures above the optimal range suppressed shoot growth, hindering further plant development (https://www.frontiersin.org).

CONCLUSION

Based on the observations and findings from the study on rooting in *Nerium oleander,* the following conclusions can be drawn:

- The optimal number of roots was achieved in three-nodal cuttings.
- The highest root length and optimal root volume were observed in three-nodal cuttings treated with IBA at 27°C.
- The optimal number of shoots was found in three-nodal cuttings treated with IBA at 6°C.

These findings suggest that temperature and IBA concentration significantly influence the rooting and shoot development of *Nerium oleander*, with three-nodal cuttings showing the best results under specific conditions.

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Effect of Gamma Radiation on Morphology, Survival and Growth of *Melampodium divaricatum*

Siril Kumara D.S.S.[1], Nanayakkara A.N.[2], Rifnas L.M.[3] and Gomas R.S.W.[2]

[2] *Department of National Botanic Garden, Henarathgoda Botanic Garden, Gampaha, Sri Lanka*
[1] *Institute for Agro Technology and Rural Sciences University of Colombo, Sri Lanka*

ABSTRACT

Gamma radiation exposure can induce genetic changes in plants, leading to the emergence of plant variety that exhibits enhanced efficiency in physiological and biochemical activities. *Melampodium divaricatum* is a perennial flowering plant belonging to the family Asteraceae. It features bright yellow flowers, grows up to 12-14 inches tall, and is often used in ornamental horticulture due to its aesthetic appeal and resilience. The seeds were subjected to different doses of gamma radiation using a 60Co research irradiator located in HORDI, Gannoruwa, Sri Lanka. Two successive experiments were conducted by exposing the seeds to dose ranging from 0 Gy to 300 Gy. Seeds in the initial experiment were exposed to gamma irradiation levels of 0 Gy, 20 Gy, 40 Gy, 60 Gy, 80 Gy, and 100 Gy. The second experiment was conducted by increasing the levels of radiation as exposed to 0 Gy, 100 Gy, 150 Gy, 200 Gy, 250 Gy, and 300 Gy, which is based on the observations of the previous experiment. The treated seeds were planted in trays and after fifteen days, they were transplanted in a field at the Henerathgoda Botanical Garden, Gampaha. The experiment was arranged in a complete randomized design (CRD) manner with 12 replications in each. The study was designed to assess morphological changes, germination, survival percentage, Plant height, flower size, flowering date, petals amount, and leaf amount of *Melampodium divaricatum*. The data collected was analyzed using Minitab 19 software and the treatment means were compared using the Tukey at a significance level of 0.05. Significant differences were found across treatments, with 100 Gy showing the highest survival rate and greatest plant height. Lower doses (20 Gy and 40 Gy) impaired germination and survival, while 300 Gy promoted the highest germination rate but stunted plant height and reduced flower and petal development. The results suggest moderate gamma radiation (100 Gy) enhances growth, but higher doses (250 Gy and 300 Gy) negatively affect plant morphology.

Keywords: Gamma radiation, *Melampodium, Seed*

INTRODUCTION

Melampodium divaricatum, commonly known as butter daisy is a flowering plant species native to Mexico and parts of the southwestern United States. It belongs to the Asteraceae family, which includes many well-known flowering plants like daisies and sunflowers. Butter Daisy is prized for its ornamental value, featuring small, daisy-like flowers. It typically grows in a spreading, low-to-the-ground habit, making it ideal as ground cover in gardens and landscapes. This drought-tolerant plant thrives in hot, dry conditions. *Melampodium divaricatum* has simple, opposite, lanceolate to ovate leaves that are bright green and range from 2 to 6 cm in length, giving it a lush appearance. The plant typically grows to a height of 30-60 cm (12-24 inches) with a bushy, spreading habit.

MATERIALS AND METHODS

There were two experiments. 1st experiment was about the germination in lower dosages of gamma radiation and based on that 2nd experiment was conducted which is about higher dosages of gamma radiation. The

*suchiraone@gmail.com

experiments were used to find out the morphological characters of *Melampodium divaricatum* with low and high dosages. The study was conducted at Henerathgoda Botanical Garden Gampaha, Sri Lanka. The study was carried out during the period from the 1st of May to the 26th of July 2024. The seed was taken from the Henerathgoda Botanical Garden Nursery section.Gamma chamber 1200 cobalt 60 research irradiator was used as the irradiation source which is available at the Horticultural Crop Research Institute (HORDI), Gannoruwa, Sri Lanka.

Experiment 01 low dosage

The seeds were radiated to evaluate the germination percentage with the lower dosages. The seeds were treated with gamma radiation as follows;

- T_0 – 0 Gy (control)
- T_1 – 20 Gy
- T_2– 40 Gy
- T_3 – 60 Gy
- T_4 – 80 Gy
- T_5 – 100 Gy

The seeds which were not radiated were considered as a control one (0 Gy). All the setup was arranged based on CRD design.

Experiment 02 high dosage

The 2nd experiment was planned to conduct with higher dosages under difference germination experiments. Hence the seeds were treated with higher dosages as follows;

- T_0 – 0 Gy (control)
- T_1 – 100 Gy
- T_2 – 150 Gy
- T_3 – 200 Gy
- T_4 – 250 Gy
- T_5 – 300 Gy

Preparation of Pots

Pots of 15cm × 12cm were prepared with black polyethylene and made holes at the bottom to facilitate the drainage of excess water. The pots were filled with the potting mixtures treated with Captan fungicide (Captan 50% WP) to sterilize the media. The growing media was prepared with a mixture of coir dust, leaf mold and sand (1:1:1).

Data collection and analysis

The germination percentage was calculated in the experiment 21 days after seeing seeds on the tray. Data was collected every week after transplanting it to the pot. The following data were collected during this process.

- Survival and germination percentage
- Morphological changes in leaf and plants
- Leaf count
- Plant height
- Flower size
- Days to flowering
- Petals amount

Collected data were statistically analyzed using ANOVA procedures using Minitab statistical software version 19, Treatment means were compared using Tukey Test at a 5% significance level.

RESULT AND DISCUSSION

Experiment 01 Germination percentage

Table 1: Effects of gamma radiation on the germination percentage of *Melampodium diviracrum*

Treatment (Gy)	Germination		
	1st week	2nd week	3rd week
0	31.08^{b}	75.00^{b}	74.50^{b}
20	27.00^{C}	53.91^{f}	54.75^{e}
40	32.16^{b}	55.83^{e}	56.41^{e}
60	50.08^{a}	70.00^{c}	69.58^{c}
80	23.66^{d}	61.50^{d}	62.66^{d}
100	23.91^{d}	80.08^{a}	82.75^{a}
Sig	*	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

The p-value of confirms that these differences across treatments are statistically significant. After the 1st week, the highest germination rate is observed at 60 Gy. lowest germination rate is at 80 Gy. The 0 Gy (control) and 40 Gy treatments both show moderate germination rates. The highest germination rate in the 2nd week is 100 Gy. This suggests that despite lower germination rates in the 1st week, seeds exposed to 100 Gy show a substantial recovery by the 2nd week. The lowest germination rate after the 2nd week is at 20 Gy. This indicates that this specific level of radiation (20 Gy) consistently impairs germination. 0 Gy (control) has a strong germination rate, but it is surpassed by the 100 Gy treatment in the second week. The 20 Gy and 40 Gy treatments exhibit the weakest performance, with respectively 100 Gy showing the highest germination rate by the 2nd week, which is given its lower performance in the 1st week. The highest germination rate in the 3rd week is at 100 Gy. This suggests that seeds treated with 100 Gy show the best overall recovery and performance by the 3rd week. Lowest value: The lowest germination rate is at 20 Gy, followed closely by 40 Gy. These treatments consistently show poor performance throughout the three weeks, indicating that lower doses of radiation (20 Gy and 40 Gy) impair germination. 0 Gy (control) has a good germination rate, though it is still lower than the 100 Gy treatment by the 3rd week. 100 Gy continues to have the best performance by the 3rd week, showing a surprising ability to enhance or recover germination at this point. 20 Gy consistently show the lowest germination rates, indicating that these levels of radiation are harmful across all time points. The control (0 Gy) treatment has good overall germination, but the 100 Gy treatment surpasses it after three weeks. The p-value of confirms that these differences across treatments are statistically significant.

Survival percentage

Table 2: Effects of gamma radiation on the survival of *Melampodium diviracrum*

Treatment (Gy)	Survival %
0	74.66^{b}
20	55.41^{e}
40	56.08^{e}
60	70.00^{b}
80	64.58^{d}
100	83.58^{a}
Sig	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

It was found that there were significant ($P<0.05$) differences between the different doses of gamma radiation treatments in the survival of *Melampodium diviractum* seeds. The highest survival rate is observed at 100 Gy, which surpasses even the control treatment. This indicates that a high dose of gamma radiation may stimulate survival. 20 Gy showing that this lower radiation dose has a negative effect on plant survival. 100 Gy shows the highest survival rate, indicating that a high dose of gamma radiation could enhance survival in *Melampodium diviractum*. 20 Gy and 40 Gy show the lowest survival rates, suggesting that these doses have a detrimental effect. The 60 Gy treatment results in a survival rate closer to the control (0 Gy), while 80 Gy slightly reduces survival compared to the control.

Plant height

Table 3: Effects of gamma radiation on the plant height of *Melampodium diviractum*

Treatment (Gy)	Plant height							
	2nd week	3rd week	4th week	5th week	6th Week	7th week	8th Week	9th Week
0	3.76^{b}	4.76^{c}	6.14^{b}	11.48^{c}	15.15^{d}	17.33^{c}	20.33^{c}	23.30^{d}
20	4.77^{ab}	5.89^{abc}	6.88^{ab}	10.95^{c}	13.43^{e}	17.69^{c}	20.81^{c}	22.90^{d}
40	4.55^{ab}	6.12^{ab}	7.10^{ab}	11.68^{c}	14.76^{d}	17.35^{c}	20.64^{c}	23.00^{d}
60	5.71^{a}	6.64^{a}	7.31^{a}	13.81^{b}	16.93^{c}	20.84^{c}	24.03^{b}	25.97^{c}
80	4.56^{ab}	5.53^{abc}	6.24^{ab}	18.48^{a}	23.59^{b}	27.45^{a}	30.21^{a}	31.73^{b}
100	3.84^{b}	5.29^{bc}	6.16^{b}	19.59^{a}	24.70^{a}	28.15^{a}	30.79^{a}	33.65^{a}
Sig	*	*	*	*	*	*	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

It was found that there were significant (P<0.05) differences between the treatments on plant height. The 60 Gy treatment initially produces the tallest plants during the early growth stages (2nd to 4th weeks). However, by the 5th week, the 80 Gy and 100 Gy treatments begin to show the highest plant heights, through the 9th week. The 0 Gy treatment consistently results in shorter plants throughout the experiment and the 100 Gy treatment consistently results in taller plants throughout the experiment, indicating that gamma radiation generally promotes plant height growth, especially at higher doses. It shows that the differences in plant height across treatments are statistically significant at every stage of growth. Higher doses of gamma radiation (80 Gy and 100 Gy) result in the greatest increase in plant height during the later stages of growth. This suggests that gamma radiation, particularly at 80 Gy and 100 Gy, has a stimulatory effect on the height growth of *Melampodium diviractum*.

Leaf count

Table 4: Effects of gamma radiation on the Leaf count of *Melampodium diviractum*

Treatment (Gy)	Leaf count				
	2nd Week	4th Week	6th Week	8th Week	10th Week
0	1.97^{a}	3.91^{a}	5.97^{a}	7.94^{a}	9.97^{a}
20	1.97^{a}	3.94^{a}	6.00^{a}	7.91^{a}	9.91^{a}
40	1.94^{a}	3.97^{a}	5.91^{a}	7.97^{a}	9.91^{a}
60	1.92^{a}	3.97^{a}	5.91^{a}	7.94^{a}	9.91^{a}
80	1.97^{a}	4.05^{a}	5.97^{a}	7.94^{a}	9.94^{a}
100	1.97^{a}	3.97^{a}	5.94^{a}	8.00^{a}	9.94^{a}
Sig	ns	ns	ns	ns	ns

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level, ns represent significance at p<0.05 and not significant, respectively*

There was no significant difference between the low dosages of gamma radiation on leaf count development in *Melampodium diviractum*. 2nd Week leaf counts for all treatments are virtually identical, with values, showing no noticeable variation across the different gamma radiation doses. The p-value indicates that the differences are not significant. 4th Week leaf counts are no significant difference. 6th Week leaf counts remain consistent across treatments but no significant differences. Also the 8th and 9th Week leaf counts have no significant difference.

Size of flowers

Table 5: Effects of gamma radiation on the size of flowers *Melampodium diviractum*

Treatment (Gy)	Flower size	
	8th week	9th week
0	2.69^{a}	2.69^{a}
20	2.61^{ab}	2.61^{ab}
40	2.57^{bc}	2.57^{bc}
60	2.51^{c}	2.50^{c}
80	2.68^{a}	2.68^{a}
100	2.58^{bc}	2.58^{bc}
Sig	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

There was a statistically significant difference in flower size among the various treatments. The 0 Gy and 80 Gy treatments consistently result in the largest flower sizes across both weeks. The 60 Gy treatment produces the smallest flowers during both the 8th and 9th weeks. This suggests that gamma radiation has a varied effect on flower size, with 80 Gy promoting large flower growth similar to the control, while 60 Gy tends to reduce flower size.

Petals amount

Table 6: Effects of gamma radiation on the petals amount of *Melampodium diviractum*

Treatment (Gy)	Petals %	
	8th week	9th week
0	11.72[a]	11.72[a]
20	10.41[b]	10.41[b]
40	10.41[b]	10.41[b]
60	10.38[b]	10.38[b]
80	10.33[b]	10.33[b]
100	10.30[b]	10.30[b]
Sig	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

There was a significant difference between the low dosages of gamma radiation. 0 Gy (control) consistently shows the highest petal percentage, meaning the absence of radiation allows for the best petal development. 20 Gy to 100 Gy treatments result in a significant decrease in petal percentages, with 100 Gy having the most suppressive effect. The slight variations between 20 Gy, 40 Gy, 60 Gy, 80 Gy, and 100 Gy suggest that increasing radiation does gradually inhibit petal development, but all treatments show significantly reduced petal percentages compared to the control.

Experiment 02 Germination percentage

Table 7: Effects of gamma radiation on the germination percentage of *Melampodium diviractum*

Treatment (Gy)	Germination		
	1st week	2nd week	3rd week
0	31.08c	75.00cd	74.50d
100	44.08b	74.00d	75.50d
150	26.58d	84.58b	84.25c
200	33.83c	75.83c	75.91d
250	25.62d	86.00b	86.46b
300	50.45a	93.54a	95.09a
Sig	*	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

The dosage was increased from 100 to 300 Gy with the control dosage of 0 Gy. In that experiment, there was a significant difference between the gamma radiation higher dosages and *Melampodium diviractum*. plant ($P<0.05$). High dosage gamma rays increased the average germination rate, 300 Gy consistently results in the highest germination rates across all weeks, with 50.45% in the 1st week, 93.54% in the 2nd week, and 95.09% in the 3rd week. Lower doses like 0 Gy and 100 Gy produce lower germination percentages, particularly by the 2nd and 3rd weeks. The 250 Gy and 150 Gy treatments also promote higher germination percentages, though not as high as 300 Gy. This suggests that higher doses of gamma radiation (250 Gy and 300 Gy) positively influence seed germination rates in *Melampodium diviractum*, while lower doses tend to result in lower germination rates.

Survival percentage

Table 8: Effects of gamma radiation on the Survival of *Melampodium diviractum*

Treatment (Gy)	Survival %
0	74.08^{c}
100	74.58^{c}
150	84.25^{b}
200	75.41^{c}
250	85.50^{b}
300	93.16^{a}
Sig	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

There was a significant difference between survival % and gamma radiation higher dosages. Higher doses of gamma radiation, especially 300 Gy, result in the highest survival percentage (93.16%), indicating a positive influence on the survival of *Melampodium diviractum.* 150 Gy and 250 Gy also show significantly higher survival rates compared to lower doses. The 0 Gy (control) and 100 Gy treatments have the lowest survival percentages, suggesting that moderate to high doses of gamma radiation may improve the plant's survival rate. This indicates that increasing gamma radiation up to 300 Gy enhances the survival of *Melampodium diviractum*.

Plant height

This table presents the effects of different doses of gamma radiation on the plant height of *Melampodium diviractum* from the 2nd week through the 9th week. Plant height between treatments are statistically significant differences. 2nd to 4th Week 0 Gy and 100 Gy treatments result in the highest plant heights early on (Table 4.3), with 100 Gy being slightly better than the control by the 3rd week.

Table 9: Effects of gamma radiation on the plant height of *Melampodium diviractum*

Treatment (Gy)	Height							
	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week	9th Week
0	3.76^{a}	4.76^{ab}	6.14^{a}	11.48^{b}	15.15^{b}	17.33^{b}	20.33^{b}	23.33^{b}
100	4.11^{a}	5.28^{a}	6.23^{a}	20.17^{a}	23.98^{a}	27.09^{a}	30.29^{a}	32.70^{a}
150	3.50^{ab}	4.08^{bc}	5.06^{b}	11.42^{b}	14.30^{c}	16.71^{b}	19.53^{b}	22.49^{bc}
200	3.80^{a}	4.45^{ab}	5.38^{ab}	10.87^{b}	12.69^{d}	14.01^{c}	17.01^{c}	21.00^{cd}
250	2.49^{c}	3.25^{cd}	4.13^{c}	8.71^{c}	10.31^{e}	14.11^{c}	16.68^{c}	19.81^{d}
300	2.55^{bc}	3.05^{d}	3.75^{c}	6.60^{d}	8.68^{f}	12.19^{d}	14.38^{d}	16.16^{e}
Sig	*	*	*	*	*	*	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

150 Gy, 200 Gy, 250 Gy, and 300 Gy treatments exhibit progressively lower plant heights as the radiation dose increases. By the 4th week, the 300 Gy treatment results in the smallest plant height. 5th to 9th Week the 100 Gy treatment continues to show significantly greater plant height throughout the later weeks, which is the tallest across all treatments. The 0 Gy (control) treatment produces consistently lower heights compared to 100 Gy. Treatments with higher doses like 150 Gy, 200 Gy, 250 Gy, and 300 Gy result in shorter plants. The 300 Gy treatment produces the shortest plants. The 100 Gy treatment consistently results in the tallest plants, suggesting that this level of gamma radiation promotes growth in *Melampodium diviractum*. Higher doses like 250 Gy and 300 Gy significantly stunt plant growth, with the 300 Gy group producing the shortest plants. The differences between treatments are statistically significant, as indicated by the p-value of 0.000 for all weeks. This suggests that moderate levels of gamma radiation, particularly 100 Gy, can enhance plant height, while higher doses tend to inhibit growth.

Table 10: Effects of gamma radiation on the leaf count of *Melampodium diviractum*

Treatment (Gy)	Leaf count				
	2nd Week	4th Week	6th Week	8th Week	10th Week
0	1.97a	3.91a	5.97a	7.94a	9.97a
100	1.94a	3.97a	5.94a	7.97a	9.97a
150	1.91a	3.97a	5.91a	7.91a	9.97a
200	1.97a	9.97a	5.91a	7.97a	9.97a
250	1.91a	3.94a	5.97a	7.97a	9.94a
300	0.97b	2.97b	4.97b	6.97b	9.05b
Sig	*	*	*	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

There was a statistically significant difference in leaf count among the various treatments. Lower dosege of gamma radiation (0 Gy to 250 Gy) demonstrate similar leaf development patterns across the weeks, indicating minimal effects on leaf count. In contrast, the 300 Gy treatment exhibits a significant reduction in leaf count at multiple time points, highlighting the negative impact of high gamma radiation levels on the leaf development of *Melampodium diviractum*. Overall, the results suggest that gamma radiation can affect the leaf count of *Melampodium diviractum*, with higher doses leading to diminished leaf growth as evidenced by the statistically significant differences observed.

Flower size

Table 11: Effects of gamma radiation on the size of *Melampodium diviractum*

Treatment (Gy)	Size of flower	
	8th week	9th week
0	2.69^{a}	2.69^{b}
100	2.61^{a}	2.61^{bc}
150	2.47^{a}	2.47^{c}
200	4.46^{a}	2.58^{bc}
250	2.95^{a}	2.95^{a}
300	2.09^{a}	2.19^{d}
Sig	ns	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level, 'ns' represent significance at p<0.05 and not significant, respectively*

8th Week there is no significant difference in sizes of flowers among the treatments, the highest flower size is recorded at 200 Gy but, 9th Week there is a significant difference in flower sizes among treatments, the highest flower size is recorded at 250 Gy. 300 Gy treated seeds show the smallest flowers. High gamma radiation treatment (300 Gy), This treatment resulted in the smallest flower sizes, suggesting that excessive gamma radiation is detrimental to flower development.

Petals amount

Table 12: Effects of gamma radiation on the petals amount of *Melampodium diviractum*

Treatment (Gy)	Petals %	
	8th week	9th week
0	11.72a	11.72a
100	10.30b	10.30b
150	10.22b	10.22b
200	10.13b	10.13b
250	11.41a	11.41a
300	9.21c	9.21c
Sig	*	*

*The values followed by different superscripts within the same column are significantly different according to Tukey's test. * Indicates significance at the 5% probability level.*

There was a statistically significant difference in petals among the various treatments. Both the 8th and 9th weeks exhibit significant differences in petal percentages. The highest percentage of petals is recorded at 0 Gy and secondly, 250 Gy, indicating that these treatments are associated with the highest petal counts. The lowest percentage is seen at 300 Gy, indicating a significant reduction in petal counts due to higher gamma radiation exposure. Demonstrating that gamma radiation negatively impacts petal development, especially at higher doses (300 Gy). The 250 Gy treatments show the best results, indicating that levels of radiation are more conducive to healthy petal development in *Melampodium diviractum*.

Observation of morphological changes

Initial observations after the radiation treatments of 300Gy treated plants showed the presence of dwarf plants and misshaped leaves. But with time, these abnormalities slowly disappeared, and the next leaves emerged had normal growth patterns. Hence the changes occurred in the plant leaves due to gamma irradiation stress are temporary and not continued in later stages. The changes that occurred in leaves may be due to the physiological damage caused by the gamma radiation. Furthermore, treated plants above 250 Gy showed color-changed leaf (from initial white colour) in five weeks after treatment. Especially plants with white colored leaf were observed. But with time, these abnormalities slowly disappeared. The early flower-induced mutagens were observed on the 6th week after seeding in T2 – 20 Gy and T5- 80 Gy.

CONCLUSION

According to experiments gamma radiation significantly impacts the germination, survival, growth, and reproductive traits of *Melampodium diviractum* in a dose-dependent manner. Experiment 01 modarte doses, particularly 100 Gy, enhance germination rates, plant height, and overall survival, indicating a stimulatory effect on plant growth. In contrast, lower doses (20 Gy and 40 Gy) consistently impair germination and survival, while in experiment 02 higher doses (250 Gy and 300 Gy) negatively affect plant height, flower size, and petal development.

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Study of Aesthetic Value of Selected Leafy Vegetables in Sri Lanka

Kaushalya J.O., Dahanayake N.* and Perera P.C.D.

Department of Agriculture biology, Faculty of Agriculture, University of Ruhuna, Sri Lanka

ABSTRACT

Twelve distinct leafy vegetables available in Sri Lanka were used in this study. A majority of these vegetables are underutilized. There are nutritional and medicinal advantages associated with the twelve species. However, there is limited information available regarding their use, geographic distribution, and aesthetic value. Besides, aesthetic value of these green vegetables is not well known. The main objective of the study was to identify the aesthetic value of the selected green species. Leafy vegetable was planted in potting media that contained cattle manure, sand, and top soil at 2:1:1 ratio. The weather condition and soil condition of the growing area were observed during four-month period. Using a completely randomized design pots were arranged at randomly with 3 replications. Characteristics of the flowers and leaves, especially their color, size, and shape were observed. Morphological characters of the plant show their unique esthetic value and how different species differ from one another. These leafy vegetables need less care and attention, and they grow quickly. Therefore, it can be utilized in landscaping as a space filler in the garden. Information gathered in this study will be useful to researchers, horticulturists, botanists, landscapers, and plant breeders interested in these leafy vegetables.

Keywords: Esthetic value, landscape, Leafy vegetables, Nutrition, Variation

INTRODUCTION

Aesthetic value refers to the appreciation of beauty or artistic qualities in objects, experiences, or concepts. It encompasses how something appeals to the senses, evokes emotions, and contributes to our understanding of art and nature. Aesthetic value can vary widely among individuals and cultures, influencing art, design, architecture, and even everyday objects (Dahanayake and Perera, Aesthetic value of weeds). There are different kinds of importance in esthetic value such developing emotions, influencing mood, well-being and quality life. Thus, beautiful environments or art can inspire joy and peace. Moreover aesthetic appeal in products can influence consumer choices, as people are often drawn to visually pleasing items. Different kinds of aesthetically valued items are found in nature but, most of them are hidden from people due to lack of awareness their esthetic value. Weeds, leafy vegetables, underutilized plants are some such examples (Eng, 2015). When considering leafy vegetables, Sri Lanka has diverse natural environments and varied abilities to produce a wide range of the same. Considered "protective foods" in the human diet, leafy vegetables are mostly abundant in vitamins, minerals, essential fatty acids, amino acids, dietary fiber, and other necessary bioactive elements. Leafy vegetables are a substantial solution for food insecurity (Nadeeshani *et al*., 2018), (Bharathidhasan *et al*., (2007). Leafy vegetables not only provide nutritional benefits but also enhance visual presentation of the environment which known as edible landscaping. These plants are used for aesthetic value as well as for consumption. Therefore they can improve garden by adding

**nilanthi@agri.ruh.ac.lk*

ornamentally with good health (Rjani *et al*., Edible landscaping-37). They can be consider as a valuable aesthetic item due to their differences in colors, textures, flowers and growth habit.

The importance and use of these leafy vegetables have drastically declined due to ignorance of their physical characters and underestimated nutritional benefits. Therefore, the primary goal of this research was to identify the aesthetic value of selected leafy vegetables.

There are two objectives, to study of esthetic value of selected leafy vegetables and to identify differences and similarities among plants.

MATERIALS AND METHODS

The study was conducted from July 2023 to October 2023, during the *yala* season, at the faculty of Agriculture, University of Ruhuna. 12 different types of selected leafy vegetables was planted in potting mixture that contained sand, top soil, cattle manure at proportionate 1:1:2 respectively. A trial 36 pots were used with 03 pots per selected variety. Completely randomized design was applied to all treatments, plants were arranged inside a prepared planting cage. Manual weeding and irrigation were practiced where necessary.

Soil analysis

Nitrogen, phosphorus and potassium content in soil were measured in this study. Three replicates were taken from each sample. To measure Nitrogen – kjeldhal method, Phosphourus – multi parameter analyzer and Potassium – flame photometer were used.

Weather station data collection

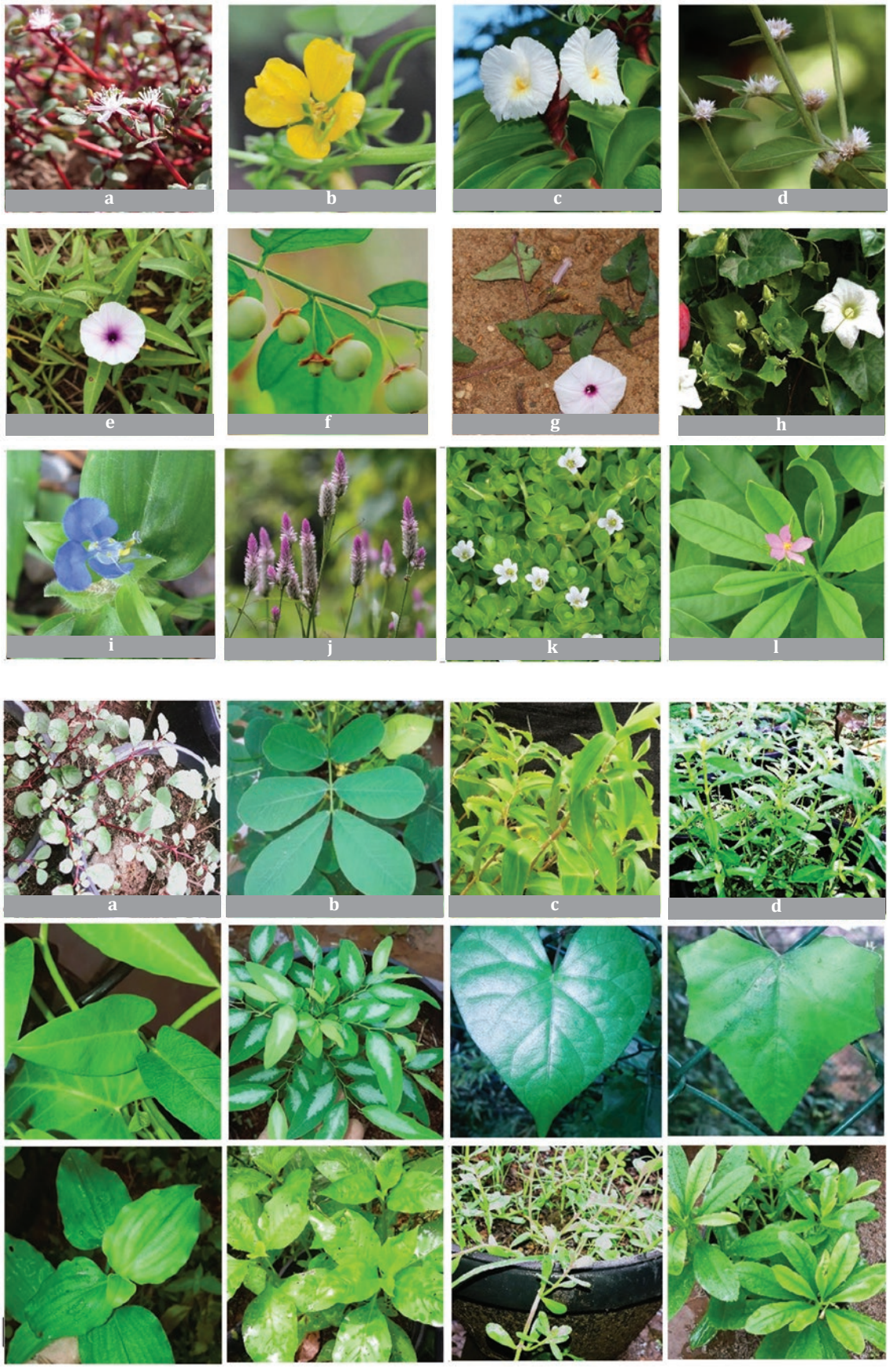
Weather station data was collected from meteorological station, Faculty of Agriculture, University of Ruhuna; Temperature (°C), Relative humidity (%) and Rainfall (mm).

Identification of aesthetic value

Morphological characters were identified from visual observation. Different criteria such as leaf shape, flower type, flower color, growth habit and form, were used for identification. Visual observation of color, texture, durability and shape of the flowers and leaves was used to identify morphological characters.

RESULT AND DISCUSSION

These twelve different green vegetables had some morphological similarities as well as major differences in some features. Following pictures show their unique aesthetic characters that are improve the beauty of the nature.



a, Tranthema portulacastrum (sarana); b, Cassia tora (pethithora); c, costus speciosus (thembu); d,Alternanathera sessilis (mukunuwenna); e,Ipomoea aquatic (kankun); f, Sauropus androgynous (singappurukola); g, Ipomoea sepiaria (thelkola); h, Coccinia grandis (kemkola); i, Commelina benghalensis; j, Celosia argentea (kirihenda); k, Bacopa monnieri (lunuwila); l, Talinum paniculatum (gasniwithi)

There was a huge diversity of traits can be seen in studied leafy vegetables. Among of them, flowers, leaves and growth habits have higher variation (Table 1). When considering flower color and leaf color have attractive form in this leafy vegetables because of that color is the characteristic that most people attention first in a landscape and it is also the main feature by which most people choose plants. Moreover, selecting a color pattern requires studying of the basic color theory. Leafy vegetables can also be used for decoration. For creating a colorful view or color variation, it is preferred to use leafy vegetables.

A lots of variation can be also be seen in the form of studied leafy vegetables. We can observed three form in these leafy vegetables such as tree form, shrub form, groundcover form. Tree form has large size, trunk, canopy, Shrub form has medium size, mass foliage covering the branches, Groundcover form has smallest size, little effect as a single plants (Zhang *et al*., 2022). We can select edible vine like *Ipomoea sepiaria* (*thelkola*), *Coccinia grandis* (*kemkola*) grow vertically on a fence, wall. It will be added value to cherish and wild theme of garden. Groundcover plant such as *Alternanathera sessilis* (*mukunuwenna*), *Ipomoea aquatica* (*kankun*) can be allocate as a space filling plant. Because they look like as a mass cover.

There are lots of advantages in the edible landscaping and gardening. This concept mostly suit for the urban and semi urban areas because they have limited space for both living and gardening. It is multi-purposed idea that are both aesthetically and produce edible fresh vegetables (Pogrel 1991). Using this kind of landscape pattern can enhance a garden providing uncommon ornamental value with addition health, wellbeing and economic advantages. We can get idea on where our vegetables comes from and what chemicals are used in its production. Having vegetables grown by us in our diet, we can earn personal satisfaction about our life due to we have a knowledge about the how to plant, harvest and prepare in our home garden. On the other hand landscaping plant need to much more care, nutrition, training, special chemicals for their healthy growth, but this kind of plant no need much more attention and caring. So we can incorporate this plant and concept for large scale landscape gardening also. It can be a big change of the landscape in beauty and opens a new chapter in landscape gardening.

Table 1. Identified morphological traits of selected leafy vegetables

Leafy vegetable	Growth habit	Leaf shape	Flower type	Flower color	Purposes they may fit in a garden
a	Postrate/Shrub	Oblong	Solitary	Pink	Groundcover
b	Erect	Obovate	Raceme	Yellow	Fence
c	Erect	Lanceolate	Spike	Pale pink	Fence
d	Postrate/Shrub	Lanceolate	Sessile	White	Groundcover
e	Postrate/Shrub	Lanceolate	Solitary	White	Groundcover
f	Erect	Lanceolate	Axillary/solitary	Dark red	Fence
g	Vine	Cordate	Cyme	Pale pink	Fence/wall
h	Vine	Cordate	Solitary	White	Fence/wall
i	Postrate/Shrub	Ovate	Sessile	Blue	Groundcover
j	Erect	Lanceolate	Spike	Pinkish white	Fence
k	Postrate/Shrub	Oblong	Solitary	White	Groundcover
l	Erect	Obovate	panicle	Pink	Fence

Results of Soil Analysis

Results of soil analysis showed variation in nitrogen, phosphorus and potassium in samples before and after planting. Samples after planting contained lower N, P, K values than before due to nutrients absorbed by the plants which may be a reason for the variation of nutrient content or else certain phenomenon such as leaching, splash erosion etc caused color and form variation of these two sample. (Table 2)

Table 2. Result of soil analysis

Sample type	N (%)	P (mg/l)	K (ppm)
Before sample	4.40	11.30	107.43
After sample	3.06	8.90	77.43

Results of Weather Condition

Experiment site is located in low country intermediate zone (IL_{a1}). Rainfall was very heavy during the experiment period. It may have be affected nutrient degradation, physical damage and color shading, of leafy vegetables. (Table 3)

Table 3. Weather station data

Month	Weather condition		
	Temperature (°C)	RH (%)	Rainfall (mm)
July	29.41	84.43	3.05
August	30.45	82.31	6.89
September	27.82	89.48	27.82
October	27.94	89.64	28.5

CONCLUSION

According to the results of this study if the aesthetic value of leafy vegetables, unique similarities and difference have been identified between each plant. Most people know leafy veggies as a part of their meal but this study helped to gain knowledge about their aesthetic value as well. Leafy vegetables are easy to grow and maintain and require very little amount of nutrients. Therefore they are very useful for landscape gardening. It is recommended to carry out this experiment in various agro-ecological zones, with different green vegetables and soil mixtures, in order to have a deeper knowledge.

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Effect of Colchicine Treatment on Vegetative Growth of *Henckelia communis* & *Aeschynanthu sceylanicus* (Family -Gesneriaceae)

Senevirathne D.P.M.V.P., Ranaweera B., Attanayake A.M.A.S. and Jayalath J.M.S.M.

[1] *Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka*
[2] *Floriculture Research and Development Unit, Royal Botanical Gardens, Peradeniya, Sri Lanka*

ABSTRACT

This study investigates the effects of colchicine treatment on the vegetative growth of two endangered Sri Lankan endemic Gesneriaceae species, *Henckelia communis* (Gardner) D.J. Middleton & Mich. *Moller and Aeschynanthus ceylanicus* Gardner, to enhance conservation, breeding, and ornamental potential. Colchicine concentrations (0.05%, 0.075%, 0.1%, and 0% as control) and treatment durations (20, 22, and 24 hours) were assessed to evaluate their impact on plant growth. Data on plant height, nodal length, shoot number, leaf dimensions, and chlorophyll content were collected using a randomized complete block design. The growth and morphological attributes of *H. communis* were found to be significantly altered by colchicine treatment; the best concentration and dipped duration for promoting shoot production and leaf characteristics was found to be 0.1% exposure for 20hrs exhibitingthe favorable characters of reduced plant height, leaf size, and chlorophyll content for ornamental purposes. *A. ceylanicus* showed reduced survival rates when treated with colchicine showing a negative impact. Results highlight the need of specialized methods for other species while also underscoring the potential of colchicine to enhance favourable features of *H. communis* as an ornamental potted plant. This study advances the economic growth of the floriculture sector by promoting sustainable use of Sri Lankan native floral species and facilitates plant conservation.

Keywords: Colchicine, *Henckelia communis*, *Aeschynanthus ceylanicus*, ornamental potential, mutation induction, plant conservation, floriculture

INTRODUCTION

The pantropical plant family Gesneriaceae, which includes about 3400 species, exhibits a great diversity in growth forms and flower morphologies that are linked to repeated adaptations, various conditions and pollinators (Ogutcen *et al*., 2021). A thorough taxonomic revision of the Gesneriaceae family, which is prized for both its vast diversity and ornamental appeal, was conducted in Sri Lanka and resulted in the identification of 14 species, including the recently identified H. wijesundarae (Ranasinghe *et al*., 2016). All 14 species were deemed vulnerable by national conservation evaluations, underscoring the critical need to save these unusual plants and their ecosystems. Sustaining these endemic species in a fast changing environment requires ongoing research to improve our understanding of their taxonomy, biogeography, and conservation needs (Middleton *et al*., 2013). This study uses colchicine-induced mutation to enhance conservation and ornamental potential of *H. communis* and *A. ceylanicus* (lipstick plant) shifting from earlier taxonomy-focused research to practical methods for improving aesthetics.

Notably, six of the seven Henckelia species in Sri Lanka are native, mainly found in central and south-western lowland and wet montane

*senevirathnevindi@gmail.com

forests (Möller *et al*., 2011). *H. communis*, a branching herb with a silky-pubescent stem (Dasanayake *et al*., 1987), grows in and along rocky streambeds of undisturbed forests, usually in dense shade.

Aeschynanthus is a genus comprising approximately 80 species world over, largely found in the Indomalaysian region and Southern China. Known for its ornamental and diverse epiphytic or lithophytic subshrubs. *A. ceylanicus* is endemic to Sri Lanka and is distinguished by its smooth, yellowish bark, thick fleshy leaves, and vibrant scarlet flowers. This species climbs and roots over rock surfaces and trees in the island's montane forests (Gardner, W. 1846).

This research aims to explore colchicine-induced mutagenesis to enhance the ornamental characteristics of *H. communis* and *A. zeylanicus* species. The study focuses on traits such as compact leaf arrangement, reduced plant height, decreased leaf size, and reduced internodal length, and variations in flower shape and color as favourable traits for ornamental plants. Sri Lanka has a rich variety of flowering plants, many of which are unique to the island. However, these plants are not widely used commercially. This situation presents a significant opportunity to develop innovative solutions that could enhance their ornamental value and increase their presence in the floriculture market (Cabahug *et al*., 2022) by determining optimal colchicine concentrations and treatment durations, this study seeks to promote the conservation of these endangered plants while simultaneously improving their aesthetic qualities. These findings may contribute to enhance biodiversity conservation and economic development within the industry.

Colchicine interferes with microtubule formation, which is essential for proper chromosome separation during cell division. By blocking this process in meiosis, it causes cells to double their chromosome number, resulting in polyploidy add reference. This can enhance desirable traits in plants.

MATERIALS AND METHODS

Planting materials were collected and disinfected. 2-3 cm softwood cuttings of *A. ceylanicus* and leaf cuttings of *H. communis* were bundled, with the petiole/stem ends covered in cotton wool and dipped in 0.05%, 0.075%, 0.1%, and 0.00% (control) concentrations of colchicine solutions at room temperature under laboratory fume hood conditions with personal protective equipment. Treated leaf cuttings were removed after different time periods (20, 22, and 24 hours). Each cutting was placed in pots (4”× 4”) filled with media (1:1 sand and coir dust for *A. ceylanicus* and sand only for *H. communis*). After propagation, single propagators were used for *A. ceylanicus* and multi-propagators for *H. communis*, which were kept under a shade house covered with a 50% shade netting.

The study employed a randomized complete block design (RCBD) to assess effects of colchicine treatment on vegetative growth and morphological characteristics of *H. communis* and *A. ceylanicus*. This experiment was structured with two main factors (colchicine concentration, and dipped duration): These two factors were applied across 12 treatment combinations(T1–T12), as shown below in table 01

Table 01: Application of Different treatment combinations

Treatment	Factor 1 -colchicine concentration (%)	Factor 2- dipped duration (hours)
T1	A- 0.005%	X-20
T2	A- 0.005%	Y -22
T3	A- 0.005%	Z -24
T4	B- 0.075%	X-20
T5	B- 0.075%	Y -22
T6	B- 0.075%	Z- 24
T7	C- 0.1%	X-20
T8	C- 0.1%	Y -22
T9	C- 0.1%	Z- 24
T10	D- 0.00%	X-20
T11	D- 0.00%	Y -22
T12	D- 0.00%	Z- 24

Treated plants were observed weekly, after 8 weeks for a 4 month duration. Plant height, number of nodes, inter nodal length, number of shoots, number of leaves, leaf length, leaf width, chlorophyll content using SPAD (Soil Plant Analysis Development) meter, and survival rates were measured.

Analysis of variance (ANOVA) was conducted using SAS 9.0 and Minitab version 19 software. Mean separation was performed using Duncan's Multiple Range Test (DMRT).

Data were analyzed using General Linear Model (GLM) ANOVA with a factorial design and Duncan's Multiple Range Test (DMRT) in SAS. A p-value (pr> F) below 0.05 indicates significant factors affecting the dependent variable.

RESULT AND DISCUSSION

Effect of the colchicine treatment on *Henckelia communis*

Colchicine treatment significantly affects various growth and physiological parameters of *H. communis*, with concentration being the primary influencing factor. Notably, both concentration and duration significantly affect only the leaf number and chlorophyll content, indicating a complex interaction between these variables as shown in table 02.

Table 02: ANOVA for the effect of colchicine concentrations, dipped durations, and their interactions on plant growth parameters for *H. communis*.

Dependent Variable	Colchicine Concentration			Dipped Duration			Interaction Effect (concentration X duration)		
	F value	p-value		F value	p-value		F value	p-value	
Plant Height	14.00	0.0001	S	0.79	0.4548	NS	2.03	0.0827	NS
Number of Shoots	7.20	0.0001	S	1.39	0.2542	NS	3.57	0.0055	NS
Number of Leaves	7.44	0.0001	S	2.34	0.0024	S	5.87	0.0001	S
Number of Nodes	4.56	0.0001	S	1.82	0.1674	NS	0.70	0.6282	NS
Internodal Length	7.29	0.0001	S	2.50	0.0877	NS	0.79	0.5587	NS
Leaf Width	11.06	0 .0001	S	1.01	0.3675	NS	0.64	0.6690	NS
Leaf Length	11.43	0.0001	S	1.09	0.3401	NS	0.29	0.9197	NS
Chlorophyll Content	7.05	0.0001	S	6.62	0.0021	S	2.83	0.0025	S

S- indicates statistical significance ($p < 0.05$)/ NS- indicates not significant ($p \geq 0.05$)

The table 03 below summarizes the results of Duncan's Multiple Range Test (DMRT) applied to the effects of various colchicine concentrations (%) on the growth parameters of *H. communis*.

The DMRT analysis shows that the Colchicine concentration positively impacts for all growth parameters of *H. communis*.

Table 03: Summary of Duncan's Multiple Range Test (DMRT) for the effect of colchicine concentration on plant growth parameters of *H. communis*.

Concentration (%)	Duncan's multiple range test results and mean values of parameters							
	Plant Height (cm)	Number of shoots	Number of leaves	Number of nodes	Inter Nodal Length (cm)	leaf width (cm)	leaf length (cm)	Chlorophyll content
0.000	9.949 a	2.189 c	16.730 b	2.973 a	4.876 a	4.749 a	7.424 a	39.103 a
0.05	4.471 b	3.115 b	14.154 b	2.115 c	1.227 b	3.015 b	4.565 bc	32.973 b
0.075	3.913 b	3.565 b	13.957 b	2.609 b	1.152 b	2.935 b	4.335 c	35.170 b
0.1	3.639 b	5.571 a	28.500 a	2.143 c	1.386 b	3.371 b	5.193 b	33.943 b

(The letters (a, b, c) indicate statistically significant differences between the means of each parameter and Mean values followed by the same letter are not significantly different)

The table 04 below summarizes the results of Duncan's Multiple Range Test (DMRT) applied to the effects of various dipped duration (hour) on the growth parameters of *H. communis*.

Table 04: Summary of Duncan's Multiple Range Test (DMRT) for the effect of dipped duration (hr.) on plant growth parameters of *H. communis*.

Duration (hours)	Duncan's multiple range test results and mean values of parameters							
	Plant Height (cm)	Number of shoots	Number of leaf	Number of nodes	Inter Nodal Length (cm)	leaf width (cm)	leaf length (cm)	Chlorophyll content
20	5.917 [a]	3.228 [a]	16.600 [a]	2.542 [a]	2.442[a]	3.757[a]	5.765 [a]	37.528 [a]
22	6.465 [a]	3.210 [a]	16.974 [a]	2.631 [a]	3.055 [a]	3.663 [a]	5.652 [a]	35.237 [b]
24	6.018 [a]	3.222 [a]	17.815 [a]	2.444 [a]	2.096 [a]	3.663 [a]	5.525 [a]	34.823 [b]

(The letters (a, b, c) indicate statistically significant differences between the means of each parameter and Mean values followed by the same letter are not significantly different)

The DMRT analysis show that the dipping duration positively impacts chlorophyll content, with group "a" (37.528) significantly higher than group "b". As a crucial pigment for photosynthesis, higher chlorophyll levels indicate better plant health and enhanced growth potential (Taiz & Zeiger, 2010). However, there are no statistically significant effects on other growth parameters like plant height, shoot number, leaf number, node count, internodal length, and leaf size.

Effect of colchicine concentration on plant height

The ANOVA results in Table 02 show a highly significant effect of colchicine on plant height, with an F-value of 14.00 at a p-value of <0.0001, indicating a significant difference between treated and untreated plants. However, there were no significant differences among the different concentrations of colchicine, and dipped durations. Plant height is influenced by environmental and genetic

factors (Isam *et al*., 2018) and is important for growth, productivity, and ornamental value (Constantino *et al*., 2015).

As depicted by Figure 01 the effect of colchicine concentration on plant height (0.05%, 0.075%, 0.1%, 0.000% as Control), the control group has the highest mean plant height, while colchicine treatment had significantly reduced plant height, regardless of concentration. Therefore, in *H. communis* colchicine treatment had resulted in shorter plants, which enhances their ornamental value, making them more desirable as a compact ornamental potted plant.

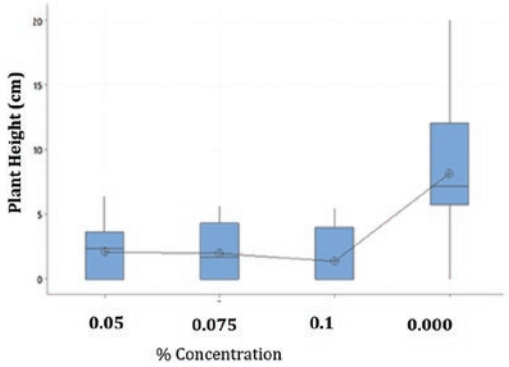

Figure 01: Effect of the colchicine concentration on plant height.

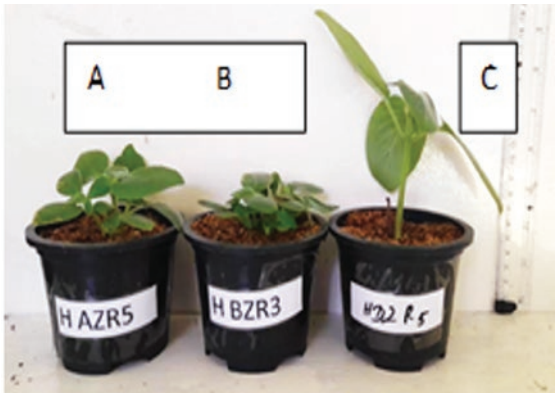

Figure 02: Effect of the colchicine on plant height. (A –0.05% colchicine treatment, B- 0.075% colchicine treatment, C- 0.000% control)

Effect of colchicine concentration on shoot formation

According to results, colchicine concentration significantly influences shoot formation, with an F-value of 7.20 at a p-value of <0.0001. Figure 03 shows results of Duncan's Multiple Range Test which indicates that the mean numbers of shoots per plant is highest in the 0.1% colchicine concentration treatment. This suggests that this concentration is the most effective in promoting shoot formation compared to the other concentrations and the control group. Results indicate that 0.1% colchicine concentration is optimal for maximizing the number of shoots. This effect is attributed to the ability of colchicines to disrupt normal cell division processes, leading to increased shoot proliferation. Additionally, colchicine treatment encourages the development of additional shoots in plants, promoting a bushier form that enhances their ornamental value.

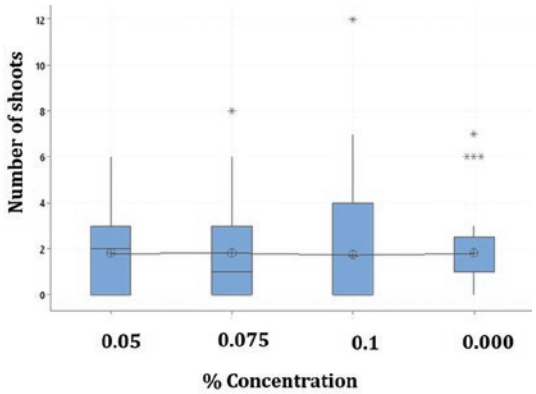

Figure 03: Effect of colchicine concentration on shoots formation

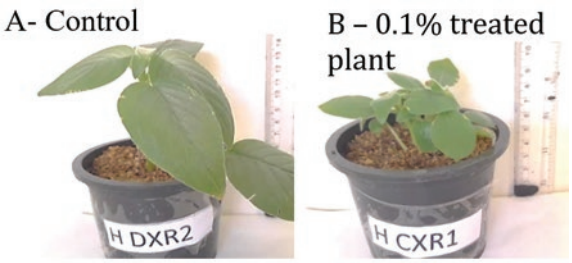

Figure 04: Effect of colchicine on shoot formation (A- Control, B -0.1% colchicine treated)

Effect of colchicine concentration on number of leaves

Statistical analysis reveals a significant effect of colchicine concentration on numbers of leaves, with an F value of 7.44 at a p-value of <0.0001. According to Duncan's Multiple Range Test, the

highest mean number of leaves was observed in the 0.1% colchicine treatment group. This suggests that, contrary to the usual expectation that colchicine inhibits cell division; the 0.1% concentration actually enhances leaf production, as illustrated in Figure 05. The effects of Colchicine on leaf production are complex, as Ali *et al*., 2019 and Shah *et al*., 2020 had shown that certain concentrations can increase number of leaves. The increased leaf production observed in this case could enhance the compact, bushy growth habit of *H. communis*, thereby improving its ornamental appeal and making it a more desirable species for horticultural applications

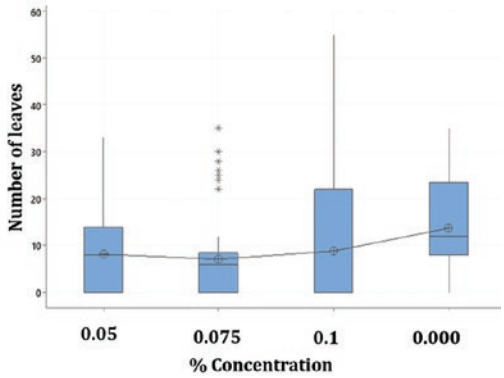

Figure 05: Effect of colchicine on Number of leaves.

Table 5 illustrates that (T7) is the best treatment for maximizing both shoots and leaves, with (T8) and (T6) providing effective alternatives based on specific growth needs. T7 (0.1% colchicine for 20 hours) is the most effective overall treatment, achieving the highest shoot and leaf counts, thus promoting robust and healthy growth without stress. T8 (0.1% colchicine for 22 hours) also performs well, especially in leaf production, though it yields slightly fewer shoots, indicating the importance of refining exposure duration to enhance outcomes. T6 (0.075% colchicine for 24 hours) offers a practical alternative with a moderately high concentration and longer exposure, leading to substantial shoot and leaf production resulting in a bushier, more ornamental plant structure.

Effect of colchicine concentration on number of nodes

The ANOVA results show a significant effect of colchicine concentration on number of nodes: F Value: 4.56 at p-value of < .0001.This indicates a significant difference between the control and colchicine-treated plants. Figure 6 shows results of Duncan's Multiple Range Test; the data indicate that number of nodes decreases as the concentration of colchicine is increased. However, the differences between the various colchicine concentrations (0.1%, and 0.05%) are not statistically significant, implying that reduction in node number does not significantly vary with concentration once colchicine is applied. The reduction in numbers of nodes observed in this study is consistent with findings from other studies where colchicine treatments led to alterations in plant structure. For instance: Singh *et al*. 2017 reported similar effects, indicating that higher concentrations of colchicine can inhibit node production and alter the structural development of plants.

Table 05: Summary of Duncan's Multiple Range Test (DMRT) Results for the Effects of Treatments on the number of shoots and number of leaves in *H. communis*

Parameters	Duncan's multiple range test results and mean values of parameters										
	T1	T2	T3	T4	T5	T6	T7	T8	T10	T11	T12
	AX	AY	AZ	BX	BY	BZ	CX	CY	DX	DY	DZ
No. of Shoots	2.7^{b}	3.6^{b}	3.2^{b}	2.8^{b}	2.6^{b}	5.5^{a}	6.0^{a}	5.3^{a}	2.3^{b}	2.4^{b}	2.0^{b}
No. of Leaves	13.2^{bc}	17.3^{b}	11.6^{bc}	8.1^{c}	8.2^{c}	27.1^{a}	28.1^{a}	28.2^{a}	17.8^{b}	16.0^{b}	16.5^{b}

(The letters (a, b, c) indicate statistically significant differences between the means of each parameter and Mean values followed by the same letter are not significantly different)

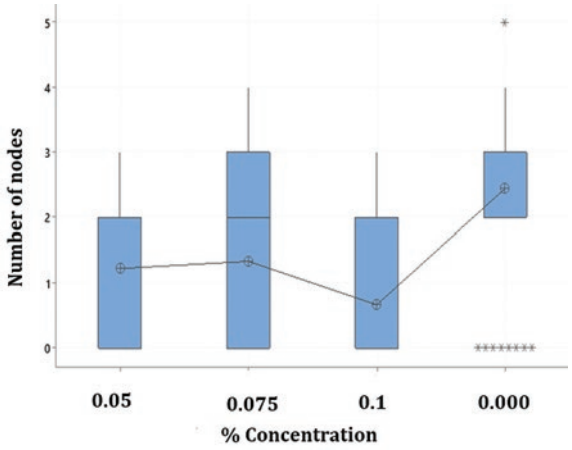

Figure 6: Effect of colchicine concentration on Number of nodes.

Effect of colchicine concentration on inter nodal length

The ANOVA results show a significant effect of colchicine concentration on inter-nodal length: F Value: 7.29at a p-value of< .0001. This indicates a significant difference between the control and colchicine-treated plants. As illustrated in the Figure 7, Duncan's Multiple Range Test from this study shows that colchicine treatment significantly reduces internodal length in all treated groups compared to the control, underscoring its strong effect on plant growth. This reduction is due to colchicine's disruption of cell division by inhibiting microtubule formation during mitosis, resulting in shorter internodes and decreased plant height. Notably, the absence of a clear dose-dependent effect across the tested concentrations (0.05%, 0.075%, and 0.1%) indicates that even the lowest concentration is sufficient to induce these changes. This finding aligns with Bouvier *et al*. 2006, who reported similar results in Rosa *hybrida*, where significant reductions in inter nodal length occurred without substantial differences between doses. Both studies suggest a threshold effect, where increasing colchicine concentration does not enhance inter nodal shortening. The significant effect of colchicine on reducing inter nodal length could be leveraged to develop ornamental varieties of *H. communis* with more attractive, bushy growth forms.

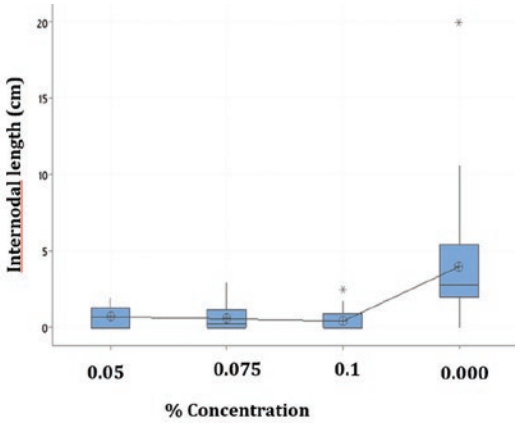

Figure 7: Effect of colchicine concentration on leaf length and leaf width

The ANOVA table shows that colchicine treatment significantly affects leaf width and length, with a p-value of less than 0.0001. According to Duncan's Multiple Range Test, as colchicine concentration increases, both leaf dimensions decrease, with the greatest reduction observed at 0.075%, indicating a dose-dependent effect. These changes are likely due to disruptions in cell division caused by colchicine. Similar findings were reported by Jaskani *et al*. 2005, who showed that colchicine induces dwarfing and reduces leaf size in ornamental plants. This reduction in leaf size may enhance the aesthetic value of *H. communis* for ornamental purposes, making it more compact and appealing.

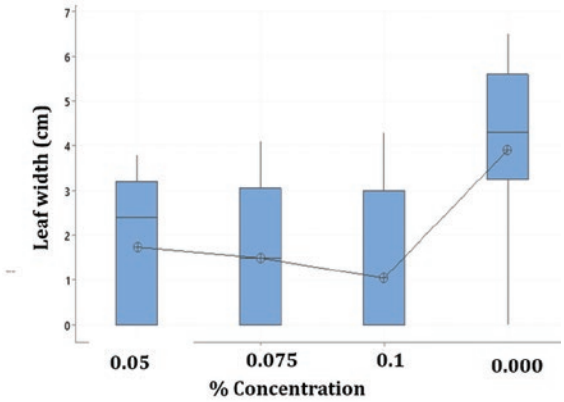

Figure 8: Effect of colchicine on (A) Leaf width

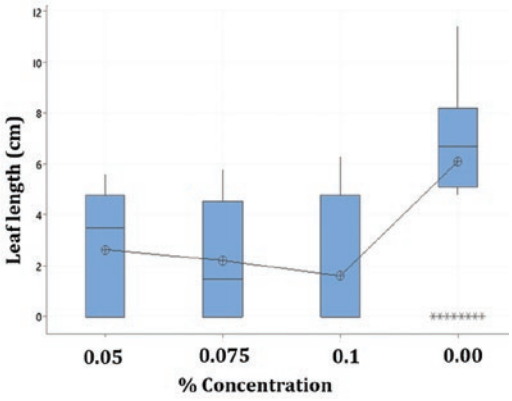

Figure 9: Effect of colchicine on (B) Leaf length

Effect of colchicine concentration on leaf chlorophyll content

The ANOVA results indicate a significant effect of colchicine concentration on leaf chlorophyll content, with an F value of 7.05 at a p-value of <0.0001. According to Duncan's Multiple Range Test, there is a significant decrease in leaf chlorophyll content as colchicine concentration increases compared to the control group, which exhibits the highest chlorophyll levels (Figure10). This finding suggests that the inhibitory effects of colchicine on chlorophyll synthesis or stability are dose-dependent; higher concentrations lead to greater reductions in chlorophyll content. Previous studies corroborate these findings, showing that colchicine treatment results in decreased chlorophyll levels due to its impact on cell division and metabolic processes. By disrupting microtubules, colchicine interferes with the normal functioning of chloroplasts and the synthesis of chlorophyll (Ali *et al*. 2019, Shah *et al*. 2020). Furthermore, chlorophyll content demonstrates a clear trend across treatment durations, peaking at 20 hours, while longer exposure times (22 and 24 hours) result in slight declines. This suggests that prolonged exposure may induce mild stress, lowering chlorophyll levels and potentially affecting photosynthetic efficiency. The optimal 20-hour duration supports healthier growth by maintaining chlorophyll levels, promoting photosynthetic efficiency, and enhancing overall plant vigor.

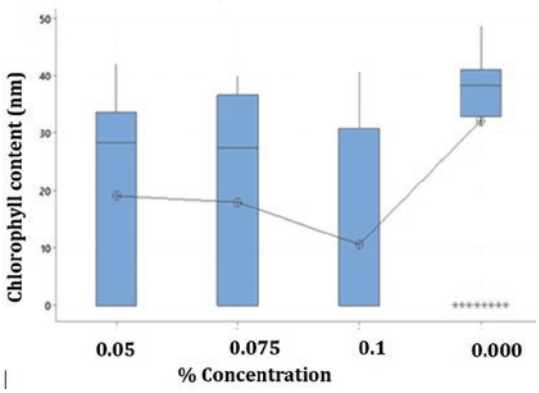

Figure 10: Effect of colchicineon chlorophyll content

Finally, Results of the colchicine treatment on *H. communis* demonstrated that both colchicine concentration and dipping duration significantly influenced various parameters, as revealed by ANOVA and Duncan's Multiple Range Test (DMRT). All colchicine concentrations led to a significant reduction in plant height, promoting a more compact form that enhances ornamental value. The optimal concentration of 0.1% colchicine was particularly effective in stimulating increased shoot proliferation, which improved the plant's bushy appearance and overall ornamental appeal. Leaf production also significantly increased at this concentration; contrary to the common expectation that colchicine inhibits growth. Notably, T7 (0.1% colchicine for 20 hours) was the most effective overall, achieving the highest shoot and leaf production, while promoting healthy growth, good ornamental quality without inducing stress—performing better than T6 (0.075% for 24 hours) and T8 (0.1% for 22 hours). The number of nodes decreased with higher colchicine concentrations, consistent with previous research indicating structural changes. Colchicine treatment also significantly reduced inter nodal length, affecting plant structure by disrupting cell division. Both leaf width and length decreased significantly with increasing

colchicine concentrations, contributing to a more compact plant shape. However, higher colchicine concentrations resulted in a significant decrease in chlorophyll content, which may negatively impact photosynthetic efficiency, with optimal chlorophyll levels observed at 20 hours of treatment.

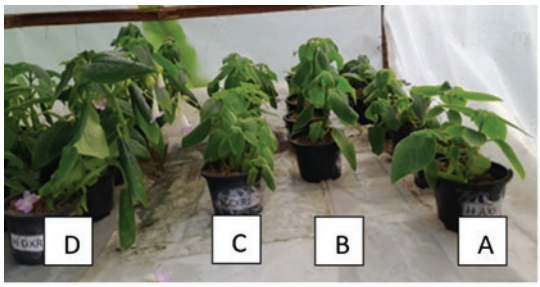

Figure 11: *H. communis* leaf propagation after four months from treatment (A -0.05%, B-0.075%, C-0.1%, D- 0.000%)

Effect of the colchicine treatment on Aeschynanthus ceylanicus

Colchicine-treated *A. ceylanicus* cuttings showed a very low survival rate, significantly lower than the untreated controls (ANOVA: p = 0.000, F = 47.999). Higher colchicine concentrations and longer exposure further decreased survival, with new shoots forming only in the control group, highlighting colchicine's detrimental impact on growth and shoot formation

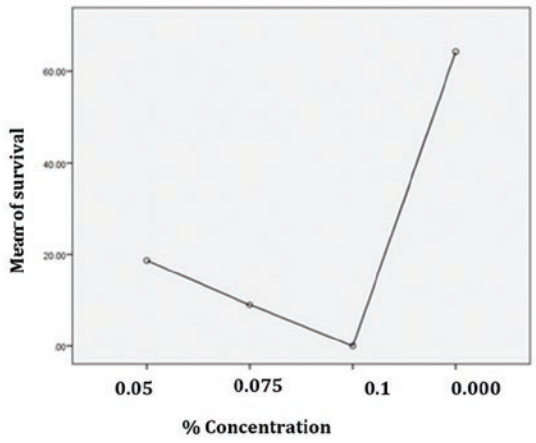

Figure 12: Survival rate of *A. ceylanicus* after four months from colchicine treatments

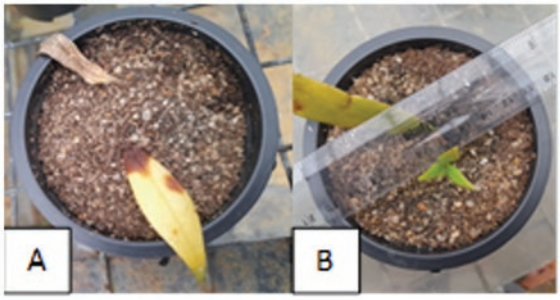

Figure 13: Effect of colchicine treated plants (A) and control treatment (B) of *A. ceylanicus*

CONCLUSION

The study demonstrates that colchicine treatment has a significant impact on the morphology of *H. communis*, enhancing its ornamental value. Key findings are as follows:

Optimal Concentration: The 0.1% colchicine concentration is most effective in promoting desirable traits such as increased shoot formation, leaf number, and a more compact, bushy growth habit. These traits improve the plant's aesthetic appeal as an ornamental potted plant.

Duration of Treatment: Time duration alone does not significantly influence growth parameters, among treatments, T7 (0.1% colchicine for 20 hours dipped duration) was most effective in promoting more shoots and leaves. It enhances bushier, more ornamental plant structure. This finding highlights the need to balance treatment factors for effective, low-stress morphological enhancement.

Plant Growth Parameters: colchicine-treated plants showed significant reductions in plant height, internodal length, and leaf size, resulting in a dwarf, compact growth form ideal for ornamental purposes. The treatment also increased shoots and leaf production, enhancing the plant's ornamental value.

Survival and Propagation: colchicine-treated plants exhibited a lower survival rate

compared to the control group. However, surviving plants with favorable traits can be vegetatively propagated to maintain these desirable characteristics.

Effect on *A. ceylanicus*: The colchicine treatment combinations used in this study were unsuitable for *A. ceylanicus*, as they significantly reduced plant survival, and no new shoots were observed in the treated groups. This suggests that *A. ceylanicus* may not tolerate these colchicine concentrations well, indicating the need for further research to optimize the treatment for this species.

In Conclusion: colchicine treatment, particularly at a concentration of 0.1% with dipped duration of 20 hours, is highly effective for enhancing the aesthetic appeal of *Henckelia communis* as an ornamental potted plant by promoting compact, bushy growth. However, the colchicine concentrations applied to *Aeschynanthus ceylanicus* are not suitable for this species.

Are all results and discussions above only for the 20 hour duration? Or discussed for concentrations only without considering duration? Was there no interaction.

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A Comparative Analysis of Developmental Traits in *Dracaena sanderiana* Varieties for Enhanced Lucky Bamboo Production

Chandrasekara C.M.N.T.[1], Wickramasinghe W.M.T.N.[2], Fonseka D.L.C.K.[1]*, Bandara M.M.L.I.W.[2]

[1] *Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*
[2] *Department of National Botanic Gardens, Peradeniya, Sri Lanka*

ABSTRACT

Dracaena sanderiana is a popular foliage plant that grows worldwide in indoor and outdoor spaces. This experiment was conducted to evaluate and compare the growth rate, morphological, and anatomical characteristics of four different *Dracaena sanderiana* varieties for value-added lucky bamboo production. The experiment was laid out as a Completely Randomized Design (CRD) with four treatments randomized with ten replicates. Treatments were the four varieties of *Dracaena sanderiana*; 'Gold', 'White', 'Victory', and 'Celes'. Cuttings were planted in pots filled with coir dust and sand (1:1) and arranged in a shade house. The data was recorded under three groups, growth parameters (plant height (cm), number of leaves, radial growth of stem (cm) and plant dry matter content) and morphological parameters (leaf color, number of internodes, internodal distance (cm) and stem breaking angle (°) and anatomical parameters (collenchyma tissues). The data obtained were tabulated and analyzed by means of one-way ANOVA using Minitab 17 software and mean comparison was done by using the Tukey test at the 0.05 probability level. Among different treatments tested, the highest increment of plant height, highest increment of radial growth of stem, highest Absolute Growth Rate (AGR), and highest stem breaking angle was recorded from variety 'Gold'. But, the highest increment number of leaves and highest number of internodes were recorded from the 'Celes' and the highest internodal distance was recorded from the 'Victory'. Statistical analysis revealed no significant differences in the Relative Growth Rate (RGR) among the four varieties. However, due to notable variations in morphological and growth parameters, the study concluded that the 'Celes' variety is unsuitable for blending with the other three varieties for value addition, while the 'Gold,' 'White,' and 'Victory' varieties are compatible for blending.

Keywords: *Dracaena sanderiana*, Lucky bamboo, value addition, blending

INTRODUCTION

Dracaena sanderiana is an important foliage plant that belongs to the family Asparagaceae (Rashid and Abdulqader, 2024). It is grown as an indoor and outdoor ornamental plant and is native to Cameroon in Tropical West Africa (Gunathilake and Abeywickrama, 2011). It has several common names including Ribbon Dracaena, Lucky Bamboo, Belgian Evergreen, and Ribbon Plant (Srikrishnah and Sutharsan, 2012). It consists of four varieties, 'Gold', 'White', 'Victory', and 'Celes'. Commercially, value-addition is very important to improve the profit margin and increase the popularity among buyers. Modifying stem architecture is a method of making value additions from *D. sanderiana*. Some of these value-added products are lucky bamboo spirals, lucky bamboo pyramids, lucky bamboo towers and different shapes made by lucky bamboo. Generally, in value addition, growers do not blend different varieties of *D. sanderiana* due to less knowledge of growth parameters,

*dlckumari@crop.ruh.ac.lk

morphological parameters, and anatomical parameters. Therefore, researchers are needed to study the growth, morphological, and anatomical characteristics of four different *D. sanderiana* varieties. Hence, the objective of this experiment was to evaluate and compare the growth rate, morphological, and anatomical characteristics of four different *D. sanderiana* varieties for value-added lucky bamboo production.

MATERIALS AND METHODS

This experiment was conducted from April to August in 2024 under a 60% shade house at the Royal Botanic Gardens, Peradeniya, Sri Lanka.

Experimental procedure

Uniform cuttings of four varieties of *D. sanderiana* 'Gold', 'White', 'Victory', and 'Celes' were obtained from Mike Flora Pvt. Ltd, Rambukkana. Cuttings were treated with fungicide (Mancozeb) and root hormone before planting. Cuttings were planted in plastic pots (top diameter – 5 inches) filled with a potting medium composed of sand and coir dust in a ratio of 1:1. All the management practices were practiced uniformly for all experimental units according to the recommendations of Royal Botanic Gardens, Peradeniya. Plants were arranged at a spacing of 40 plants/m^2.

Experimental design

Four varieties of *D. sanderiana* were considered as treatments (Gold-T_1), (White-T_2), (Victory-T_3), and (Celes-T_4) and all treatments were arranged in a completely Randomized Design (CRD) with 10 replicates. Each treatment contained ten plants and an experimental unit consisted of one plant.

Data recording

The data collected in this study were categorized into three groups: growth parameters, morphological parameters, and anatomical parameters.

Growth parameters

Plant height (cm), number of leaves, and radial growth of stem (cm) were observed at two weeks intervals. Plant dry matter content was measured initially and at the end. Plant height was measured from pot level to the top leaf whorl using a ruler. Fully open leaves were counted as the number of leaves. Radial growth of stem (cm) was measured using a ruler and a twine thread. Plant dry matter content was measured using an oven and an analytical balance. Cuttings were placed in a preheated oven at 105°C until became a constant weight and dry weight was taken. Dry weight was expressed as Relative Growth Rate (RGR) and Absolute growth rate (AGR).

Morphological parameters

Leaf color, number of internodes, internodal distance (cm) and stem breaking angle (°) were observed at the end. Leaf color was analyzed using a Royal Horticultural Society (RHS) color chart (5^{th} edition) and expressed as RHS color codes. Internodal distance was measured from 1^{st} ten internodes using a ruler and the stem breaking angle was measured using a protractor.

Anatomical parameters

Collenchyma tissues were observed using an Olympus BX53 system microscope and expressed as microscopy images.

Data analysis

The data were statistically analyzed using one-way ANOVA using Minitab 17 software and mean comparison was done by using Tukey test at the 0.05 probability level.

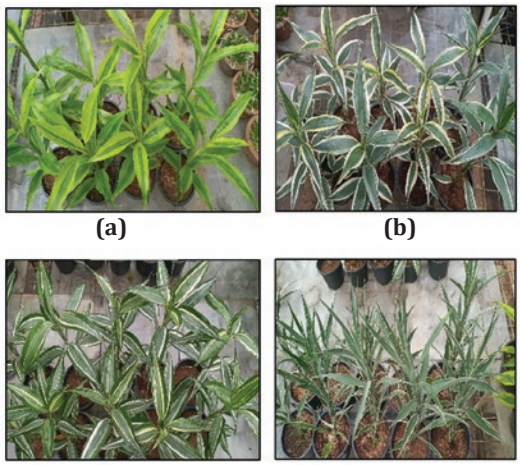

Fig 1: D. sanderiana varieties (a) Gold, (b) White, (c) Victory, and (d) Celes

RESULT AND DISCUSSION

Plant height (cm):

The varieties had a significant effect on the plant height of *D. sanderiana*. There was a significant difference between the plant height of varieties 'Gold' and 'Celes'. The variety 'Gold' had significantly higher plant height than other varieties. Further, the lowest plant height was observed in variety 'Celes'.

Table 1: Increment plant height of four varieties of *D. sanderiana*

Treatment	Plant height (cm)*
T_1 (Gold)	10.98^{a}
T_2 (White)	9.02^{ab}
T_3 (Victory)	9.38^{ab}
T_4 (Celes)	7.45^{b}

**Means followed by the same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.002)*

Radial growth of stem (cm)

The varieties had a significant effect on the radial growth of stem of *D. sanderiana*. There was a significant difference between radial growth of stem of variety 'Gold' with varieties 'Victory' and 'Celes'. The variety 'Gold' had significantly higher radial growth of stem than other varieties. Further, the lowest radial growth of stem was observed in variety 'Victory'.

Table 2: Increment radial growth of stem of four varieties of *D. sanderiana*

Treatment	Radial growth of stem (cm)*
T_1 (Gold)	0.35^{a}
T_2 (White)	0.32^{ab}
T_3 (Victory)	0.12^{bc}
T_4 (Celes)	0.19^{c}

**Means followed by same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.000)*

Number of leaves

The varieties had a significant effect on number of leaves of *D. sanderiana*. There were no significant differences between number of leaves of varieties 'Gold', 'White' and 'Victory'. The variety 'Celes' produced significantly higher number of leaves than other varieties. Further, the lowest Number of leaves was observed in variety 'Victory'.

Table 3: Increment number of leaves of four varieties of *D. sanderiana*

Treatment	Number of leaves*
T_1 (Gold)	5.4^{b}
T_2 (White)	4.9^{b}
T_3 (Victory)	4.4^{b}
T_4 (Celes)	7.2^{a}

**Means followed by same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.000)*

Relative Growth Rate (RGR)

There was no significant difference in Relative Growth Rate of four varieties of *D. sanderiana*, 'Gold', 'White', 'Victory', and 'Celes'. However, the Relative Growth Rate of T2 (White) showed the lowest value.

Table 4: Relative Growth Rate of four varieties of *D. sanderiana*

Treatment	Relative Growth Rate (g/g/day) *
T_1 (Gold)	0.004246^{a}
T_2 (White)	0.002959^{a}
T_3 (Victory)	0.004078^{a}
T_4 (Celes)	0.003422^{a}

**Means not significantly different (p=0.07)*

Absolute Growth Rate (AGR)

The varieties had a significant effect on the Absolute Growth Rate of *D. sanderiana*. There was a significant difference between the Absolute Growth Rate of varieties 'Gold' and 'Celes'. The variety 'Gold' had a significantly higher Absolute Growth Rate than other varieties. Further, the lowest Absolute Growth Rate was observed in the variety 'Celes'.

Table 5: Absolute Growth Rate of four varieties of *D. sanderiana*

Treatment	Absolute Growth Rate (cm/day)*
T_1 (Gold)	0.10765[a]
T_2 (White)	0.08843[ab]
T_3 (Victory)	0.09196[ab]
T_4 (Celes)	0.07304[b]

**Means followed by same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.002)*

Leaf color

The colors of 'Gold' were completely different from other three varieties and 'White', 'Victory' and 'Celes' have some common colors in their leaves.

Table 6: Leaf color of four varieties of *D. sanderiana*

Treatment		T1 Gold	T2 White	T3 Victory	T4 Celes
Leaf color (RHS codes)	Mature leaves	YGG 144A	YG 2D	GG N137A	YGG 147A
		YGG 146A	GGG N189A	YG 4D	YG 2D
			GGG N189C	YGG 147A	
				GGG N189C	
	Immature leaves		YGG 150A	GG 143A	
			YGG 147A	GG 143B	
			YGG 145B	GG 137B	
				YG 2C	

YGG- Yellow Green Group, YG- Yellow Group, GGG- Greyed-Green Group, GG- Green Group

Internodal distance (cm)

The varieties had a significant effect on Internodal distance of *D. sanderiana*. There were no significant differences between the Internodal distance of varieties 'Gold' and 'White'. The variety 'Victory' had significantly higher Internodal distance than other varieties. Further, the lowest Internodal distance was observed in variety 'Celes'.

Table 7: Internodal distance of four varieties of *D. sanderiana*

Treatment	Internodal distance (cm)*
T_1 (Gold)	1.8671[b]
T_2 (White)	1.942[b]
T_3 (Victory)	2.2466[a]
T_4 (Celes)	1.18[c]

**Means followed by same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.000)*

Number of internodes

The varieties had a significant effect on number of internodes of *D. sanderiana*. There were no significant differences between number of internodes of varieties 'Gold', 'White', and 'Victory'. The variety 'Celes' produced significantly higher number of internodes than other varieties. Further, the lowest Number of internodes was observed in variety 'Victory'.

Table 8: Number of internodes of four varieties of *D. sanderiana*

Treatment	Number of internodes*
T_1 (Gold)	10.8[b]
T_2 (White)	11.1[b]
T_3 (Victory)	10.1[b]
T_4 (Celes)	18.5[a]

**Means followed by the same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.000)*

Stem breaking angle (°)

The varieties had a significant effect on stem-breaking angle of *D. sanderiana*. There were no significant differences between Stem breaking angles of varieties 'Gold', 'White', and 'Victory'. The variety 'Celes' recorded significantly lower Stem breaking angle than other varieties. Further, the highest Stem breaking angle was observed in variety 'Gold'.

Table 9: Stem breaking angle (°) of four varieties of *D. sanderiana*

Treatment	Stem breaking angle (°) *
T_1 (Gold)	192.5[a]
T_2 (White)	171[a]
T_3 (Victory)	183[a]
T_4 (Celes)	120[b]

**Means followed by same letter (s) are not significantly different with the Tukey test at 5% level of probability. (p=0.000)*

Collenchyma tissues

Collenchyma tissues were not clearly visible.

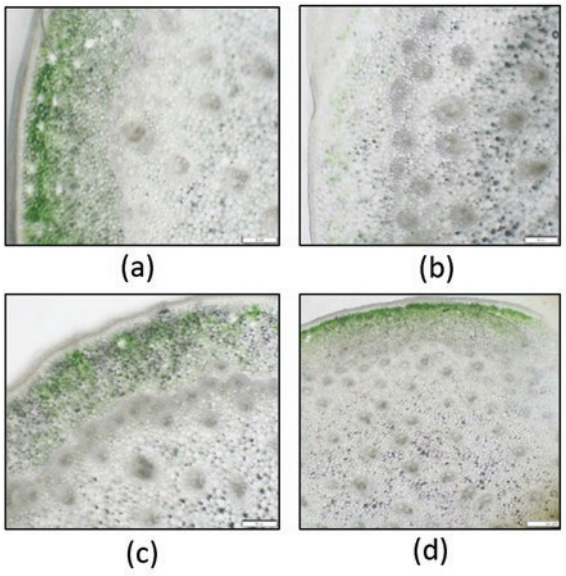

Figure 2: Microscopy images of transverse sections of (a) Gold, (b) White, (c) Victory, and (d) Celes (10x)

CONCLUSION

Due to significant differences in morphological and growth parameters (14 weeks after planting); particularly in radial growth, leaf count, internode number, and stem breaking angle; the 'Celes' variety is unsuitable for blending with the other three varieties in arrangements. However, the 'Gold,' 'White,' and 'Victory' varieties are compatible for blending, as their growth parameters are relatively similar. For contrast color combination, the 'Gold' variety can be blended with both 'White' and 'Victory'.

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Analysis of the Orchid Value Chain of SMEs in the Southern Province

Silva K.N.N.

[1] *Department of Agricultural Economics & Agribusiness, Faculty of Agriculture, University of Rununa, Sri Lanka*

ABSTRACT

The floriculture industry, particularly orchids, plays a significant role in generating income for small and medium-scale entrepreneurs and contributes notably to national revenue. In 2022, the sector earned nearly USD 14 million. Despite its potential, inefficiencies in material and information flow have hindered the realization of higher profit margins, especially within the small and medium-scale segments. Value chain analysis is crucial for enhancing productivity and profit, focusing on how income from consumers is distributed among chain members and how resources and information flow within the chain. This study examines the orchid value chain in Matara District, Sri Lanka, specifically targeting the decorative and bridal segments, which are often underrepresented by growers. The orchid industry is recognized as a vital contributor to the rural economy, offering income opportunities to marginalized groups. Key actors in this value chain include input suppliers, growers, collectors, retailers, and consumers. The study uses focus group discussions and consumer surveys to identify critical product attributes and challenges within the orchid value chain. Findings reveal that consumers are quality-sensitive and willing to pay more for desirable attributes such as size and color. Growers must maintain high quality to meet consumer expectations. The study also highlights challenges in ensuring a consistent supply of orchids and diverse purchasing strategies. Recommendations are provided to enhance the effectiveness of the orchid value chain for all stakeholders.

Keywords: Floriculture, Value Chain Analysis, Orchids, Small and Medium Enterprises (SMEs), Consumer Preferences

INTRODUCTION

In the floriculture industry, orchids are regarded as one of the most beautiful and attractive plant species. There are two main types of orchids: ground orchids and those grown with supportive structures or artificial supports. The most commonly commercially grown orchid varieties include Dendrobium, Vanda, Phalaenopsis, Cattleya, and Oncidium. Orchids are recognized for their essential role and appeal in various occasions, particularly ceremonial events, due to their fragrance, vibrant colors, and durability.

Among the orchid varieties, Dendrobium is notably popular in the Sri Lankan market, where it is sold as a whole plant. In contrast, Phalaenopsis is widely used as a decorative cut flower. Dendrobium is priced relatively low (ranging from Rs. 8.00 to 10.00 per flower) but has a high growth rate, providing quick economic benefits to growers. On the other hand, larger and more attractive Cattleya cut flowers are priced between Rs. 300 and 600 (Export Development board, 2022).

Orchids are commercially grown primarily in the Western, North Western, and Central Provinces of Sri Lanka. In the Colombo district, orchids have proven to be economically beneficial. However, orchids face biological challenges, such as the difficulty of germinating their very small seeds, which limits human intervention (De, & Medhi, 2015). As a result, plant propagation is typically done using

*nadee@agri.ruh.ac.lk

tissue culture technologies, which can be cost-prohibitive for small-scale farmers. Additionally, integrating tissue-cultured orchids into normal growing conditions poses challenges for many growers.

Recent export data indicates that Sri Lanka exported 435 shipments of orchids, with 41 exporters supplying to 29 buyers. The primary destinations for Sri Lankan orchids are the United States, Japan, and Saudi Arabia (OEC,2024).

Problem Statement

Despite being a profitable floriculture industry in the Southern Province, the orchid sector faces several challenges. More than 90 percent of orchid growers are women who encounter difficulties due to a lack of input providers, necessary knowledge, and technology, as well as weak relationships with other actors in the orchid value chain. Consequently, growers are unable to achieve the expected profit, and the supply to consumers remains insufficient in the Southern Province.

This study focuses on analyzing the flow of materials, communication, and relationships among actors in the orchid value chain. It aims to improve information and communication flow and address challenges faced by small-scale orchid growers, hoteliers, reception halls, florists, wedding decorators, beauticians, future brides, and flower consumers.

The primary objective of this study is to understand and enhance the flow of materials, communication, and relationships within the orchid value chain in the Matara District of the Southern Province. Specifically, the research aims to:

- Understand the flow of materials, communication, and relationships in the orchid value chain to improve its performance.
- Identify the value attributes within the orchid value chain to enhance value for end consumers.
- Explore issues and constraints affecting the orchid value chain and provide recommendations to strengthen material and communication flows, as well as improve relationships among value chain actors.

MATERIALS AND METHODS

This study employed the Rapid Value Chain Analysis tool developed by Dent and Collins (2021) to identify key features of the orchid value chain (VC). A minimal set of information was collected from major actors in the VC through focus group discussions and questionnaire surveys, using a small sample size.

Study Area

Although the floriculture industry is well-established in the Central and Western Provinces of Sri Lanka, the Southern Province has recently emerged as a key area for promoting small and medium-scale floriculture (EDB, 2020). This region offers significant potential due to its unutilized resources and the presence of resource-poor small and medium-scale women farmers and other marginalized groups. Therefore, the Matara District in the Southern Province was purposively selected for this study.

Sampling and Sample Size

Focus group discussions were initially conducted with selected orchid growers to identify the key actors in the orchid value chain. Ten growers from three Divisional Secretariats (DS) were purposively selected for these discussions. Interview guidelines were then developed for subsequent interviews with florists, wedding hall decorators, beauticians, and consumers who utilize orchids for

decorative purposes. A semi-structured interview was conducted with ten florists, hotel decorators, and beauticians. Additionally, informal telephone conversations were held with three input suppliers and two collectors. Finally, a survey was conducted with 30 consumers who acquire orchids from florists and other decorative industry professionals. This data collection aimed to identify the needs, wants, and requirements of end consumers to enhance the orchid value chain.

Data Collection

Primary data was collected through focus group discussions and questionnaire interviews. A major focus group discussion was held with orchid growers, while information from input suppliers and collectors was gathered via telephone interviews due to current transportation issues. A consumer survey was conducted with 30 end consumers of orchid cut flowers. Secondary data was also collected through a review of existing literature on the subject.

Limitations and Constraints

A significant limitation of this study was the lack of well-defined roles within the orchid value chain, which required considerable time to explore the actors and their relationships. As a result, the study relied on a small sample size to represent each actor in the value chain. Additionally, the findings are specific to the Matara District in the Southern Province and may not be generalizable to other regions.

RESULT AND DISCUSSION

Orchid cut flower Consumers' research

The profit performance of the Orchid VC chain is mainly determined by the amount of money that consumer pays for the product as it flows through the whole VC. Therefore, the most critical VC analysis is the understanding of the attributes of Orchid flowers which consumers value and how much they are willing to pay for these attributes. Hence, first, this study identified the value attributes of Orchid cut flowers that are most attractive to consumers, their willingness to buy, how much they are willing to pay and frequency of purchase of other cut flower varieties used in Decorative purposes. Table 01 shows the value attributes of the Orchid cut flowers used in Decorative purposes.

Table 1: Consumers value attributes for Orchid Cut flowers

Product Attributes	Value Characteristics (Annexed 2)
Variety	Dendrobium, Phelanopsis, Sonia, Vanda
Colour	Off White, white, Yellow (Phelanopsis, Dendrobium)
	Purple colour (Dendrobium and Sonia)
	Pink, Yellow (Vanda)
Size of single flowers	Medium and large size flowers
Stem length	Medium size stem length
Whole flower length	Long and medium size flowers
Shape of the flower	Oval shape flowers
Weight of the flower	Light weight flowers as to easily used for decorations
Shelf life	1-2 weeks of shelf life without wilting petals or stems
Flower form	Fresh form

Source: Authors' own data, 2022

There are main nine value attributes that have been identified through this study that would influence consumer purchasing behaviour, as shown in Table 1.

Though there are many Orchids varieties available in the markets, Dendrobium, Phelanopsis, Sonia and Vanda have been identified as the most demanded varieties by the consumers due to colourfulness and attractiveness of the flowers for decoration. Among them, Dendrobium and Phelanopsis

varieties are much loved by brides for their flower bouquets while Sonia and Vanda varieties used for other decorative purposes.

Secondly, off white and white colours flowers are mostly valued by brides and purple and yellow colours were mostly valued by consumers who used flowers for other table decorations, welcome functions, birthday celebrations etc. Thirdly, size of the single flowers, stem of the flowers and size of the whole flower have been identified as other important value attributes. Small and medium Size single flowers and demanded for bride flower bouquets and medium and large flowers is important for making table decorations, reef decorations and other decorations.

Moreover, stem of the flower is important for its usage. if it is required to use long stem flowers for hanging purposes, this is valued by consumers and short stem flowers valued by consumers uses flowers for cake, hairdress and other simple decorations. As orchids varieties and different shapes, consumers did not highlight the importance of shapes so much and the majority prefer Oval shaped flowers as Orchids exist naturally. Generally, Orchid flowers have long shelf life under favourable climatic conditions. However, consumers prefer 1-2 weeks' time of shelf life with the natural appearance of flowers. More importantly, the majority of, consumers valued the fresh form of flowers rather than processed or preserved form of flowers.

Then we proceeded to identify the critical control points of Orchid VC with the guidance of value attributes identified through the consumer data. This critical control points will assist to identify the effect of VC actors and activities on each value attributes. The following table 2 shows the Critical control points of the Orchid VC.

Table 2: Critical control points of the Orchid VC

Product Attributes	Value Characteristics	Critical control point of value	Responsible chain members
Variety	Dendrobium, Phelanopsis, Sonia, Vanda	Variety selection	Input supplier Growers
Colour	Off White, white, Yellow (Phelanopsis, Dendrobium)	Variety selection	Input supplier Growers
	Purple colour (Dendrobium and Sonia)		
	Pink, Yellow (Vanda)		
Size of single flowers	Medium and large size flowers	Variety selection	Input supplier Growers
Stem length	Medium size stem length	Variety selection	Input supplier Growers
Whole flower length	Long and medium size flowers	Variety selection	Input supplier Growers
Shape of the flower	Oval shape flowers	Variety selection	Input supplier Growers
Weight of the flower	Light weight flowers as to easily used for decorations	Variety selection	Input supplier Growers
Shelf life	1-2 weeks of shelf life without wilting petals or stems	Transportation Storage	Collectors, Retailors
Flower form	Fresh form	Transportation	Collectors
		Processors/	Retailors

Selection of most demanding varieties with required attributes was identified as one of the most important critical control points of Orchid VC at the production stage. Almost all value attributes of the Orchid VC were determined by the variety selection as colour, length, weight, shape of the flower, shelf life etc. Therefore, input suppliers and growers were the most responsible actors of Orchid VC. In addition, keeping the 1-2 weeks' shelf life with the fresh form were identified as another critical points of the VC. In this regards the flowers collectors and retailors such as florist were responsible actors of the VC.

Value chain map and actor-specific findings

The value chain map shows the different actors of the VC, their activities which create the value attributes of the particular product. Moreover, VC map represent the different activities that cause to incurred wastages along the chain. Further, it shows those activities that are necessary for the VC, but do not influence any consumer value attributes.

Actor specific findings

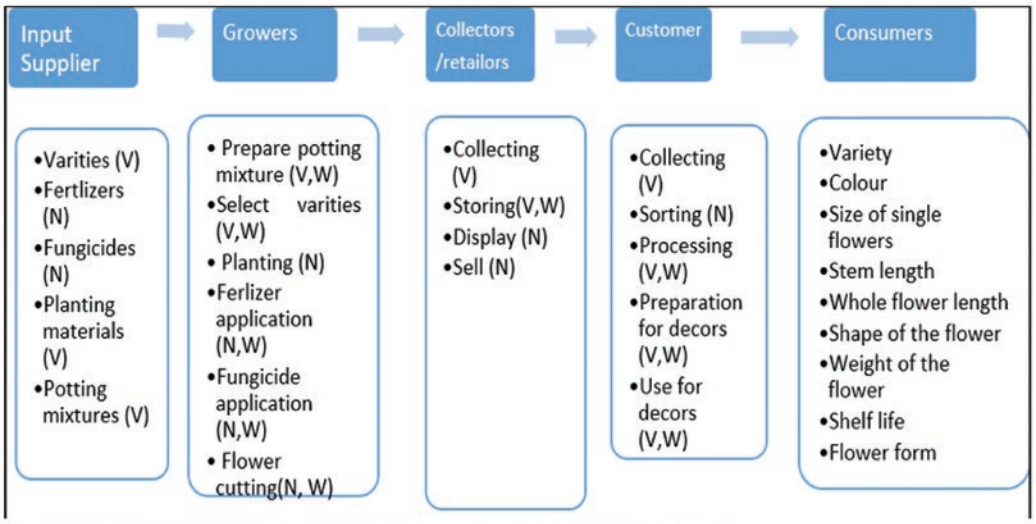
This section will present findings on material flow within the chain.

Input suppliers

Though there are many input suppliers in Colombo, Gampaha and other Orchid growing areas in Sri Lanka, there were only very few input suppliers near Matara. In particular, it is difficult to purchase new Orchid varieties developed through tissue culture techniques due to unsafe transport handling procedures. Therefore, it has been identified that the numbers of input suppliers are not adequate to cater to the demand of Orchid. There was one large scale planting material supplier in Matara area who used tissue cultured planting materials. Anyhow, he does `not supply small numbers of Orchid plants and not affordable for small and medium scale growers. Anyhow, there were adequate input suppliers for potting mixtures, other planting materials, fertilizers, and other chemicals.

Orchid Growers

According to the data obtained through, divisional secretariats of Matara district, there were large number of Orchid growers are there in Matara district. Anyhow, those growers are cultivating different plant varieties and it was hard to find sole Orchid growers in study area. The majority of interview growers had net



Key: V = Value-adding N = Necessary but not value-adding W = Wasteful

Figure 1: Orchid cut flower value chain

houses with required shading for the Orchids. Anyhow, many of them do not sell Orchid cut flowers at commercial scale and they sell whole orchid plants. However, there were few growers who used to sell cut flowers either to collectors or retailers directly and few of them sell to the customers (Hotels, wedding receptions., etc).

None of them were use additional labours for the cultivations and almost all activities are done by themselves. Anyhow, they have not been practiced adequate fertilize, other growth hormones and chemicals applications due to high price of those inputs incurred due to chemical fertilizer banning policy. Therefore, they could not expect Orchid flowers with the required size, colour, and quality at the correct blooming time. Moreover, it is also difficult to control fungal attacks that happened to orchids so frequently.

Farm gate price of the Orchid is determined solely on an Orchid variety and demand basis. In general, the price for a single flower of Dendrobium, Sonia, and Vanda varied from 8.00 to 12.00 Rupees while the price of one single Phelanopsis flower varied between 250.00- 450.00 rupees.

However, Orchid small-scale growers reported weak negotiating power in the market and are basically price takers. More frequently, flower collectors or retailers decided the farm gate price, and therefore, some growers do not intend to sell cut flowers in spite of the higher demand for cut flowers.

Majority of growers in Matara district are challenging with purchasing quality planting materials from surrounded area. Only two main input suppliers are there. Anyhow, they do not sell small quantity of planting materials. When they purchased them from remote areas, some wastages are happened due to poor handling practices.

Retailors

In this study, retailors and collectors have similar characteristics and was few in numbers. Though there are many flower collectors and retailors, only few were engage in Orchid marketing. Florist were the main retailors and 2 major collectors were found and they are facing challenges of fulfilling supply of Orchid cut flowers to their customers.

Those florists reported that customers requesting wide range of Orchids cut flowers for their decorations and it is difficult to forecast the exact demand of customers. Retailers also reported problems of lack of information of Orchid growers to collect Orchid when they have excess demand during wedding and festival seasons. The majority of retailers use primary preservative methods to keep flowers for few days in their stores.

Waste along the chain

Waste is an important factor of an any value chain can be referred as the any product which is not consumed by consumers, any kind of unnecessary activities, or applying

unnecessary/excessive inputs. Moreover, any product which sells for a lower price than it could sell for elsewhere also a waste and making a better product than it need to be also a waste. Any of these activities can occur at several stages along the Orchid VC. Orchid growers do much waste during applications of chemical fertilizers and fungicides at a higher price. Selling whole Orchid plants rather than most demanded cut flowers is also a waste occur at growers' level.

Relationships and information flow

In a VC thinking approach, we can identify the relationship of the actors who working together in value chain. In this approach, collectively, we can offer more value more effectively to

our end consumers. Therefore, information flow and relationships along the Orchid value chain was analysed to understand the level of collaboration among chain members. These information flow and relationship mapping is shown in Figure 2.

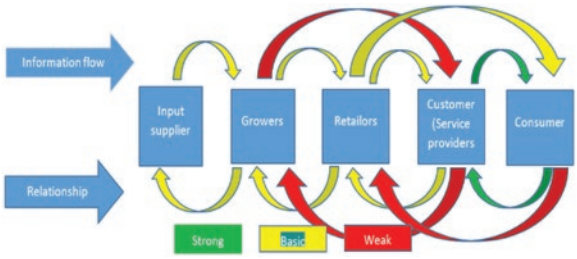


Figure 2: Relationships and information flow along the Orchid value chain

Input supplier/producer

According to the Orchid VC, both Information flow and the relationship between input suppliers and producers is basic and growers are facing a major challenge of purchasing quality planting materials, highly demanding variety and chemical inputs. Both input suppliers and growers were not satisfied in this relationship.

Growers/Retailors

The information flow and relationship between growers and retailors also were basic and both actors facing challenges of meeting their demand and supply need due to this poor relationship. Both actors believed that a better relationship would enhance the chain performances than in the current situation.

Retailors/customers (Hotels receptions and beauticians)

Retailers and service providers also have a basic relationship and information flow also was basic. Due to this basic relationship and information flow, there are some wastages that occurred between these two stages. Hotels and other customers purchase Orchid cut flowers at higher prices from other areas due to these poor linkages.

Customer/ Consumers

The only strong relationship that occurred in this Orchid value chain was between service providers and end consumers. Both information flow and relationship were strong in order to provide better consumer satisfaction as well to attract their customers. Service-providing customers always had good relationship with their consumers and were concerned their needs and want when create value for the decorative outcomes.

Weak information flow and relationship

In this Orchid value chain, there were weak information flow between growers and service providing customer. If there were sufficient information flow between these two actors, the value creation of the chain would be more efficient.

The relationship between end consumers with customers, retailers, and growers were weak and customer relationship with retailers and growers. However, all these actors believed that better relationships would develop more value to their consumers while improving the income of each actor.

Table 03: SWOT analysis

Strengths	Opportunities
1) Growers have motivation and intension to cultivate high demanding Orchid varieties in their nurseries and sell cut flowers instead of whole potted plants if it means getting higher economic returns. 2) sufficient knowledge and awareness on Orchid cultivations 3) Consumers understand the beauty of Orchid based decorations/arrangement over other flowers varieties.	1) Availability of online input suppliers and safe transport services. 2) Orchid growers' associations to ensure collaborative work arrangement under high demand. 3) favourable climatic conditions and therefore, less disease prevalence 4) Government/NGOs support programme/ subsidy programme for small scale Orchid growers.
Weaknesses	**Threats**
1) Less awareness on Consumer value attributes by other important actors of the chain. 2) Lack of input suppliers 3) Under the current economic crisis of the country, Consumers are not willing to pay high prices for ceremonial activities and way from functions/ wedding and celebrations.	1) High cost for inputs due to government policies. 2) Large number of flowers varieties that can be used as substitutes products at lower prices and with greater value to the consumers. 3) Insufficient relationship between chain actors. 4) Poor training and advisory services available growers 5) High cost of planting materials 6) Overall poor information flow and partnerships along the chain

These recommendations will present what an ideal Orchid value chain would look like when all actors meet their expectations and having good financial returns shared equitably along the chain.

Ideal Orchid value chain

In a well-performing value chain:

- It is understood, created, and delivered what consumers value most.
- There will be high consumer demand for more valued products.
- There will be the ability to compete with other flower species in the floral industry.
- Input suppliers will provide the necessary inputs at a low price to develop and multiply groundnut varieties that deliver the valued attributes.
- Growers will have access to high-quality planting materials at an affordable price.
- Growers are paid according to value-based pricing.
- All chain members are well aware of the importance of the value chain for better economic returns.
- All chain actors have a clear role, and one actor leads the value chain.

Recommendations for the Current Chain

Input Suppliers:

- Produce a sufficient number of inputs/ planting materials to meet the needs of small-scale growers based on consumer value attributes at reasonable prices.
- Maintain effective relationships with growers.

Producers:

- Use high-quality inputs to meet consumer value attributes.
- Maintain effective information flow and relationships with other actors in the value chain.
- Utilize growers' associations as a strong unit to negotiate with governments, cater to consumer demand, ensure a consistent supply, and benefit from technical assistance.
- Provide training on value chain thinking.

Retailers:

Develop effective marketing strategies to promote orchid cut flowers among hotels, wedding receptions, and bridal dressers through various media platforms.

Government and NGOs:

- Effectively monitor and evaluate the existing orchid growers' subsidy program.
- Provide necessary technical assistance programs for orchid chain actors as needed.

CONCLUSION

This study has identified nine attributes that consumers value in the orchid value chain. Consumers show a strong preference for using orchid-based products for their ceremonial functions. However, these valued attributes have not been effectively delivered by the actors within the value chain. Some key actors, such as growers and retailers, must perform more effectively to improve the chain's overall performance. The relationship between growers and retailers is a critical aspect of the chain that needs to be strengthened to meet market demand.

Due to the prevailing economic crisis in the country, consumers have become price-sensitive when deciding on prices for decorative activities. This has presented a new challenge for the orchid cut flower industry in the Matara district. A lack of awareness among chain actors about consumer value attributes, poor access to quality inputs at affordable prices, and inadequate information flow and relationships among chain actors are major factors that undermine the performance and efficiency of the orchid cut flower value chain.

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Potential of Panicles from Selected Grass Species as Fillers for Dried Flower Arrangements

Jayasinghe W.V.S.[1]*, Kumara G.D.K.[1], Perera L.N.S.[2]

[1] *Department of Export Agriculture, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka*
[2] *Floriculture Research and Development Unit, Royal Botanic Gardens, Peradeniya, Sri Lanka*

ABSTRACT

In dried flower arrangements, grass panicles though captivating, are often overlooked and not explored as much as common plant fillers. This study investigates the feasibility of incorporating Bristly foxtail (*Setaria barbata*) and Bajiri (*Echinochloa crus-galli*) grass panicles as fillers in dried flower arrangements by identifying optimal panicle maturity stage to harvest and effective drying methods. A survey was conducted to identify customer preference for these panicles in dried flower arrangements. Additionally, a germination test was conducted to evaluate the potential risk of the species spreading as a weed. Panicles were harvested at two different growth stages and dried using three methods: air drying, hot air oven drying and silica gel drying. The evaluated parameters included color, spikelet retention, branch brittleness, overall shape, and moisture absorption percentage. The results indicated that silica gel drying was the ideal drying method for panicles of both species in term of color. Harvesting at partially emerged stage panicles and air dried panicles of *S. barbata* showed the minimum moisture absorption percentage. According to the overall median score ranks, spikelet retention and branch brittleness of all treatment combinations of both species remained at their highest ranks. With the exception of silica gel-dried panicles at the fully emerged stage of *S. barbata*, all other combinations for both species achieved an optimal rank in terms of overall shape. The germination test revealed that the panicle maturity stages tested had no potential risk of dispersion of both species as weeds. The survey revealed that 77.7% of florists were willing to incorporate both species into their arrangements. These findings indicate that both species hold significant potential for use as fillers in dried floral designs.

Keywords: branch brittleness, *Echinochloa crus-galli*, moisture absorption, *Setaria barbata*, spikelet retention

INTRODUCTION

Currently the demand for dry flower based items is consistently expanding due to their remarkable properties such as never-ending quality, year-round accessibility, eco-friendliness, and suitability for the manufacture of various value-added products (Mir and Kalpana Sawant, 2022). Fresh cut flowers are remarkable and attractive, but maintaining their beauty for extended periods is challenging, even with the best chemicals (Rani and Reddy, 2015). Dried flowers can have a longer shelf life if they are dried under proper technique (Koley, 2020). They are also natural and inexpensive. Thus, dried flowers and plant parts come as a fantastic substitution for fresh flowers and foliage for interior design and other artistic and commercial applications (Mir, 2023).

Fillers play a crucial role in enhancing the aesthetics of these arrangements, providing structure, volume, and contrast to the primary blooms. However, the incorporation of grass panicles introduces a new dimension to the overall aesthetic appeal of the compositions. The panicle, the most common kind of grass inflorescence, has one to several orders of branching (Moore and Moser, 1995). This

*vsjviraji96@gmail.com

study aims to assess the suitability of panicles from two distinct grass species, namely Bristly foxtail/Mary grass (*Setaria barbata*) and Bajiri (*Echinochloa crus-galli*), as potential fillers. *Setaria barbata* is a versatile plant. Its distinct appearance, characterized by slender, bristle-like seed heads, imparts a unique texture and captivating visual interest to any floral arrangement (Doust and Kellogg, 2002). *Echinochloa crus-galli*, is one of the serious weeds in agricultural fields worldwide (Guo *et al*., 2017). But their panicles can enhance the appeal of dried arrangements.

To produce dried, attractive plant material, various techniques are used, such as air drying, press drying, glycerin drying, silica gel drying, microwave drying, hot air oven drying, water drying, and skeletonization (Mir and Kalpana Sawant, 2022).

Air drying is a simple and cheaper method of drying (Mir *et al*., 2021). Plant materials are hung on rope or wire in a warm, dry, dark, well-ventilated space with low humidity for air drying (Rai *et al*., 2016). In the hot air oven drying method, plant material is dried at a controlled temperature for a specific time, depending on the species. The drying of flowers and other ornamental plant components is greatly influenced by temperature (Dilta *et al*., 2011). Silica gel is a fairly expensive moisture-absorbing chemical desiccant. It is an excellent product for drying (Rani and Reddy, 2015).

In contrast to other floricultural fields, only a few research and development projects have been undertaken on the dried flower industry across the globe (Dilta *et al*., 2011).There is a notable lack of research on the use of grass panicles as fillers in dried flower arrangements. This study seeks to explore the potential of selected grass panicles for enhancing dried flower arrangements.

MATERIALS AND METHODS

The experiment was conducted during the period from September to December, 2023 at the Post Harvest Laboratory, Royal Botanic Gardens, Peradeniya.

Plant Materials

Panicles of *Setaria barbata* and *Echinochloa crus-galli* were collected from the fields in the Kegalle district. Panicles from both species were harvested at two distinct stages of development. For *Setaria barbata,* panicles were collected at the partially emerged stage and the fully emerged stage. For *Echinochloa crus-galli*, panicles were harvested at the young, green stage and at the stage when they began turning brown. Panicles were harvested in dry morning and they were free from insects, disease symptoms or mechanical damages. All harvested panicles were trimmed to a stem length of up to 15 cm, with any unwanted parts removed.

For *Setaria barbata*,

Growth stage 1 - Partially emerged panicles
Growth stage 2 - Fully emerged panicles

For *Echinochloa crus-galli*,

Growth stage 1 - Panicles at green color, young stage

Growth stage 2 - Panicles at turning to brown in color

Panicles from each species were dried using three different methods: air drying, hot air oven drying, and silica gel drying.

Air Drying

Panicles were tied with ropes and hung upside down in a clean, dark, and well-ventilated area. They were kept in the same position without touching for three weeks to ensure absolute drying.

Hot Air Oven Drying

The oven was set to 50°C and the panicles were dried until they reached a constant weight. Throughout this process, samples were periodically checked for dryness.

Silica Gel Drying

Plastic containers large enough to hold the panicles were selected and sealed. The bottom of each container was filled with a 2 cm layer of silica gel. The panicles were arranged on this layer without overlap, and another layer of silica gel was gently applied on top to cover them completely. The prepared containers were placed in a well-ventilated area for drying.

Germination Test

A germination test was carried out to assess the potential risk of dispersion of selected grass species as weeds. The test specifically focused on panicles at the second growth stage for both species (For *Setaria barbata* - Panicles at fully emerged stage, For *Echinochloa crus-galli*- Panicles at turning to brown color stage. This assessment was conducted twice after the panicles reached a constant weight: once in the 1st week and again in the 3rd week.

A separate panicle was used for each replicate for the germination test and 10 seeds were taken from one replicate. The assessment employed the 'Top of Paper' method (Rao *et al*., 2006).

Field Survey

A field survey was conducted to identify the current market status of the dried flower industry in Sri Lanka and to assess customer preference for selected panicles as fillers in dried flower arrangements. Information was gathered through a questionnaire by interviewing 20 florists in the country.

Data Collection

After reaching a constant weight, the panicles were stored under normal environmental conditions for seven weeks. Data collection for all parameters, except color, was conducted at the end of the 7-week period. Color measurements were taken during the first week. The germination test was conducted twice, at the 1st and 3rd weeks. Assessed parameters were color, spikelet retention, branch brittleness, overall shape, and moisture absorption percentage.

The moisture absorption percentage (MA) of panicles was calculated by considering the weight difference between the constant weight and the weight after seven weeks, using the following formula.

$$MA\% = \frac{\text{(Final weight-Initial weight)}}{\text{Initial weight}} \times 100$$

The number of germinated seeds was counted and the germination percentage (GE) was calculated using the following formula.

$$GE\% = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

The panicle colors, spikelet retention, branch brittleness, overall shape of the panicles were qualitatively ranked.

Experimental Design and Statistical Analysis

The experiment was carried out as two factor factorial Completely Randomized Design (CRD) with four replicates and three panicles per each replicate. The data were analyzed using Minitab software (version 21.4.2) following the application of a two-way Analysis of Variance (ANOVA). The survey was analyzed using SPSS software (21 versions) and the graphical illustrations were done using Microsoft Excel 2010.

RESULT AND DISCUSSION

Bristly Foxtail Grass (*Setaria barbata*)

The analysis revealed no significant interaction effect ($P > 0.05$) between growth stage and drying method on the average moisture absorption percentage of *S. barbata* panicles. But a significant difference ($p < 0.05$) in the average moisture absorption percentage of *S. barbata* panicles was observed between the two growth stages (Figure1). The highest moisture absorption percentage occurred at growth stage two, while the lowest was observed at growth stage one.

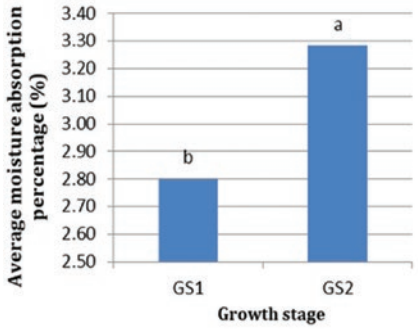
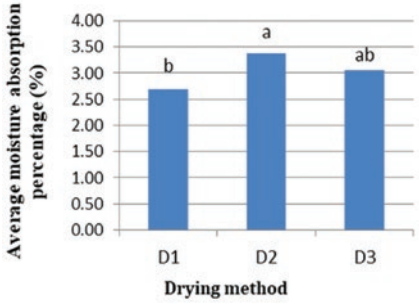


Figure 1. Variation of moisture absorption percentage of panicles between two growth stages

Figure 2 shows the variation in moisture absorption percentage of panicles among drying methods. According to that there was a significant difference ($P<0.05$) between air drying and oven drying methods in terms of moisture absorption percentage. The lowest moisture absorption percentage was observed in air dried panicles.

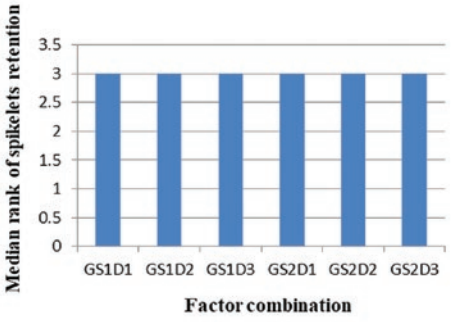


D1 = Air drying D2 = Oven drying
D3 = Silica gel drying

Figure 2. Variation of moisture absorption percentage of panicles among different drying methods

Singh *et al.* (2004) reported that moisture content in the flowers after drying influenced flower shape. Moisture content also in dried flowers influenced longevity. Lower moisture content shows higher longevity. This experiment has reported lower moisture content at growth stage one, indicating that this stage is ideal for panicle harvesting and air drying is the ideal drying method for *S. barbata* in dry flower arrangements.

Spikelet retention of panicles of *S. barbata* did not significantly vary ($P>0.05$) among factor combinations (Figure 3). All the combinations were at their highest median rank of spikelet retention even after seven weeks. Consequently, each of these combinations possesses the potential for utilization in dried flower arrangements.



GS1D1 = Growth stage 1 , Air drying
GS1D2 = Growth stage 2 , Oven drying
GS1D3 = Growth stage 1 , Silica gel drying
GS2D1 = Growth stage 2 , Air drying
GS2D2 = Growth stage 2 , Oven drying
GS2D3 = Growth stage 2 , Silica gel drying

Figure 3. Variation of spikelet retention of panicles among factor combinations

Color of panicles did not significantly vary ($P>0.05$) among factor combinations. However, a significant difference was observed among drying methods. The highest rank of color was reported for silica gel dried panicles. That means silica gel drying yielded panicles with highly acceptable color. Therefore, silica gel drying emerges as the ideal method for drying *S. barbata* panicles to use in dry flower arrangement.

Branch brittleness of panicles of *S. barbata* also did not significantly vary (P>0.05) among factor combinations. All the combinations were at their highest median rank of branch brittleness after seven weeks. Therefore all of these combinations possess the potential for utilization in dried flower arrangement.

The growth stage and drying methods did not independently affect the overall shape. They were interacting with each other in a way that impacts overall shape. GS2D3 (Silica gel dried panicles at growth stage two) has a significantly lower rank compared to all other combinations. It was at the lowest rank in terms of overall shape. So, except for combination GS2D3, all other combinations have the potential for use in dry floral arrangements.

Bajiri (*Echinochloa crus-galli*)

The results revealed that the moisture absorption percentage of *E. crus-galli* panicles did not vary significantly (P > 0.05) among the factor combinations.

Color of panicles did not significantly vary (P>0.05) among factor combinations. Nevertheless, a significant difference was observed among drying methods. The highest rank was reported for Silica gel dried panicles. That means silica gel drying yielded panicles of *E. crus-galli* with highly acceptable color. Therefore, silica gel drying emerges as the ideal method for drying *E. crus-galli* panicles for use in dry flower arrangements. Similar results have observed by Raval *et al*. (2020). According to them embedded drying silica gel is the best medium to get excellent dried flowers which retain color of flowers.

The branch brittleness, spikelet retention and overall shape of *E. crus-galli* panicles did not vary significantly (P > 0.05) among the factor combinations. All combinations exhibited the highest rank after seven weeks, indicating their suitability for use in dried flower arrangements.

Germination Test

The germination test revealed that only one seed from air-dried panicles at growth stage two of *Echinochloa crus-galli* germinated in the first week, with an overall average germination rate of about 2.5%, indicating very limited seed viability. All other factor combinations showed zero germination for both *Setaria barbata* and *Echinochloa crus-galli* across the first and third weeks. Here the *Echinochloa crus-galli* panicles were harvested at the colour turning to brown stage and *Setaria barbata* was harvested at the fully emerged panicle stage but not at full seed maturity. This choice in the harvesting stages indicates that the seeds were not fully mature, which may be a significant reason to the observed low germination rates.

Field Survey

According to the findings of the study, present state of the dry flower industry indicates an emerging trend within the country. A significant challenge faced by florists is the insufficient availability of materials in the required quantity, preventing many from actively participating in the market. However, all florists expressed a willingness to expand their services to include dried flowers in arrangements, if an adequate supply of materials becomes accessible. Moreover, the current average price of dried materials-incorporated arrangements remains relatively high. This is due to the costs associated with materials obtained from local suppliers and imported sources. Their native availability makes them easily attainable, and Florists can preserve them easily on their own. This substitution has the potential to reduce production costs, facilitating the expansion of the dry flower industry.

The data revealed that 77.7% of florists were currently familiar with Bristly foxtail (*S. barbata*) grass while 100% of florists were familiar with Bajiri grass (*E. crus-galli*). However, they have not been incorporating them into their arrangements, primarily due to uncertainty about whether these grasses meet the required quality standards for dry flower arrangements. Our experiment has proven that they have the necessary qualities for such arrangements. Additionally, 77.7% of florists expressed the willingness to mix both species in their arrangements. Therefore, there is a potential to use these grass panicles in the dry flower industry.

CONCLUSION

Silica gel drying is the most effective method for preserving the color of panicles in both *S. barbata* and *E. crus-galli* for use in dried flower arrangements. Both species exhibit excellent spikelet retention and minimal branch brittleness while maintaining an ideal overall shape, except for silica gel-dried *S. barbata* at growth stage two. For moisture absorption, growth stage one of *S. barbata* is optimal for harvesting, with air drying being the most suitable drying method for this species.

Furthermore, germination tests confirm no risk of weed dispersion at the selected growth stages. A survey indicated that 77.7% of florists are willing to include both species in their arrangements. These findings highlight the strong potential of *S. barbata* and *E. crus-galli* as versatile and attractive fillers in dried floral designs.

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Seaweeds in Marine Aquascaping: Exploring the Benefits of *Cladophora herpestica* for Aesthetic and Ecosystem Health

Bandara D.R.[1], Gangabadaarachchi L.[1], Perera P.C.D.[2], Pushpitha N.P.G.[1] and Dahanyake N.[2]*

[1] *Department of Fisheries and Ocean Sciences, Ocean University of Sri Lanka, Mahawela Road, Tangalle, Sri Lanka*
[2] *Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*

ABSTRACT

Marine algae play a fundamental role in marine ecosystems. These roles include acting as primary producers, contributing to biodiversity, and producing oxygen. Marine aquascaping, or underwater gardening, is a popular hobby that not only enhances the beauty of aquariums but also provides personal benefits like stress relief, creative expression, and a sense of accomplishment for those who take part in it. *Cladophora herpestica* stands out as a good candidate for incorporating into marine aquascaping. It is a green alga that consists of a cushion-like structure that adds vibrant color and texture, increasing the visual appeal of aquascapes while enhancing water quality by absorbing excess nutrients. It also promotes biodiversity by offering shelter and food to small organisms. However, *Cladophora herpestica* requires careful management due to its rapid growth that may affect the balance of the tank without supervision. Integration of these types of algae into aquascaping showcases a sustainable and visually enriching approach to marine aquarium designs. This paper explores the application of *Cladophora herpestica* in aquascaping, highlighting its ecological importance and aesthetic contributions.

Keywords: Marine Algae, Marine Aquascaping, *Cladophora herpestica*, Sustainable Aquarium, Ecosystem balance

INTRODUCTION

Algae are a diverse photosynthetic group that can be found in a range of environments such as freshwater, moist soil and marine ecosystems. Algae are classified as Protists and are not true plants yet share some characteristics like photosynthesis and are in a diverse range of sizes and shapes (Andersen, 1998). They can range from microscopic single-celled organisms like phytoplankton to giant multicellular species such as Giant kelp (*Macrocystis* sp.). Marine algae, often known as seaweeds plays an important role in marine ecosystems as primary producers. Generally, marine algae are divided into four different groups, according to their color. Blue-green algae, also known as cyano bacteria consist of up to 1500 species. It is a type of bacteria that has photosynthetic ability, hence categorized as an algae. Red algae also known as Rhodophyta has around 6000 species. They contain Phycoerithrin as one of the pigments for photosynthesis. Brown algae which belong to phylum Ochrophyta is made up of around 1750 species. They have Fucoxanthin as one of their pigments. Lastly, Green algae also known as Phylum chlorophyte has around 1200 species that belongs to five classes, known as Bryopsidophyceae, Chlorophyceae, Dasycladophyceae, Prasinophyceae and Ulvophyceae (Kilinc *et al*., 2013).

**chathura@agri.ruh.ac.lk*

Marine Algae in Ecosystems

Marine algae serve a fundamental role in marine ecosystems. One of the key roles is oxygen production. It is known that 45% of the earth's oxygen supply is generated by marine phytoplankton (Sournia, 1982). Also, it is responsible for creating and maintaining the foundation of marine food webs. Marine algae, specifically phytoplankton are the main primary producers in marine environments (Anbuchezhian *et al*., 2015). Phytoplankton and larger seaweeds support entire marine life ranging from smallest zooplankton to large fish and whales. Moreover, marine algae have the ability to aid in carbon sequestration as well. They play a significant role by capturing the carbon dioxide from the atmosphere, helping to mitigate climate change by reducing the carbon from the atmosphere and storing it in ocean ecosystems (Chung *et al*., 2011). Furthermore, there are entire marine ecosystems called kelp forests, which are made up of brown algae types commonly called kelp. These kelps grow up to 45m in height creating underwater habitats which is similar to forests. They provide shelter to many marine species and are considered as one of the most important marine habitats in the globe (Steneck *et al*., 2002).

Conventional Applications of Marine Algae

Due to the availability of many bioactive compounds and fast growth rates marine algae has various industrial applications (Table 1). Other than that there are many uses of marine algae in the world. One of the less popular uses of marine algae is for aquascaping in saltwater aquariums.

Table 1. Marine algae species and their common uses

Marine Algae Species	Uses	Description	Reference
Nori (*Porphyra* sp.)	Food	Use in Sushi and other Asian dishes	Goni *et al*., 2000
Kombu (*Laminaria* sp.)	Food and Flavor enhancers	Use in soups and broths, especially in Japanese cuisine	Kato *et al*., 2016
Agar (*Glacilaria* sp.)	Thickening agent in food and research	Use as a gelling agent in desserts and to solidify culture media in laboratories.	Pandya *et al*., 2022
Carrageenan (*Chondrus* sp.)	Food additives and thickener	Use to stabilize and thicken dairy products such as ice cream	Hotchkiss *et al*, 2016
Sargassum sp.	Biofuel and Biofertilizer	Potential source of biofuels and is currently used as a natural fertilizer	Lopez *et al*., 2022
Ulva sp.	Food and animal feed	Also known as sea lettuce and used in salads and also as feed for livestock	Simon *et al*., 2022 Hofmann *et al*., 2024
Caulerpa sp.	Food	Popular as a vegan alternative to caviar	De Gaillande *et al*., 2017
Kelp (*Macrocystic* sp.)	Cosmetic and pharmaceutical industries	Use as an alginate source in creams, lotions and medical products	Liu *et al*., 2023 Purcell *et al*., 2021
Spirulina sp.	Dietary supplement	High protein superfood that is commonly used in health supplements	Zahroojian *et al*., 2013

Aquascaping and the role of seaweed

Aquascaping, also known as underwater gardening, involves creating artistic underwater environments while incorporating technical aspects to maintain sustainable landscapes (Elden *et al*., 2023). This concept integrates fish, plants, wood, and gravel, balancing biological and chemical factors to support both living and non-living components (Buta *et al*., 2013). Proper control of substrates, water quality, fish, plants, and aquascaping ornaments is necessary to sustain these systems.

Seaweeds offer a valuable opportunity to enhance both water conditions and aesthetics in aquascaping (Critchley *et al*., 2006). They improve water quality by absorbing excess nutrients like nitrates and phosphates, functioning as a sustainable way to manage the waste products of aquarium organisms, ultimately promoting a healthier ecosystem. Their ability to absorb heavy metals also minimizes health risks for aquarium biota, preventing harmful algae blooms (Adey *et al*., 2007). Additionally, seaweeds contribute to biodiversity by providing habitats for fish, invertebrates, and microorganisms. They act as a food source for herbivorous fish and offer refuge for small species in marine aquariums (Bhadury *et al*., 2004)

Seaweeds also significantly increase the aesthetic appeal of aquascapes, creating visually pleasing underwater landscapes. Popular seaweed species for marine aquascaping include *Ulva* sp., (Strand et al, 1996) *Gracilaria*, (Kauhgardi et al., 2014) *Cladophora, Chaetomorpha, Halimeda, Caulerpa, Sargassum*, and *Padina* (Adey et al., 2011). Among these, *Cladophora herpestica* stands out as a highly suitable species for both aesthetics and water purification.

Focus on *Cladophora herpestica*

Cladophora herpestica (Figure 01) is a marine green algae from the genus *Cladophora*, forming thick, compact, cushion-like structures firmly attached to hard substrates. Its tangled filaments create a dark green, moss-ball like appearance, with filaments growing up to 10 mm in length (Coppejans *et al*., 2009). It naturally thrives in the intertidal zones of tropical and subtropical regions of the Indo-Pacific Ocean, where it endures constant wave action. (Sealifebase.ca, 2024).

The moss-like carpets of *Cladophora herpestica* add visual dynamism to marine aquariums, effectively covering rocks and hardscapes, and providing a lush, natural appearance. This species can locally achieve the popular "moss ball" look, often associated with the trendy Japanese marimo moss ball (*Aegagropilalinnaei*) from the Cladophorales order, which is absent in Sri Lanka. As a substitute, *Cladophora herpestica* can even be exported from Sri Lanka.

In aquascaping, *Cladophora herpestica*'s vibrant green color contrasts beautifully with corals, creating visually stunning combinations. Its fine filaments add delicate textures and a sense of depth to aquariums, enhancing their naturalistic appeal (Critchley *et al*., 2006). In addition to its visual benefits, its nutrient absorption capacity prevents undesirable algae overgrowth and promotes water quality by acting as a biological filter (Guiry *et al*., 2023). The filamentous structures also provide hiding places for larvae, copepods, and other small invertebrates, contributing to the ecosystem's health (Abbott *et al.*, 1976).

However, due to its fast growth, regular trimming and monitoring are necessary to prevent it from overwhelming other plants and disrupting the intended aquascaping design. If not properly managed, *Cladophora herpestica* can become invasive in limited marine tank spaces and has a tendency to trap debris, which can lead to nutrient buildup and affect tank cleanliness.

CONCLUSION

Marine algae, particularly *Cladophora herpestica*, play a dual role in enhancing marine aquascapes by contributing to both ecosystem health and aesthetic appeal. The nutrient-absorbing properties of *C. herpestica* improve water quality and mitigate the risk of algal blooms, while its unique structure provides habitats for small marine organisms, fostering biodiversity. Its aesthetic characteristics,

such as vibrant color and fine textures, make it a visually striking addition to aquascaping designs. However, its potential to grow rapidly necessitates vigilant management to prevent ecological imbalance within aquarium systems. By incorporating species like *C. herpestica*, aquascaping transcends mere artistry, embodying sustainable practices that harmonize ecological integrity with design innovation. Future studies could focus on optimizing the management of *C. herpestica* in aquariums to maximize its benefits while mitigating challenges, paving the way for its broader application in marine ornamental practices.

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Flowers and Foliage PreservationTechniques – A Review

Edirisinghe E.A.A.I.K., Dahanayake N.* and Perera P.C.D.

[1] *Department of Agricultural Biology, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka*

ABSTRACT

Fresh flowers and foliage are highly sensitive and can lead to significant losses for farmers during harvesting, transporting and storing. To address this, alternative options are proposed, such as transforming decorative foliage, flowers and inflorescences into value-added products. If there is a potential for the creating value-added flower products in Sri Lanka, it has not very much popular among people. Therefore, this review was conducted to identify effective methods that can be preserved flowers for long period of time while making value-added products. This review thoroughly discusses different flower preservation techniques. Air drying, microwave drying, hot air oven drying and embedded drying are some techniques which is used to dehydrate flowers. These techniques are relatively straightforward and can be operated by unskilled workers. Additionally, can be created self-employment opportunities for youth and women. In addition, this will lead to researchers to identify most effective method for preservation of tropical flowers.

Keywords: floral crafts, flower drying techniques, value-added products, self-employment

INTRODUCTION

Floriculture is one of the export oriented sector in Sri Lanka. Even though, there is a high potential for the development of floriculture sector, it has not shown a sufficient growth in the export market in past few years. In 2021, Sri Lanka has produced cut foliage (~87%), live cut flowers (~1%), flower seeds (~6.2%) and aquatic plants (~5.6%) for the world market and earned revenue was USD 16 Million (Export Development Board, Sri Lanka, 2022). Netherlands, Germany, Japan and United Arab Emirates are being main buyers of Sri Lankan floriculture products (Beneragama and Peiris, 2016).

Even though fresh flowers are highly attractive they are highly perishable, short lived and very expensive. Postharvest losses of fresh flowers are about 10-30% due to poor postharvest practices (Rathnayake *et al*., 2024).Therefore, extending shelf life using various preservation methods is important to increase market value through longevity, aesthetic properties, and year round availability. In Sri Lanka Production of dry flowers and foliage is at minor level but There is a high demand for the dry flowers and their value-added products in the world. So, it is essential to pay attention on this innovative sector as a developing country (Beneragama and Peiris, 2016).

Freshness of flowers can be maintained for little period of time by using preservative solutions. They can be chemical or natural floral preservative solutions (Rathnayake *et al*., 2024). Dehydration of flowers and foliage is long lasting. Drying of natural foliage has been done from ancient time. Earlier, botanists have made herbarium for the identification of various species (Prasad *et al*., 1997). Dehydration is the process of removing water from fresh flowers and foliage. There are numerous methods are used to drying flowers such as air drying, sun drying, microwave oven drying, freeze drying and embedded drying.

**daha27@yahoo.com*

There are some Dehydration techniques that can be maintained flower color and shape as original for a longer time (Kumar *et al*., 2022).A number of flowers respond well to drying techniques such as zinnia, carnation, chrysanthemum, daffodils, marigold, rose etc. and foliage like ferns, eucalyptus, etc. (Dilta *et al*., 2011).In addition, there are lots of wild species with ornamental features are available and can be used them to make various dry flower products with higher market value such as greeting cards, book marks, floral segments, wall hangings, calendars, potpourris, table mats, suweniers etc. (Kumar *et al*., 2022).

Therefore, flower preservation and production of dry flower products can become a profitable venture. This industry can be used as an income source for especially women and rural unemployed persons. Therefore, this review was conducted with the objective of identifying possible methods that could be used to preserve flowers and foliage as well as their value added products which can be gained high demand in local and export markets.

MATERIALS AND METHODS

Longevity of fresh flowers can be extended by using preservatives and dehydration techniques. In this review, has been discussed about suitable dehydration techniques, preservatives and value added products for various flowers.

2.1 Use of preservatives

2.1.1 Chemical preservatives

Silver nitrate, cobalt sulfate, aluminum sulfate, citric acid, boric acid, ascorbic acid are used as preservatives. These preservatives can control ethylene production, pathogen development and water maintenance while retain color (Barani *et al*., 2022).

2.1.2 Natural preservatives

Rathnayake *et al*., 2024 revealed that post-harvest life of lotus can be increased up to 10 days with coconut water under 30% (v/v) concentration. This concentration has been made using 600ml of fresh coconut water diluting with 2 liter of distilled water. Lowest browning, fading, petal falling, and wilting has been observed for *Nelumbo nucifera*.

2.1.3 Household wax

Atapattu *et al*., 2017 used household wax (paraffin wax) to identify as an effective method for preserving flowers with good appearance and quality. Melted paraffin wax at 70°C were used. Melted paraffin wax was colored using colour pastels (Atlas) and Food colou rings in 1:1 ratio. Flowers was dipped into the wax until stem is covered. Then flower has gently shaken to remove the excess wax and immediately dip in cold water for 5 minutes. Then it was kept for remove excess water and dry. After drying, flowers have been kept in refrigerator in different durations. Results revealed that the wax coated and 24 hours chilled flowers (Bougainville and Orchid) have a very good appearance even after replacing in room temperature for 48 hours.

2.2 Dehydration of flowers

2.2.1 Air Drying

The easiest method of preserving flowers and foliage. Flowers are tied together at the stem ends as loose bunches using rubber bands and hung upside down position. Large flowers should be hung individually. Flowers with weak stems should be tied with a wire. Air drying should be done in a warm, dry place with good air circulation. Flowers take 1 to 3 weeks to dry completely (Rani and Reddy, 2015).Time which is taken for complete drying depend on atmospheric temperature, humidity, air circulation and shape of flowers (Rathod *et*

al., 2016).Relative humidity of the drying area should be less than 75 per cent to prevent mould growth on flowers (Jain *et al*., 2016). In this method most flowers became dark and some flowers turn to brown and light colored flowers will be faded and will be brittle. As a result of the brittle nature of air-dried flowers, creating the bouquet is tough. Blue and yellow flowers retain their colour when air dried but pink flowers fade (Rani and Reddy, 2015).

2.2.2 Embedding Method

The flowers can be dried by embedding in desiccants. The moisture content of the flower is completely absorbed by the desiccant (Kumar *et al*., 2021).The important desiccants are silica gel, borax Powder, river sand, alum powder, corn powder, saw dust, etc. desiccants should be pouredup to 4 to 5 cm above the flower without disturbing the shape of it. All the gaps between flowers should be filled (Rani and Reddy, 2015).After drying, flowers should be carefully removed from the desiccant and brushing off the remaining desiccant from flowers. After cleaning, dried flower preservative can be sprayed to protect them for longer period of time. There are some precautions that should be concerned in this method. Such as, Embedding plant material immediately after plucking, one type of flower or foliage embedded at a time, cut all undesirable portions of flower and foliage and two specimens should not be touch each other or sides of the container. (Jain *et al*., 2016).

2.2.2.1 Sand Drying

Sand must be very clean, fine and dry. 1 or 2 inches sand layer should be placed in a container. Flowers should be positioned as head upright and spread little amount of sand around each petal by making a fine stream. Sand should be equally spread on all sides of petals to retain shape of the flowers. It takes about three weeks to dry. Papery texture is the indicator that all the flowers have been dried well (Rani and Reddy, 2015).

2.2.2.2 Borax drying

It takes 2 weeks or more for drying process. Borax is a moisture absorbing desiccant. Borax should be spared in the bottom of the box and place flowers according to their shape. Flat flowers like daisies, should be placed as face down. Cup flowers like roses should be kept as face up. Sides of the flowers should be supported by borax. It should be added until flowers are fully covered and sides of the flowers should be supported by borax. In Borax drying can be retained shape and color except pink and red. Red colour become darker and white colour become off white. Shrinkage is minimal. But if flowers remain in borax mixture too long, they become brittle and lose petals (Rani and Reddy, 2015).

2.2.2.3 Silica gel drying

Silica gel is a best material for drying flowers than borax. It is a moisture-absorbing chemical desiccant. Flowers should be kept in the air tight container and light layer (about 1 inch depth) of silica gel is spread top of the flower. After that, container should be tightly covered using the lid and keep in dry place. It takes 4 to 10 days for drying. Flowers can be dried in various positions in the silica gel such as; face up, facedown and horizontally. Flat flowers like daisies and coneflowers can be dried in face down posture. Elongated, spike-type flowers should be kept horizontally. All other flower types can be dried face up. Silica gel can be reused by drying it in a shallow pan at 250°F for 1 hour (Rani and Reddy, 2015).

2.2.3 Hot air oven drying

Flowers are dried in hot air oven at 45°C - 65°C temperature. There is a fan inside the conventional chamber. In this method, atmospheric conditions does not influence for the drying process (Rathod *et al*., 2016). It takes few hours to 3 days depending on

the species. Compact flowers like marigolds, chrysanthemums, cornflowers and zinnias are dried well with the hot air oven drying.Flowers retained colour but flowers become shrivel and lose their shape. Roses have dried as the best with hot air oven technique. Roses can be dried with stalks and can be directly used in dry flower arrangements (Rani and Reddy, 2015).

2.2.4 Microwave drying

Usually, it takes 2-5 minutes for drying but it can be changed according to the size and moisture content of the flower. When doing Microwave drying, flowers should be kept in upright position and a small cup of water is kept in the microwave to prevent excessive drying (Rani and Reddy, 2015). Flowers can be embedded in sand and kept in the microwave (Rathod *et al*., 2016). However, plant materials should be kept at room temperature for 4-5 hours for setting after microwave drying. This method give more fresh and colorful output. Shrinkage is minimal (Rani and Reddy, 2015). After the drying process, flower petals should be sprayed with transparent lacquer to prevent absorption of air moisture (Jain *et al*., 2016).

2.2.5 Water Drying

Water drying is done by removing most of the leaves, and place the flower stems in 2 inches depth water. It should be kept in a warm place avoiding direct sunlight. Flower become dry because absorbed water is removed by evaporation. In this method, do not retaine colour and shape and shrinkage of flowers can be seen (Rani and Reddy, 2015).

2.2.6 Pressing

Flowers or leaves are placed between paper layers and apply weight on it. It takes minimum 5 to 10 days to dry planting materials. Newspapers, blotter papers and tissue papers are commonly used. Most flowers will be darkened and browned in nature (Rani and Reddy, 2015). To prevent fungal attack should be turned the side of flower as well as papers alternatively (Jain *et al*., 2016). The drying period can be reduced by keeping sheets in the oven (Kumar *et al*., 2021).

2.2.7 Glycerin drying

In this method, flower is preserved and do not dried. It can be maintained the leaf texture and colour. Moisture of flower is replaced with glycerin and water (Kumar *et al*., 2021). One part of glycerin is mixed with two parts of warm water. Strip off the lower leaves from the stem and keep in glycerin mixture at 5 cm depth. It takes 6-7 days for drying depending on climate conditions. Eucalyptus, maple leaves, hydrangea, gypsophilla, anthurium and corn flowers can be dried well (Jain *et al*., 2016). Dried materials have their natural shape and flexibility. This method is best for preserving small leafy branches, stem and leaves and their color is turn into brown (Kumar *et al*., 2021).

2.2.8 Freeze drying

Freeze drying is also known as lyophilization because the flowers are dried by using lyophilizers. In this process temperature of flower is lowered and then moisture is removed by using vacuum. The flowers are arranged in lyophilizer and temperature is maintained up to -7°C so that all the moisture is converted to ice. Frozen ice crystals are then sublimed with the application of heat using a vacuum oven. The product obtained by this method is excellent. Shape, size and colour are retained as like the fresh ones. This process takes long time for drying up to 4 weeks. Freeze dried flowers appear similar to the natural fresh flower and excellent quality. The main disadvantage of this method is its high costs and precise processing techniques are need. This method has been successfully employed in flowers like carnations, snapdragons, rose, etc. (Jain *et al*., 2016).

RESULT AND DISCUSSION

Stage of harvesting plant materials

Harvesting planting materials at the correct stage is important because quality of dry product is influenced by the harvesting stage. Usually, the best time to harvest is fully open stage of flowers or beginning of the maturity stage. Fresh materials should be harvested. If delay harvesting for 2-3 days petals become fold and shattering can be occurred. Dilta *et al*., 2011, harvested flowers at half bloom stage and got minimum time for drying. When harvesting time is delay, dehydration become faster because moisture is reduced with the beginning senescence. Full bloom stage is ideal for French marigold and zinnia (Kumar *et al*., 2021). Kumar *et al*., 2022, stated that, harvesting at early morning or late evening is suitable for drying flowers.

Pre drying treatment

Before drying of flowers some preservatives can be added to ensure color, texture and size. Citric acid is commonly used as a pre drying treatment of flowers. Its acidity can be reduced the pH of the cell fluid and preventing xylem vessel obstructions. Therefore, it helps to maintain color, texture and size of drying flower product (Kumar *et al*., 2022).

Comparative analysis of different drying techniques

Flowers such as chrysanthemums, marigolds, roses are best suited for hot air drying and microwave drying. Microwave drying with silica gel ensures the color and shape of flowers. Flowers were embedded in silica gel and dried in a hot air oven at 30 °C for 24 h and then micro-waved for 35 s showed the highest carotene and the least size reduction in flower. (Bhalla *et al*., 2006).

Jhanji *et al*. (2018) dried three types of leaves such as *Asparagus cetaceus* (asparagus), *Nephrolepis exaltata* (ferns) and *Gravilea robusta* (silver oak) under different drying techniques. 20 percent glycerinization under a well-ventilated darkroom was the best method for drying these leaves and higher acceptability as compared to other drying methods.

According to Singh (2004), sand drying results a smooth texture in petals, while drying with borax results a higher roughness in petals. Sujatha *et al*. (2001) found in the brighter color of flowers can be preserved when employed borax crystals with sand in 1:1 ratio.

For some important flowers like dahlia, roses, carnations, etc. silica gel is an excellent drying technique (Prasad *et al*., 1997). Dhatt *et al*. (2007) revealed that the silica gel treated rose buds best in terms of color, size as well as the quality of products. Rani and Reddy., 2015 revealed that carnations took 12 days to air-dry, while borax mixtures take 7–8 days, although dried in 4 days in silica gel, and microwave ovens take only 4 min. (Table 1).

Karunananda and Peiris, 2007 studied effective drying method for *Plumeria rubra* L. (Rathu Araliya). Fully open flowers have been harvested in sunny days for the experiment. Silica gel, borax, corn meal, river sand and sea sand were used as treatments while air drying method was used as the control. The results revealed that flowers were dried within 8 days for all the treatments. Silica gel and river sand are suitable for drying *Plumeria rubra*. Color retention of flowers has constant throughout the drying period and quick drying has occurred within 4 days. Sea sand and borax with corn meal also has shown good performance but color retention of this method has gradually decreased. In the control, (air drying) flowers has become shrunken and color retention is less. The experiment proves that remaining color of flowers depend on the drying time. Color retention is high when they are dry quickly.

Table 1: Drying time of some flowers with different dehydration techniques

Flower	Method							
	Air drying	Borax drying	Silica gel drying	Microwave drying	Press drying	Water drying	Hot air oven	Microwave oven drying
Carnation	10-12days	7-8 days	4 days	4 days	12-14 days	12-14 days	<1day	4 mts
Chrysanthemum	10 days	10 days	6 days	2 days	8-10 days	12-14 days	2 days	2 mts
Gerbera	8-10 days	10 days	4 days	4 days	8-10 days	8 days	<1day	4 mts
Marigold	12 days	10 days	5 days	8-10 days	10-12 days	8 days	2 days	8-10mts
Daisy	10 days	5-7 days	5 days	2 days	6 days	8 days	<1day	2 mts
Gladioli	6-8 days	5-7 days	4 days	2 days	10-12 days	12-14 days	<1day	2 mts
Orchid	8-10 days	7-8 days	4 days	2 days	6 days	12-14 days	<1day	2 mts
Rose	10 days	7-8 days	4 days	2 days	8-10 days	12-14 days	2 days	2 mts

(Rani and Reddy., 2015)

Kumari and Peiris, 2000 carried out an experiment for two flower varieties of rose (Rosa spp.) and statice (*Limonium sinuatum*). Results showed that, colour retention is highest in air drying for statice flowers. Colour has retained throughout the 5 week period. Colour retention of rose petals was high in silica gel method. There was no shrinkage and cracking of rose petals. Conical shape of the rose flower also retain in silica gel method. In glycerin drying, the colour of petals did not retain. The reason for that is, glycerin absorption process has long distant. First it should be absorbed into the xylem and then diffuce into cells. Glycerin has high viscosity. Therefore, uneven distribution of glycerin can be occurred. So, natural air drying process starts due to evaporation of water from the flowers. Grayston, 1988, sated that glycerin drying may not be suitable for flowers with large number of petals and arranged into a cone. When submerge in glycerin, physical damages can be happened to flowers. So shape and quality can be reduced drastically.

Foliage that are preserved with glycerin become soft and can be used for natural arrangements but it cannot preserve their green color (Rani and Reddy, 2015). Glycerin drying is used for foliage species which loose moisture and luster very rapidly. Fresh and fairly matured foliage is ideal for glycerine drying (Jain *et al*., 2016).

Karunananda and Peiris, 2007 stated that, chrysanthemum, statice and roses which are subjected to dessicant drying can be stored for more than 6 months in sealed containers.

Fresh Orchids are famous in floriculture industry and it has high economic value. Drying orchids is a challenging because they are considered as difficult to be preserved. However, use of silica gel for microwave drying or by freeze drying is recommended. Bright flowers of orchid genera like Dendrobium, Cymbidium, Paphiopedilum Cattleya, Pholidota etc. can be used for drying (De and Singh, 2016).

Drying flowers with high temperature reduce the time for dehydration process but it degrade pigments such as; chlorophylls, carotenes, xanthophylls and anthocyanins (Jain *et al*., 2016).

Carotenoids and some flavonoids such as aurones and 6-deoxychalcones give yellow and orange color (Karunananda and Peiris, 2007). Anthocyanin are the main source which are responsible for flower color and it produce red, yellow, and brown colors. Anthocyanin are natural pigments, water soluble and related to flavonoid group. Cyaniding derivatives are the most common anthocyanins found

in most of flowers. However, delphinidin-3-O-sambubioside can be found in hibiscus, peonidin 3-O-sophoroside, peonidin 3,5- di-O-glucoside; and peonidin 3-O-glucoside can be found in rose petals. Malvidin-3-O-glucoside and delphinidin-3- O-glucoside in *Nelumbo nucifera*. The anthocyanin stability was influenced during the drying process because it cause structural damages in cells. When extract anthocyanin from cells, Polyphenol oxidase and peroxidase enzymes accelerate the degradation. Polyphenol oxidase catalyzes the conversion of phenolic to quinones. As a result of this chemical conversion, browning occur in fresh plant materials. Polyphenol oxidase is relatively thermally stable enzyme. However, if they subjected to over 50°C for longer period, it becomes denature (Barani *et al*., 2021). Vaknin *et al*. (2005) revealed that pigments degradation and dilution occurred with the expansion of flower petals. Luo *et al*. (2017) also studied the anthocyanins degradation in the petals of *Rosa chinensis* and *Brunfelsia calycina* species. The petals of *B. calycina* are collected in stages 1 to 4, representing the bud, partial opening, fully open, and beginning to senescense. Based on the results, the anthocyanin content has decreased with the age. However, anthocyanin concentration has increased at the first stage and decreased slightly at fourth stage.

Dry weight, texture, brittleness and appearance of the dried flowers were influenced significantly by different drying treatments and it depends on the moisture content of foliage after dehydration. In dehydration process, colour of plant materials become fade due to oxidative reactions that occur when the compartmentation within plant cells. The texture is increased up to certain period of drying and then it decrease and surface texture become rough. Drying over for longer period result maximum brittleness in dried flower (Ragupathi *et al*., 2020).When slow drying, senescence of cells is occurred with the time. Pigment oxidation and hydroxylation enzymes are activated and pigment become denaturing. So, color retention of flowers reduced with the drying period (Karunananda and Peiris, 2007).

Economically and commercially viable methods are embedding in sand, silica gel and Borax. The flowers dried in these techniques can be used for making floral arrangements, greeting cards, book marks wall hangings, table mats, Photo frames, paper weights, magnets and other creative arts (Rani and Reddy, 2015).

Processing of dry flowers

Blanching

Blanching is a heat treatment which is done before processing such as freezing and drying. Blanching can deactivate quality deteriorate enzymes such as polyphenol oxidase and peroxidase, removing pesticide and toxic materials, minimizing non-enzymatic browning reactions and finally, enhancing quality of the product and drying rate (Raghupathi *et al*., 2020).

Skeletonizing

Skeletonizing is the process of removal of mesophyll layers of leaves. Leaves are embedded in 40 percent NaOH for 2 days give maximum vein visible. These skeleton leaves can be used dry flower arrangements because it gives an attracting glossy look (Kumar *et al*., 2024).

Coloring of flowers

This can be used for improve quality of dried flowers because pigments can lose, light or dull when drying process. So, artificial coloring of flowers using food dyes such as bromocresol blue, eosin yellow, ammonium purpurate, and bromocresol green (Kumar *et al*., 2024).

Handling of dry flowers

Dry flowers and foliage should be protect from direct sunlight and moisture. They should be handled carefully because of their brittle nature. Plant materials should be completely dry before storing them. If remaining moisture content of plant materials more than 11.50 percent, it can be deteriorate. Pressed flower should be kept using blotting sheets under slight pressure. Plant materials that have been air dried or dried with borax should be wrapped using newspapers and store in large cardboard boxes to prevent damages from insects, dust and light. Flowers that have been dried using silica gel should be stored in air-tight containers to prevent moisture absorbance. However, air-tight containers with small amount of silica gel are recommended for storing dry flowers (Jain *et al*., 2016). Moisture content of dried flowers within the rage of 8-11.5 per cent will ensure good quality and firmness and can be kept for more than six months with the good quality (Dilta *et al*., 2011).

In case where water content falls below 10 per cent in the flowers and foliage tend to become brittle. At high humidity, all humectants absorb high level of water from the atmosphere, and so proportionally less humectant are required to keep foliage flexible. Humectants can be absorbed into plant tissue either by transpiration or by immersing the cut foliage in a humectants solution (Jain *et al*., 2016).

Dry Flowers Products

This floral craft can become an industry both for domestic and International Markets. Development of awareness among the youth and Rural women about dehydration of flowers and preparation of value added dried flowers is essential.

Dried flower arrangements

Making of dried floral arrangements are more flexible than handling of fresh flowers. Normally, it should be included 'main flowers,' 'liners,' 'exotics' and 'fillers'. Main flowers should be large with various shapes and colors. Statice, strawfower, and roses are commonly used as main flowers. Dried grasses, twigs and branches are used as liners and length of stems vary from 15 to 40 cm look (Kumar *et al*., 2024).

Pot pourri

Potpourri is a mixture of bowl that consist with dried, petals, leaves, stems and roots. Plant materials that are used for making pot pourri able to absorb aromatic oils and release them slowly. They are commonly used as room fresheners and also repel moths. Rose petals, marigold petals, lotus, rosemary, basil, lavender, mint are commonly used for pot pourri (Jain *et al*., 2016).

Candle making

Dry flowers can be used for candle making. It gives beauty for plain candles. Dried flowers can be placed outside of the plain candle and then pour small amount of melted wax over the flowers (Jain *et al*., 2016).

CONCLUSION

Sri Lanka is a rich source for natural flowers and foliage. But significant amount of these flowers and foliage are wasted due to its perishability, extreme weather conditions, poor handling in harvesting, transporting etc. Use of better preservation techniques is a good solution to extend longevity and prevent the wastage. In addition, can be developed value-added products such as; bouquet decorations, making floral handicrafts, greetings and wedding cards, wall hangings, calendars, colorful candles, picture frames etc. These techniques are simple and can be handled by unskilled persons, and also promotion of self-employment and helps to increase income of rural communities.

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Investigate The Potential of Using *Lepironia Articulata* (ETA Pan) as an Ornamental Indoor Pot Plant for the Table Arrangements

Amarakoon A.M.M.R.R.[1], Nanayakkara A.N.[2], Gunasekera H.K.L.K.[1] and Gomes R.W.S.[2]

[1] *Department of Agricultural and Plantation Engineering, The Open University of Sri Lanka*
[2] *Department of National Botanic Gardens, Peradeniya ,Sri Lanka*

ABSTRACT

Lepironia articulata (Eta Pan) emerges a standout choice as an ornamental plant due to its distinctive charm and elegance. This study was conducted to explore the potential of cultivating *L. articulata* as an indoor pot plant, ideal for adding a touch of sophistication to table arrangements. This experiment was conducted as a pot experiment using 4 different media treatments; T1 [Water + Water soluble basal dressings (Control)], T2 [Soil mixture Water + Water soluble basal dressings], T3 [GA3 + soil mixture + Water + Water soluble basal dressings], T4 [GA3 + Water + Water soluble basal dressings] and 3 different shade treatment; V1 [Providing 40 % shade], V2 [Providing 60 % shade], V3 [Providing 80 % shade]. Completely Randomized Design (CRD) was applied for this two-factor factorial experiment, with 12 treatments combinations for 20 replicates. Methodology involved subjecting *L. articulata* to different growth media and shade levels in controlled experimental conditions to evaluate the most suitable growth media and shade level, effectiveness of using liquid media and assessing aesthetic appeal of the *L. articulata*. Results highlight significant variations in plant height (cm), leaf length (cm), number of shoots / leaf density, flower production, lifespan, and survival percentage across different treatment combinations. Treatment combination T3V2, comprising GA3, a specific soil mixture, water, and water-soluble basal dressing under a 60% shade level, emerged as particularly effective in promoting plant resilience, longevity, and aesthetic appeal by showing positive and higher effectiveness on all the collected data. Management practices including regular application of basal dressings and GA3, along with proper algaecide use, adequate plant support, and pot cleanliness, are essential for successful cultivation of *L. articulata* indoors.

Keywords: Indoor pot plants, *Lepironia articulata*, Ornamental plants, Plant aesthetics, Table arrangements

INTRODUCTION

Lepironia articulata, commonly known as "grey sedge" or "Eta Pan" in Sinhala, is a unique aquatic sedge plant native to Sri Lanka and distributed across parts of Asia, the Pacific, and Africa. Known for its ornamental and ecological value, *L. articulata* thrives in wetland environments, displaying a distinctive, leafless structure with hollow, cylindrical stems. It has been widely utilized as a durable weaving material, making straw and increasingly valued for phytoremediation due to its heavy metal absorption capabilities (Dassanayake, 1980; Cowie *et al*., 2000; Mahendra & Rezky, 2023; Brotonegoro, 2003).

In recent years, *L. articulata* has attracted attention as an ornamental species suitable for wetland restoration, urban runoff management, and interior decoration. Despite its natural preference for outdoor aquatic environments, emerging studies suggest that *L. articulata* can adapt to indoor cultivation as an ornamental pot plant, particularly for table arrangements in settings such as homes, offices, and hotels. However, specific growth conditions, including light levels, soil media,

*raveenaamarakoon95@gmail.com

and maintenance requirements, remain understudied. Given the global growth of the floriculture industry and the rising demand for native, sustainable plants, this research seeks to investigate the feasibility of cultivating *L. articulata* as an indoor ornamental plant (Gruda, 2009; Johnson *et al*., 2019). The study will examine optimal growth media, shade tolerance, aesthetic appeal, and adaptability to table potting, contributing valuable insights to enhance its indoor ornamental potential. Through this research, *L. articulata* could offer a fresh addition to the indoor plant market, aligning with trends in biophilic design and sustainable landscaping.

MATERIALS AND METHODS

This experiment was conducted as a pot experiment using 4 different media treatments; T1 [Water + Water soluble basal dressings (Control)], T2 [Soil mixture + Water + Water soluble basal dressings], T3 [GA3 + soil mixture + Water + Water soluble basal dressings], T4 [GA3 + Water + Water soluble basal dressings] and 3 different shade level; V1 [Providing 40 % shade], V2 [Providing 60 % shade], V3 [Providing 80 % shade] at Henarathgoda Botanical Garden – Gampaha. A mixture of soil, sand and organic matter in 1:1:1 ratio was used as soil mixture. Mugasol N plus (30:10:10) & Mugasol P-52 (10:52:10) fertilizers were used as water soluble basal dressings to provide nutrients for *L. articulata* in this experiment. Methodology involved subjecting *L. articulata* to different growth media and shade levels in controlled experimental conditions to evaluate the most suitable growth media and shade level, effectiveness of using liquid media and assessing aesthetic appeal of the *L. articulata*. Completely Randomized Design (CRD) was applied for this two-factor factorial experiment, with 12 treatments combinations for 20 replicates.

RESULT AND DISCUSSION

The ANOVA results have demonstrated a statistically significant ($p < 0.05$) interaction effect between growth media and shade levels on all the data collected.

Effect of different growth media and shade levels on the height of the *L. articulata*

The tallest *L. articulata* plants were observed in treatment T3V2 (a bottle with GA3, soil mixture, water, and water-soluble basal dressings under 60% shade), statistically comparable to T2V2, T2V3, T3V3, and T4V3, while the shortest plants were seen in T4V2 (GA3, water and basal dressings under 60% shade).

Table 1. Effect of different media treatment and shade levels on height of *L. articulata*

Treatment combination	Height of the plant (cm)
T1V1	11.595^{b}
T1V2	13.380^{b}
T1V3	13.975^{b}
T2V1	16.320^{b}
T2V2	17.815^{ab}
T2V3	19.090^{ab}
T3V1	11.110^{b}
T3V2	27.180^{a}
T3V3	20.100^{ab}
T4V1	11.110^{b}
T4V2	11.035^{b}
T4V3	17.900^{ab}

Note: Means with same letters along the column are not significantly different at p=0.05. Measurements are the means of 20 replicates.

This suggests that GA3 with soil mixture and moderate shade enhances height, aligning with previous studies showing that growth regulators and appropriate light levels improve plant growth (Kim & Lee, 2011; Benny *et al*., 2017). Liquid media treatments were less effective, likely due to issues such as nutrient imbalances, supporting findings by Stevens

et al. (2012) and Smith & Johnson (2014), who demonstrated that soil-based media often support better growth. Treatments under 60-80% shade levels promoted optimal growth, consistent with studies indicating that moderate shading benefits plant vigor (Wagh *et al*., 2021; Jackson *et al*., 2015). This study underscores the importance of balancing growth media and shade, with T3V2 emerging as the most effective treatment for cultivating *L. articulata* as an indoor pot plant.

Effect of different growth media and shade levels on leaf length of *L. articulata*

The longest leaf lengths in *L. articulata* were observed in T3V2 and were similar to T3V3. The shortest leaf length was observed in T3V1 which was at 40% shade level.

Table 2. Effect of different growth media and shade levels on leaf length of *L. articulata*

Treatment combination	Average leaf length (cm)
T1V1	2.585^{d}
T1V2	8.025^{bcd}
T1V3	5.640^{bcd}
T2V1	6.115^{d}
T2V2	9.968^{bcd}
T2V3	11.545^{bc}
T3V1	02.185^{d}
T3V2	21.670^{a}
T3V3	13.010^{ac}
T4V1	02.460^{bcd}
T4V2	03.533^{bd}
T4V3	08.873^{bcd}

Note: Means with same letters along the column are not significantly different at p=0.05. Measurements are the means of 20 replicates.

This suggests moderate shade and soil mixtures significantly enhanced leaf length, supporting findings by Thompson *et al*. (2016) on the interaction of growth media and light conditions. Soil-based mixtures with growth enhancers like GA3 promote longer leaves, consistent with prior research by Smith *et al*. (2018) and Lee *et al*. (2017), who found that organic soil mixtures improve growth over water-based solutions. Studies by Jones and Green (2017) and Roberts and Thompson (2016) further highlight the importance of optimal light and media for plant morphology, aligning with this study's results that moderate shade (60%) yields longer leave, while lower shade limits growth.

Effect of different growth media and shade levels on number of shoots (Leaf density) of *L. articulata*

The highest number of shoots in was observed in treatment T3V2.

Table 3. Effect of different media treatment and shade levels on number of shoots of *L. articulata*

Treatment combination	Number of shoots
T1V1	1.90^{b}
T1V2	1.65^{b}
T1V3	1.40^{b}
T2V1	2.35^{b}
T2V2	2.25^{b}
T2V3	2.80^{b}
T3V1	2.40^{b}
T3V2	7.25^{a}
T3V3	2.05^{b}
T4V1	1.95^{b}
T4V2	1.25^{b}
T4V3	1.40^{b}

T3V2 (GA3, soil mixture, water, and water-soluble basal dressings under 60% shade), which was statistically distinct from other treatments. In contrast, the fewest shoots were seen in T4V2 (same shade, but without soil), underscoring the importance of soil for shoot proliferation. This aligns with Smith *et al*. (2017) as well as Johnson and Brown (2018), who found that soil combined with moderate shade optimizes shoot density in ornamental plants. Moderate shade (60%) enhances shoot density, as also reported by Ali and Naeem (2015), who found that intermediate

shade reduces stress and fosters growth in similar species. Additionally, studies by Lee *et al*. (2020) highlight the role of shade and growth media interactions in shoot formation, supporting this study's finding that soil-based growth media combined with GA3 the most robust shoot growth in *L. articulata*.

Effect of different growth media and shade levels on number of flowers of *L. articulata*

The T3V2 treatment (GA3, soil mixture, water, and water-soluble basal dressing under 60% shade) yielded the highest number of flowers, significantly outperforming other treatments. In contrast, the lowest flower counts were observed in T1V3 and T4V2.

Table 4. Effect of different media treatment and shade levels on number of flowers of *L. articulata*

Treatment combination	Number of flowers
T1V1	0.50^{c}
T1V2	0.50^{c}
T1V3	0.35^{c}
T2V1	0.45^{c}
T2V2	4.00^{b}
T2V3	5.25^{b}
T3V1	0.45^{c}
T3V2	14.40^{a}
T3V3	3.65^{b}
T4V1	0.45^{c}
T4V2	0.35^{c}
T4V3	0.55^{c}

Note: Means with same letters along the column are not significantly different at p=0.05. Measurements are the means of 20 replicates

In contrast, lowest flower counts were observed in T1V3 and T4V2, which lacked soil and had high shade levels, consistent with findings by Lee *et al*. (2017) that high shading limits photosynthesis and flowering. Research by Smith *et al*. (2018) and Patel *et al*. (2018) similarly supports the role of growth regulators combined with soil in enhancing flower production, with moderate shading (60%) proving optimal, as noted by Sullivan *et al*. (2016). This study also found that soil-based media outperform liquid media, aligning with Nguyen and Tran (2019), who reported that soil provides essential support and nutrients that liquid media cannot.

Effect of different growth media and shade levels on Life span of *L. articulata*

T3V2 (GA3, soil mixture, water, and water-soluble basal dressing under 60% shade) demonstrated the longest lifespan, significantly outperforming other treatments. In contrast, T1V1 (water and basal dressing under 40% shade) exhibited the shortest lifespan, aligning with research by Barko *et al*. (1986) and Smith *et al*. (2018), who emphasize the role of nutrient-rich substrates and optimal shading in extending plant longevity. Studies by Garcia *et al*. (2019) and Brown *et al*. (2020) support these findings, noting that soil-based media and balanced shading enhance plant health and lifespan. Results also confirm the importance of moderate shading for plant longevity, as documented by Cronin and Lodge (2003).

Table 5. Effect of different media treatment and shade levels on Life span of *L. articulata*

Treatment combination	Life span (Days)
T1V1	18.20^{c}
T1V2	24.80^{c}
T1V3	20.30^{c}
T2V1	34.85^{bc}
T2V2	46.90^{bc}
T2V3	41.75^{bc}
T3V1	19.25^{c}
T3V2	126.00^{a}
T3V3	60.45^{b}
T4V1	22.30^{c}
T4V2	21.60^{c}
T4V3	36.65^{bc}

Note: Means with same letters along the column are not significantly different at p=0.05. Measurements are the means of 20 replicates.

Effect of different media treatment and shade levels on survival percentage of *L. articulata*

Results indicated a clear trend in survival percentages across different treatments and shade levels. T3V2 (soil mixture, water, and water-soluble basal dressing under 60% shade) achieved the highest survival rate of 40%, suggesting optimal conditions for plant resilience.

The survival percentage of plants in each treatment combination is graphically illustrated as mentioned below.

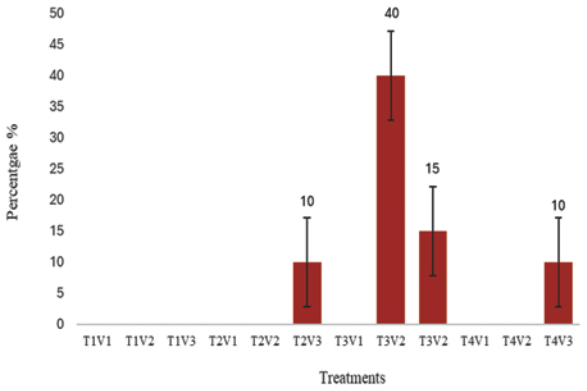

Figure 1: Survival percentage of *L. articulata* at different treatment combinations.

In contrast, liquid media treatments (T1 and T4) showed 0% survival, highlighting the importance of soil-based media for plant survival (Garcia *et al*., 2019; Smith *et al*., 2021). Treatment T3V3, with 10% survival under 80% shade, demonstrated some adaptability, echoing findings by Lee *et al*. (2022). Moderate shading (60% to 80%) may reduce stress and enhance plant growth, as noted by Lynch and Poorter (2017). The ineffectiveness of liquid media aligns with Wetzel (2001) and Chen and Wang (2018), who emphasized the need for solid substrates to support root development. These results reinforce the importance of tailored nutrients and shade management for plant survival.

CONCLUSION

This study provided valuable insights into cultivating *Lepironia articulata* as an indoor pot plant for table arrangements. The most effective treatment combination was T3V2, which consisted of GA3, a specific soil mixture, water, and water-soluble basal dressing under 60% shade. This combination promoted plant resilience, aesthetic appeal, and longevity, making it ideal for use in indoor table arrangements. The 60% shade level was found to be the optimal condition, closely mimicking indoor environments and enhancing plant health. In contrast, liquid media treatments (T1 and T4) consistently showed poor performance in supporting growth and survival, underscoring

the importance of nutrient-rich soil mixtures and proper shading. Under the experimental conditions, the maximum lifespan of *L. articulata* was 126 days, further supporting its viability as a fresh indoor plant for table arrangements.

RECOMMENDATION

Management practices employed in this study were key to promoting the growth of *L. articulata* as an indoor plant for table arrangements. To ensure plant health and vitality, regular applications of basal dressings and GA3 were essential.

However, challenges such as algae growth and issues with plant support and pot cleanliness were encountered. To address these, it is recommended to conduct regular maintenance, including changing the liquid media monthly and following a weekly schedule for basal dressings and GA3 application. An appropriate algaecide should be used to control algae growth. Proper plant support is crucial to prevent damage, and pots

should be thoroughly cleaned and sterilized before planting to avoid contamination as well as promote optimal growth.

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