Full Text | Scholarly Journal

In Vitro Propagation of *Philodendron erubescens* 'Pink Princess' and Ex Vitro Acclimatization of the Plantlets

Klanrit, Preekamol; Kitwetcharoen, Haruthairat; Thanonkeo, Pornthap; Thanonkeo, Sudarat. **Horticulturae; Basel** Vol. 9, Iss. 6, (2023): 688.
DOI:10.3390/horticulturae9060688

Full Text

Translate

1. Introduction

Philodendron is the second largest and most diverse genus of the Araceae family, consisting of more than 500 species [1]. *Philodendron* species are native to tropical and subtropical regions of the Americas and West Indies [2], and they are widely diverse in morphological characteristics, such as leaf size (i.e., from small to large), leaf shape (i.e., from heart-shaped to palm-like), and leaf color (i.e., from green to red and burgundy). Furthermore, these plants' growth habits vary from climbing to arborescent or tree-like structures, making them ideal for ornamental desk plants, hanging baskets, totems, and potted plants [1,3,4,5]. Due to their attractive foliage and the ability to survive interior environments, *Philodendron* species are the most popular in the foliage plant market, especially in Thailand.

Philodendron erubescens, also known as *Philodendron* pink princess, is a hybrid species among the most popular ornamental variegated foliage plants because it is rare and expensive [6]. Additionally, the multicolored heart-shaped leaves of this plant, dark purplish-green with contrasting pink variegation, make it more attractive to the grower. The conventional propagation of *Philodendron* pink princess is mainly via stem cutting and seed. However, because of its slow growth, short internodes, and large stems and because the plant seeds are also rather short-lived, these propagation procedures are not chosen for this plant. In addition, plants developed from seed or typical stem cuttings also produce few lateral shoots. As a result of the limitations of the conventional propagation of this plant, in vitro propagation techniques for commercial production were introduced, as they facilitate the continuous generation of plants with a high degree of uniformity and quality in a short period [7]. In addition to eliminating systemic diseases caused by plant pathogens, such as viruses, fungi, and bacteria, in vitro propagation produces fuller and more compact plants than traditional methods [8].

Generally, in vitro propagation comprises four major steps: (1) the initiation stage, in which the explants are surface-sterilized and transferred to the culture medium; (2) the multiplication stage, in which the number of plant propagules is multiplied through repeated subcultures until the desired number is reached; (3) the rooting stage, in which the explants are subjected to root induction; and (4) the acclimatization stage, in which the in vitro plantlets are exposed to ex vitro environments [9]. The successful development of in vitro plantlets depends on numerous parameters, including the composition of the culture medium, the environmental conditions, and the plant species. Plant growth regulators (PGRs) are among the most critical factors influencing plant morphogenesis; specifically, auxin and cytokinin, the most widely used PGRs in micropropagation, play crucial roles in shoot and root proliferation [7,10]. The types and concentrations of PGRs used are mostly determined by the plant species, the types of plant organs and tissues used, and the purpose of cultivation [9]. In addition, the types of cultivation systems also have an impact on in vitro culture. Liquid culture systems are reported to be more cost-effective for in vitro propagation than solid or gel cultures [11].

Several plant species of the genus *Philodendron* have been propagated via in vitro cultures, such as *Philodendron oxycardium* [12], *Philodendron cannifolium* [13], *Philodendron selloum* [14,15], *Philodendron bipinnatifidum* [16], *Philodendron xanadu* [17], and *Philodendron* birkin [10], but less information is available for the in vitro propagation of *Philodendron erubescens* cv. pink princess. Only one study on the in vitro propagation of *Philodendron erubescens*

cv. red emerald has been reported since 1998 [6]. Therefore, this study aimed to establish an efficient in vitro propagation procedure for *Philodendron* pink princess using the protocorm-like body as the starting material or explant. The effects of auxins and cytokinins on in vitro shoot and root proliferation were determined in solid and liquid culture systems. In addition, the quality of the in vitro plantlets was also evaluated based on their ability to adapt to ex vitro environments.

2. Materials and Methods

2.1. Chemical and Plant Materials

Murashige and Skoog (MS) basal medium was purchased from PhytoTech Labs, Kansas, MO, USA. In addition, 6-benzylaminopurine (BAP), 1-naphthaleneacetic acid (NAA), indole-3-butyric acid (IBA), and 2,4-dichlorophenoxyacetic acid (2,4-D) were obtained from Sigma Aldrich Corporation, St. Louis, MO, USA. Perlite, vermiculite, and peat moss were purchased from Bee Garden and Farm Co., Ltd., Khon Kaen, Thailand.

The protocorm-like bodies of *Philodendron* pink princess were obtained from Mrs. Nuntipa Khumkarjorn, Udon Thani, Thailand. The plants were maintained on MS basal medium supplemented with 2.0 mg/L BAP and 0.5 mg/L NAA and cultivated in a standard culture room at 25 ± 2 °C with a light intensity of 2000 Lux and a photoperiod of 16 h. Before being used, they were subcultured on fresh solid MS basal medium supplemented with BAP and NAA and cultivated under the abovementioned conditions for 30 days.

2.2. Effect of PGRs on Shoot Proliferation

Protocorm-like bodies of *Philodendron* pink princess that measured approximately 0.5 cm were selected and placed on MS basal agar medium supplemented with combinations of BAP (0, 1.0, and 2.0 mg/L) and NAA (0, 0.5, and 1.0 mg/L). All of the explants were cultured in a standard culture room at 25 ± 2 °C with a light intensity of 2000 Lux and a photoperiod of 16 h. The numbers of shoots and leaves were recorded after 30 days of cultivation.

A comparative study on the effect of PGRs on shoot proliferation between solid and liquid culture systems was also evaluated. The selected protocorm-like bodies of *Philodendron* pink princess were cultured using solid and liquid MS basal media supplemented with 1.0 mg/L BAP and different concentrations of NAA (0, 0.5, and 1.0 mg/L). For the solid culture system, the explants were cultivated in a standard culture room at 25 ± 2 °C with a light intensity of 2000

Lux and a photoperiod of 16 h. For the liquid culture system, the explants were cultivated in a controlled incubator shaker at 110 rpm and 25 ± 2 °C with a light intensity of 2000 Lux and a photoperiod of 16 h. After 30 days of cultivation, the numbers of shoots and leaves were recorded.

Ten explants per treatment were used, and the experiments were conducted twice.

2.3. Effect of Auxins on Root Proliferation

The microshoots established from the best shoot proliferation treatment were selected and individually placed in a culture vessel containing 30 mL of MS basal medium supplemented with NAA, IBA, and 2,4-D at 0, 0.5, 1.0, 2.0, and 3.0 mg/L. The explants were cultivated in a standard culture room with a light intensity of 2000 Lux, a photoperiod of 16 h, and a temperature of 25 ± 2 °C. The number and length of the induced roots were recorded after 30 days of cultivation. The experiment was repeated twice, each with ten replicates.

2.4. Ex Vitro Acclimatization of the Plantlets

Well-developed plantlets from the in vitro culture with a height of 1.0–1.5 cm, 4–5 leaves, and at least three roots were selected for ex vitro acclimatization. The plantlets were carefully collected from the culture vessel, and their roots were rinsed with tap water to remove the adhering culture medium. The resulting plantlets were transplanted into 5.0 cm diameter plastic pots filled with perlite, vermiculite, and peat moss. The potted plants were placed directly in a growth chamber at 25 ± 2 °C with a 16 h light period at approximately 250 µmol/m.s light intensity and 45−55% relative humidity. The survival rate, plant height, number of leaves and roots, and root length were recorded after 45 days of cultivation. The experiments were performed twice, each with ten replicates.

2.5. Experimental Design and Statistical Analysis

A completely randomized design (CRD) was used throughout this study. Experimental data were collected and subjected to analysis of variance (ANOVA) using the SPSS program for Windows. The results were expressed as the mean ± standard deviation (SD), and the means of each treatment were compared using Duncan’s Multiple Range Test (DMRT) at the 95% level or a probability of $p \leq 0.05$.

3. Results and Discussion

3.1. Effect of PGRs on Shoot Proliferation

Cytokinins are adenine-derived, small-molecule PGRs that play significant roles in plant cell division, cell elongation and enlargement, plant morphogenesis, nutrient allocation, and plant adaptations to various abiotic stresses [18,19,20]. Several cytokinins are available for plant micropropagation, and their biological functions in plant cells depend on several factors, such as plant species, plant age, and explant type [20]. Previous studies have demonstrated that BAP is more effective for shoot induction in several species of *Philodendron*, such as *Philodendron cannifolium* [13], *Philodendron tuxtlanum* [21], and *Philodendron* sp. [7], compared with other cytokinins. Furthermore, a recent study also reported that combining cytokinins and auxins stimulated the elongation of shoots and yielded a more significant shoot number, shoot length, and fresh weight of several crops, including *Philodendron bipinnatifidum*, than treatments with cytokinins alone [16,22]. Thus, the effect of cytokinin (BAP) and auxin (NAA) at different concentrations on the shoot proliferation of *Philodendron erubescens* pink princess was investigated in this study. Table 1 and Figure 1 show that treatment with BAP alone at 1.0 mg/L (Treatment 4) yielded the highest numbers of shoots and leaves, accounting for 7.7 shoots/explant and 4.1 leaves/explant, compared with other BAP concentrations. A high concentration of BAP (2.0 mg/L) tended to reduce the number of both shoots and leaves, consistent with the finding reported by Thao et al. [23], who observed a reduction in shoot multiplication and the formation of abnormal shoots of *Alocasia* sp. when cultured under a high concentration of cytokinin. Treatment with NAA alone (Treatments 1–3) resulted in fewer shoots and leaves than the BAP treatments, suggesting that BAP was more effective in inducing *Philodendron* pink princess shoot proliferation than NAA. Generally, NAA, a member of the auxin family, plays an essential role in plant cell growth, differentiation, and development, specifically the formation of roots [24,25]. Although auxins have been reported to stimulate shoot elongation [22], the application of NAA alone did not significantly improve the shoot formation of *Philodendron* pink princess compared to the control without the supplementation of PGRs (Treatment 1).

Considering the combinations of BAP and NAA, these treatments did not exert a synergistic effect on shoot proliferation compared with treatment using BAP at 1.0 mg/L alone. However, among the different combinations, BAP at 1.0 mg/L and NAA at 0.5 mg/L produced a greater number of shoots (7.0 shoots/explant) and leaves (3.8 leaves/explant) than the other treatment combinations. Notably, the combination of BAP at 2 mg/L and NAA at 1.0 mg/L (Treatment 9) yielded the lowest number of shoots (2.7 shoots/explant) and leaves (2.3

leaves/explant) compared to the control and other treatments. This observation could be attributed to a hormonal imbalance, which may alter the action of another hormone, leading to the suppression of shoot and leaf formation and growth [22,26].

Compared with other studies, the results in the current study differ from those reported for *Philodendron selloum* [14] and *Philodendron bipinnatifidum* [16]. For *Philodendron selloum*, the combination of 6-benzyladenine (BA) at 8 mg/L and NAA at 0.4 mg/L yielded the highest number of shoots (10.0 shoots/explant), longest shoot lengths (9.8 cm), and number of leaves (5.7 leaves/explant) after 12 weeks of cultivation compared with cytokinin treatment alone or other combinations of BA and NAA, while a combination of BAP at 1.0 mg/L and IBA at 0.5 mg/L produced the highest number of shoots of *Philodendron bipinnatifidum* (10.9 shoots/explant) after 6 weeks of cultivation. According to Chen et al. [8], BA at a concentration of 0.5 mg/L yielded the highest number of shoots of *Philodendron* imperial green (48.7 shoots/explant), imperial red (47.4 shoots/explant), and imperial rainbow (50.4 shoots/explant). These data suggest that different plant species respond differently to different types and concentrations of PGRs. Based on the current findings, BAP at 1.0 mg/L and combinations of BAP (1.0 mg/L) and NAA (0.5 and 1.0 mg/L) were selected to further examine their effect on shoot proliferation in a liquid culture system.

Table 2 and Figure 2 summarize the effects of PGRs on the shoot proliferation of *Philodendron* pink princess in liquid MS medium. The MS medium without PGRs produced a relatively low number of shoots and leaves, while the MS medium supplemented with 1.0 mg/L BAP yielded the highest number of shoots (11.2 shoots/explant) and leaves (4.7 leaves/explant). Furthermore, the combinations of BAP and NAA produced fewer shoots and leaves than the treatment with BAP alone. Notably, the combination of BAP at 1.0 mg/L and NAA at 1.0 mg/L produced the lowest numbers of shoots (4.9 shoots/explant) and leaves (3.1 leaves/explant) when cultured in liquid medium, and the established microshoots displayed abnormal and hyperhydricity symptoms, similar to the observation in *Alkanna tinctoria* cultured in medium supplemented with high concentrations of cytokinins and auxins [27]. Another study conducted by Ziv and Ariel [28] discovered that *Philodendron hastatum* burgundy leaves developed necrosis during the proliferation stage in agitated liquid culture.

When the shoot proliferation of *Philodendron* pink princess was compared between solid and liquid culture systems, the liquid culture system produced a greater number of shoots and leaves than solid culture, except when the liquid

culture used a combination of 1.0 mg/L BAP and 1.0 mg/L NAA (Table 1 and Table 2). This finding revealed that the liquid culture system was more effective for shoot multiplication than the solid culture system, possibly due to suitable aeration and the continuous contact of the explants with the culture medium, which allows for a continual supply and high absorption of nutrients [16]. The growth enhancement of explants using a liquid culture system has also been reported for several Araceae species, such as *A. amazonica* [29] and *Spathiphyllum cannifolium* [30].

3.2. Effect of Auxins on Root Proliferation

Auxins are among the most critical PGRs since they are involved in all physiological processes in plants. They promote shoot elongation and initiate the formation of adventitious and lateral roots [22]. Different plant species have diverse responses to different kinds and concentrations of auxins. This study investigated the effect of auxins, including NAA, IBA, and 2,4-D, on the root induction of *Philodendron* pink princess. The microshoots established from the explants cultured in liquid MS medium supplemented with 1.0 mg/L BAP were tested for their ability to induce roots. As shown in Table 3, no root formation was observed when the explants were cultured on solid MS medium without the supplementation of auxins (control treatment) and MS medium supplemented with 0.5 mg/L NAA. Among the different auxins tested, IBA was more effective for the root induction of *Philodendron* pink princess than the other auxins, consistent with the findings of Bartel et al. [31], Chen et al. [8], and Hassan et al. [14]. This observation might be correlated with the indole ring of the IBA molecule, which allows it to be efficiently absorbed by plant cells [32]. IBA has been applied for the in vitro rooting of many Araceae species, including *Dieffenbachia compacta* [33] and *Aglaonema* cochin [34]. In contrast, some species of Araceae also respond well to different forms of auxins. For instance, the in vitro rooting of *Philodendron bipinnatifidum* was significantly enhanced when the plant was treated with 1.0 to 2.0 mg/L NAA [16].

Notably, treatment with IBA at 3.0 mg/L resulted in the highest number of roots (3.2 roots/explant) and longest root lengths (1.9 cm) compared to the other treatments, which is consistent with the findings reported for *Aglaonema* cochin [34]. However, the current results contrast with previous findings in other *Philodendron* species. For instance, Chen et al. [8] demonstrated that IBA at 0.5 and 1.0 mg/L favored the root formation of *Philodendron* imperial green, imperial red, and imperial rainbow, and Hassan et al. [14] noted that 1.0 mg/L

IBA yielded the maximum root number (31.67 roots/explant) in *Philodendron selloum*. Notably, some species of *Philodendron* root easily in MS medium without supplementation with PGRs [7].

3.3. Ex Vitro Acclimatization of the Plantlets

In vitro plantlets require an ex vitro acclimatization process to ensure plant growth and survival when transferred to soil or field environments. Several supporting materials have been used as planting media for ex vitro acclimatization, and peat moss, vermiculite, and perlite are the most commonly used materials [8,14,16,35]. This study investigated the ex vitro acclimatization of micropropagated *Philodendron* pink princess using peat moss, vermiculite, and perlite as planting materials. As shown in Table 4 and Figure 3, the in vitro plantlets of *Philodendron* pink princess were successfully acclimatized with morphologies comparable to those of the mother plants. Peat moss and vermiculite yielded 100% survival, while a slight reduction in survival was observed when the in vitro plantlets were acclimatized in perlite (80% survival), similar to the findings reported by Alawaadh et al. [16]. The highest values of plant height (2.48 cm) and number of leaves (10.9 leaves/plantlet) were observed when the in vitro plantlets were grown in peat moss, followed by vermiculite and perlite. On the other hand, vermiculite and perlite yielded the highest number of roots and root length values, respectively. Although the acclimatized plantlets grown in peat moss had fewer roots and shorter root lengths than the other treatments, the roots that formed in this planting material were thicker than those that formed in vermiculite and perlite.

Considering the chemical and physical properties of the planting materials used in this study, peat moss contained higher concentrations of nutrients than vermiculite and perlite. Furthermore, peat moss and vermiculite also have a higher water-holding capacity than perlite [35,36,37]. Thus, the better growth of *Philodendron* pink princess plantlets in peat moss and vermiculite in terms of plant height and the number of leaves might be associated with these planting materials' nutrient and moisture supplies. Unlike peat moss, vermiculite and perlite are porous supporting materials, allowing oxygen diffusion to stimulate root proliferation and respiration. Therefore, the in vitro plantlets grown in vermiculite and perlite exhibited a higher number of roots and longer root lengths than those grown in peat moss. These results agree with the findings of Hoang et al. [35].

The current study demonstrated that peat moss, vermiculite, and perlite can be used as planting materials for the ex vitro acclimatization of *Philodendron* pink princess plantlets, with peat moss enhancing vegetative development and

vermiculite and perlite promoting root growth. However, based on a literature review, a mixture of peat moss and vermiculite or perlite has been shown to promote the vegetative and root growth of several crops [14,35]. Thus, the ex vitro acclimatization of *Philodendron* pink princess plantlets employing a variety of these planting materials at different ratios should be evaluated in the future.

4. Conclusions

As demonstrated in this study, BAP alone at a concentration of 1.0 mg/L promoted the shoot proliferation of *Philodendron* pink princess more than treatment using NAA and a combination of BAP and NAA, yielding the maximum numbers of shoots and leaves in both solid and liquid culture systems. Among the auxins tested, IBA at 3.0 mg/L was the best condition for the root induction of *Philodendron* pink princess, yielding a maximum number of roots (3.2 roots/explant) and root length (1.9 cm). The plantlets of *Philodendron* pink princess acclimatized with a relatively high survival frequency in all planting materials without morphological abnormalities. Peat moss promoted the vegetative growth of *Philodendron* pink princess plantlets more than the other growth media. Liquid MS medium supplemented with 1.0 mg/L BAP was the best culture medium for shoot proliferation, while solid MS medium supplemented with 3 mg/L IBA was the best culture medium for the root formation and proliferation of *Philodendron* pink princess. The established protocol can be used for large-scale production using protocorm-like bodies as explants. Additionally, peat moss alone could also be utilized as planting material for the ex vitro acclimatization of the plantlets.
Conceptualization, P.K., P.T. and S.T.; methodology, P.K., H.K. and S.T.; software, H.K. and P.T.; validation, P.K. and S.T.; formal analysis, P.K. and S.T.; investigation, P.K., H.K. and S.T.; resources, P.K. and S.T.; data curation, P.K. and S.T.; writing—original draft preparation, P.K., H.K. and S.T.; writing—review and editing, P.K., P.T. and S.T.; visualization, H.K. and P.T.; supervision, P.K. and S.T.; project administration, P.K. and S.T.; funding acquisition, P.K. and S.T. All authors have read and agreed to the published version of the manuscript.

Not applicable.

Not applicable.

Not applicable.

The authors thank Pornprom Klawikkam and Chotpipat Thongkote for their technical support.

The authors declare no conflict of interest.

Footnotes

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

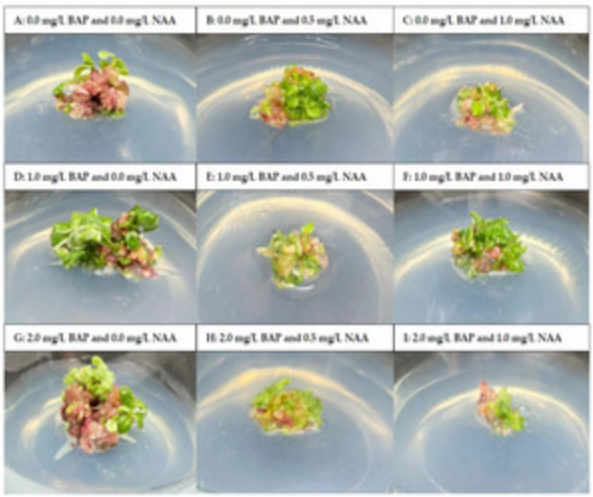

Figure 1. Shoot proliferation of Philodendron pink princess on MS media supplemented with different concentrations of BAP and NAA after 30 days of cultivation.

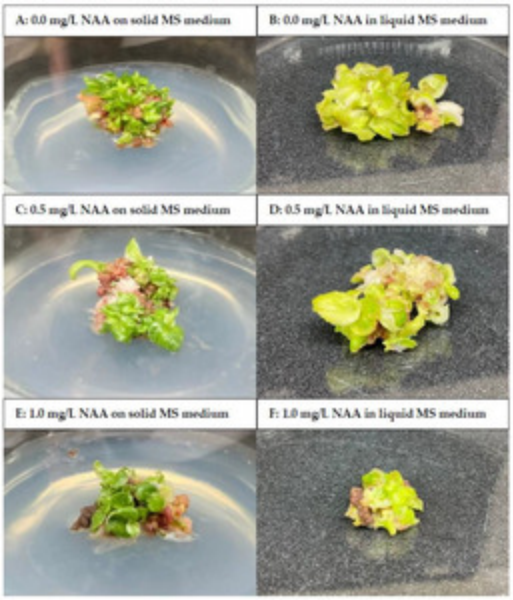

Figure 2. Shoot proliferation of Philodendron pink princess in solid and liquid MS medium supplemented with 1.0 mg/L BAP and different concentrations of NAA after 30 days of cultivation.

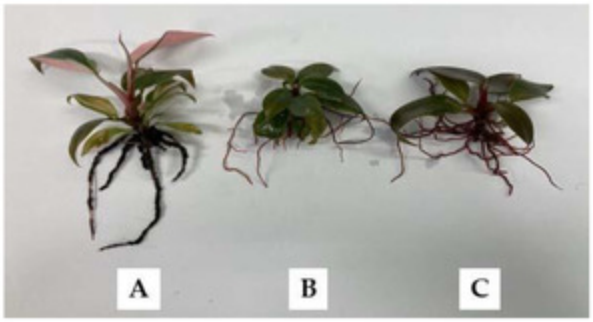

Figure 3. The plantlets of Philodendron pink princess after ex vitro acclimatization for 45 days using (A) peat moss, (B) vermiculite, and (C) perlite as planting material.

Table 1

Effects of BAP and NAA on the shoot proliferation of *Philodendron* pink princess.

Treatment	**PGRs**		**Number of Shoots(Shoots/Explant)**	**Number of Leaves(Leaves**
	BAP (mg/L)	**NAA (mg/L)**		
1	0.0	0.0	4.4 ± 1.2 ^{ab}	2.4 ± 0.5 ^{b}
2	0.0	0.5	5.5 ± 1.9 ^{ab}	2.6 ± 0.5 ^{b}
3	0.0	1.0	4.2 ± 0.9 ^{b}	2.4 ± 0.5 ^{b}
4	1.0	0.0	7.7 ± 1.1 ^{a}	4.1 ± 0.7 ^{a}
5	1.0	0.5	7.0 ± 1.8 ^{a}	3.8 ± 0.6 ^{a}
6	1.0	1.0	6.6 ± 1.5 ^{ab}	3.7 ± 0.7 ^{a}
7	2.0	0.0	6.3 ± 1.4 ^{ab}	3.5 ± 0.7 ^{a}
8	2.0	0.5	6.4 ± 1.8 ^{ab}	3.5 ± 0.7 ^{a}

Treatment	PGRs		Number of Shoots(Shoots/Explant)	Number of Leaves(Leaves
	BAP (mg/L)	NAA (mg/L)		
9	2.0	1.0	2.7 ± 1.1 [b]	2.3 ± 0.5 [b]

Means ± SDs followed by different letters within a column are significantly different at $p \leq 0.05$ based on DMRT analysis.

Table 2

Effect of BAP and NAA on the shoot proliferation of *Philodendron* pink princess cultured in liquid MS medium for 30 days.

BAP (mg/L)	NAA (mg/L)	Liquid MS Medium	
		Number of Shoots(Shoots/Explant)	Number of Leaves(Leaves/Explant)
0.0	0.0	5.0 ± 0.9 [c]	3.3 ± 0.8 [c]
1.0	0.0	11.2 ± 2.0 [a]	4.7 ± 0.5 [a]
	0.5	8.1 ± 2.4 [b]	4.0 ± 0.7 [b]
	1.0	4.9 ± 1.2 [c]	3.1 ± 0.7 [c]

Means ± SDs followed by different letters within a column are significantly different at $p \leq 0.05$ based on DMRT analysis.

Table 3

Effect of auxins on the root induction of *Philodendron* pink princess.

Treatment	Concentration (mg/L)	Number of Roots (Roots/Explant)	Root Length (cm)
Control	0.0	0.0 [e]	0.0 [c]
NAA	0.5	0.0 [e]	0.0 [c]

Abstract

Treatment Details	Concentration (mg/L)	Number of Roots (Roots/Explant)	Root Length (cm)
	1.0	1.5 ± 0.8 ^{cd}	0.8 ± 0.3 ^{bc}
	2.0	1.6 ± 0.9 ^{cd}	1.2 ± 0.4 ^{ab}
	3.0	1.4 ± 0.5 ^{cd}	0.7 ± 0.3 ^{bc}
IBA	0.5	1.4 ± 0.5 ^{cd}	1.6 ± 0.8 ^{ab}
	1.0	2.2 ± 1.2 ^{bc}	1.6 ± 0.9 ^{ab}
	2.0	2.6 ± 0.5 ^{ab}	1.7 ± 1.0 ^{ab}
	3.0	3.2 ± 0.8 ^{a}	1.9 ± 0.6 ^{a}
2,4-D	0.5	1.4 ± 0.5 ^{cd}	0.8 ± 0.3 ^{bc}
	1.0	1.0 ± 0.0 ^{d}	0.8 ± 0.2 ^{bc}
	2.0	1.0 ± 0.0 ^{d}	0.8 ± 0.3 ^{bc}
	3.0	0.8 ± 0.4 ^{de}	1.0 ± 0.3 ^{b}

Means ± SDs followed by different letters within a column are significantly different at $p \leq 0.05$ based on DMRT analysis.

Table 4

Effect of planting media on the survivability of *Philodendron* pink princess plantlets after 45 days during the acclimatization stage.

Planting Material	Survival (%)	Plant Height (cm)	Number of Leaves (Leaves/Plantlet)	Number of Roots (Roots/Plantlet)	Ro Le (cr
Peat moss	100	2.48 ± 0.4 ^{a}	10.9 ± 1.3 ^{a}	4.1 ± 1.6 ^{b}	5.5 1.0
Vermiculite	100	1.82 ± 0.3 ^{b}	7.1 ± 1.7 ^{b}	8.0 ± 1.5 ^{a}	6.7 0.3

Planting Material	Survival (%)	Plant Height (cm)	Number of Leaves (Leaves/Plantlet)	Number of Roots (Roots/Plantlet)	Ro Le (cr
Perlite	80	1.75 ± 0.4 [b]	6.5 ± 1.3 [b]	7.5 ± 1.2 [a]	7.2 0.6

Means ± SDs followed by different letters within a column are significantly different at $p \leq 0.05$ based on DMRT analysis.

References

1. Croat, T.B. A revision of *Philodendron* subgenus *Philodendron* (Araceae) for Mexico and Central America. *Ann. Mo. Bot. Gard.*; 1997; *84*, pp. 311-704. [DOI: https://dx.doi.org/10.2307/2992022]

2. Mayo, S.J.; Bogner, J.; Boyce, P.C. *The Genera of Araceae*; Royal Botanical Gardens, Kew, The European Union by Continental Printing: Brussels, Belgium, 1997.

3. Mayo, S.J. A revision of *Philodendron* subgenus *Meconostigma* (Araceae). *Kew Bull.*; 1991; *46*, pp. 601-681. [DOI: https://dx.doi.org/10.2307/4110410]

4. Grayum, M.H. Revision of *Philodendron* subgenus *Pteromischum* (Araceae) for Pacific and Caribbean Tropical America. *Syst. Bot. Monogr.*; 1996; *47*, pp. 1-233. [DOI: https://dx.doi.org/10.2307/25027858]

5. Chen, J.; McConnell, D.B.; Norman, D.J.; Henny, R.J. The Foliage Plant Industry. *Horticultural Reviews*; Janick, J. John Wiley and Sons, Inc.: Hoboken, NJ, USA, 2005; pp. 45-110.

6. Fahmy, G.E.; Arafa, A.M.S.; Ibrahim, I.A.; Zaynab, E.Z. In vitro propagation of *Philodendron erubescens* cv. Red Emerald. *Ann. Agric. Sci. Moshtohor.*; 1998; *36*, pp. 1653-1666.

7. Sreekumar, S.; Mukunthakumar, S.; Seeni, S. Morphogenetic response of six *Philodendron* cultivars in vitro. *Indian J. Exp. Biol.*; 2001; *39*, pp. 1280-1287. [PubMed: https://www.ncbi.nlm.nih.gov/pubmed/12018525]

8. Chen, F.C.; Wang, C.Y.; Fang, J.Y. Micropropagation of self-heading *Philodendron* via direct shoot regeneration. *Sci. Hortic-Amsterdam.*; 2012; *141*, pp. 23-29. [DOI: https://dx.doi.org/10.1016/j.scienta.2012.04.011]

9. Hussain, A.; Ahmed, I.; Nazir, H.; Ullah, I. Plant Tissue Culture: Current Status and Opportunities. *Recent Advances in Plant In Vitro Culture*; Leva, A.; Rinaldi, L.M.R. IntechOpen: Rijeka, Croatia, 2012; pp. 1-28.

10. Mongkolsawat, W.; Punjansing, T.; Loma-in, P. Effects of BA, TDZ, and NAA on growth of *Philodendron* 'Birkin' in vitro. *PSRU J. Sci. Technol.*; 2023; *8*, pp. 27-36. (In Thai)

11. Paek, K.Y.; Chakrabarty, D.; Hahn, E.J. Application of Bioreactor System for Large Scale Production of Horticultural and Medicinal Plants. *Liquid Culture Systems for In Vitro Plant Propagation*; Hvoslef-Eide, A.K.; Preil, W. Springer: New York, NY, USA, 2005.

12. Koriesh, E.M.; Al-Manie, F.A. Growth and root formation of *Philodendron oxycardium* grown in vitro as affected by benzyladenine and indole acetic acid. *Egypt. J. Hort.*; 2000; *27*, pp. 1-6.

13. Han, B.H.; Park, B.M. In vitro micropropagation of *Philodendron cannafolium*. *J. Plant Biotechnol.*; 2008; *35*, pp. 203-208. [DOI: https://dx.doi.org/10.5010/JPB.2008.35.3.203]

14. Hassan, H.M.S.; Ali, M.A.M.; Soliman, D.A. Effect of low cost gelling agents and some growth regulators on micropropagation of *Philodendron selloum*. *J. Plant Production. Mansoura Univ.*; 2016; *7*, pp. 169-176. [DOI: https://dx.doi.org/10.21608/jpp.2016.45250]

15. Seliem, M.K.; El-Mahrouk, M.E.; El-Banna, A.N.; Hafez, Y.M.; Dewir, Y.H. Micropropagation of *Philodendron selloum*: Influence of copper sulfate on endophytic bacterial contamination, antioxidant enzyme activity, electrolyte leakage, and plant survival. *South Afr. J. Bot.*; 2021; *139*, pp. 230-240. [DOI: https://dx.doi.org/10.1016/j.sajb.2021.01.024]

16. Alawaadh, A.A.; Dewir, Y.H.; Alwihibi, M.S.; Aldubai, A.A.; El-Hendawy, S.; Naidoo, Y. Micropropagation of lacy tree *Philodendron* (*Philodendron bipinnatifidum* Schott ex Endl.). *HortScience.*; 2020; *55*, pp. 294-299. [DOI: https://dx.doi.org/10.21273/HORTSCI14612-19]

17. Lara-Ascencio, M.; Andrade-Rodriguez, M.; Guillen-Sanchez, D.; Sotelo-Nava, H.; Villegas-Torres, O.G. Establishment of in vitro aseptic culture of *Philodendron xanadu* Croat. *Rev. Cienc. Agron.*; 2021; *52*, e20197034. [DOI: https://dx.doi.org/10.5935/1806-6690.20210024]

18. Kieber, J.J.; Schaller, G.E. Cytokinin signaling in plant development. *Development*; 2018; *145*, dev149344. [DOI: https://dx.doi.org/10.1242/dev.149344] [PubMed: https://www.ncbi.nlm.nih.gov/pubmed/29487105]

19. Akhtar, S.S.; Mekureyaw, M.F.; Pandey, C.; Roitsch, T. Role of cytokinins for interactions of plants with microbial pathogens and pest insects. *Front. Plant Sci.*; 2020; *10*, 1777. [DOI: https://dx.doi.org/10.3389/fpls.2019.01777]

20. Emery, R.J.N.; Kisiala, A. The roles of cytokinins in plants and their response to environmental stimuli. *Plants*; 2020; *9*, 1158. [DOI: https://dx.doi.org/10.3390/plants9091158] [PubMed: https://www.ncbi.nlm.nih.gov/pubmed/32911673]

21. Jambor-Benczur, E.; Marta-Riffer, A. In vitro propagation of *Philodendron tuxilanum* Bunting with benzylaminopurine. *Acta Agron. Hung.*; 1990; *39*, pp. 341-348.

22. Sosnowski, J.; Truba, M.; Vasileva, V. The impact of auxin and cytokinin on the growth and development of selected crops. *Agriculture*; 2023; *13*, 724. [DOI: https://dx.doi.org/10.3390/agriculture13030724]

23. Thao, N.T.P.; Ozaki, Y.; Okubo, H. Callus induction and plantlet regeneration in ornamental *Alocasia micholitziana*. *Plant Cell Tissue Org. Cult.*; 2003; *73*, pp. 285-289. [DOI: https://dx.doi.org/10.1023/A:1023025717271]

24. Woodward, A.W.; Bartel, B. Auxin: Regulation, action, and interaction. *Ann. Bot.*; 2005; *95*, pp. 707-735. [DOI: https://dx.doi.org/10.1093/aob/mci083]

25. Jamil, M.; Saher, A.; Javed, S.; Farooq, Q.; Shakir, M.; Zafar, T.; Komal, L.; Hussain, K.; Shabir, A.; Javed, A. et al. A review on potential role of auxins in plants, current applications and future directions. *J. Bio. Env. Sci.*; 2021; *18*, pp. 11-16.

26. Zhang, Q.; Gong, M.; Xu, X.; Li, H.; Deng, W. Roles of auxin in the growth, development, and stress tolerance of horticultural plants. *Cells*; 2022; *11*, 2761. [DOI: https://dx.doi.org/10.3390/cells11172761] [PubMed: https://www.ncbi.nlm.nih.gov/pubmed/36078168]

27. Cartabia, A.; Sarropoulou, V.; Grigoriadou, K.; Maloupa, E.; Declerck, S. In vitro propagation of *Alkanna tinctoria* Tausch.: A medicinal plant of the *Boraginaceae* family with high pharmaceutical value. *Ind. Crop. Prod.*; 2022; *182*, 114860. [DOI: https://dx.doi.org/10.1016/j.indcrop.2022.114860]

28. Ziv, M.; Ariel, T. Bud proliferation and plant regeneration in liquid-cultured *Philodendron* treated with ancymidol and paclobutrazol. *J. Plant Growth Regul.*; 1991; *10*, pp. 53-57. [DOI: https://dx.doi.org/10.1007/BF02279311]

29. Jo, E.A.; Murthy, H.N.; Hahn, E.J.; Paek, K.Y. Micropropagation of *Alocasia amazonica* using semisolid and liquid cultures. *In Vitro Cell. Dev. Biol. Plant*; 2008; *44*, pp. 26-32. [DOI: https://dx.doi.org/10.1007/s11627-007-9081-2]

30. Dewir, Y.H.; Chakrabarty, D.; Hahn, E.J.; Paek, K.Y. A simple method for mass propagation of *Spathiphyllum cannifolium* using an airlift bioreactor. *In Vitro Cell. Dev. Biol. Plant*; 2006; *42*, pp. 291-297. [DOI: https://dx.doi.org/10.1079/IVP2006764]

31. Bartel, B.; LeClere, S.; Magidion, M.; Zolman, B.K. Inputs to the active indole-acetic acid pool: *De novo* synthesis, conjugate hydrolysis and indole-3-butyric acid β-oxidation. *J. Plant Growth Regul.*; 2001; *20*, pp. 198-216. [DOI: https://dx.doi.org/10.1007/s003440010025]

32. Marquez, G.; Alarcon, M.V.; Salguero, J. Differential responses of primary and lateral roots to indole-3-acetic acid, indole-3-butyric acid, and 1-naphthaleneacetic acid in maize seedlings. *Biol. Plant.*; 2016; *60*, pp. 367-375. [DOI: https://dx.doi.org/10.1007/s10535-015-0576-0]

33. Azza, M.E.S.; Khalafalla, M.M. In vitro shoot micropropagation and plant establishment of an ornamental plant dumb cane (*Dieffenbachia compacta*). *Int. J. Curr. Res.*; 2010; *6*, pp. 27-32.

34. Mariani, T.S.; Fitriani, A.; Teixeira da Silva, J.A.; Wicaksono, A.; Chia, T.F. Micropropagation of *Aglaonema* using axillary shoot explants. *Int. J. Basic Appl. Sci.*; 2011; *11*, pp. 46-53.

35. Hoang, N.N.; Kitaya, Y.; Shibuya, T.; Endo, R. Effects of supporting materials in in vitro acclimatization stage on *ex vitro* growth of wasabi plants. *Sci. Hortic. -Amsterdam.*; 2020; *261*, 109042. [DOI: https://dx.doi.org/10.1016/j.scienta.2019.109042]

36. Choi, J.M.; Chung, H.J.; Choi, J.S. Physico-chemical properties of organic and inorganic materials used as container media. *Korean Soc. Hortic. Sci.*; 2000; *18*, pp. 529-535.

37. Oh, M.M.; Seo, J.H.; Park, J.S.; Son, J.E. Physicochemical properties of mixtures of inorganic supporting materials affect growth of potato (*Solanum tuberosum* L.) plantlets cultured photoautotrophically in a nutrient-circulated

micropropagation system. *Hortic. Environ. Biotechnol.*; 2012; *53*, pp. 497-504. [DOI: https://dx.doi.org/10.1007/s13580-012-0043-1]

Abstract

Translate

This study describes the in vitro propagation and ex vitro acclimatization of *Philodendron erubescens* pink princess, one of the most popular ornamental variegated foliage plants. For shoot proliferation, the protocorm-like bodies of the *Philodendron* pink princess were cultured on solid Murashige and Skoog (MS) media supplemented with 6-benzylaminopurine (BAP) and 1-naphthaleneacetic acid (NAA) at different concentrations. The results revealed that supplementation with BAP alone at a concentration of 1.0 mg/L yielded the maximum number of shoots and leaves. Furthermore, the application of BAP at 1.0 mg/L significantly enhanced the shoot proliferation of *Philodendron* pink princess when grown in liquid MS medium, yielding 11.2 shoots/explant and 4.7 leaves/explant. When the established microshoots were subjected to root induction using solid MS media supplemented with different kinds and concentrations of auxins, indole-3-butyric acid (IBA) at 3 mg/L resulted in the highest number of roots (3.2 roots/explant) and longest root length (1.9 cm). Three supporting materials, i.e., peat moss, vermiculite, and perlite, were used
More

Details

Title In Vitro Propagation of *Philodendron erubescens* 'Pink Princess' and Ex Vitro Acclimatization of the Plantlets

Author Klanrit, Preekamol [1] ; Kitwetcharoen, Haruthairat [2] ; Thanonkeo, Pornthap [1] ; Thanonkeo, Sudarat [3]

[1] Department of Biotechnology, Faculty of Technology, Khon Kaen University, Khon Kaen 40002, Thailand; kpreek@kku.ac.th (P.K.); kharuthairat29@gmail.com (H.K.); portha@kku.ac.th (P.T.); Fermentation Research Center for Value Added Agricultural Products (FerVAAPs), Khon Kaen University, Khon Kaen 40002, Thailand
[2] Department of Biotechnology, Faculty of Technology, Khon Kaen University, Khon Kaen 40002, Thailand; kpreek@kku.ac.th (P.K.); kharuthairat29@gmail.com (H.K.); portha@kku.ac.th (P.T.)
[3] Walai Rukhavej Botanical Research Institute, Mahasarakham University, Maha Sarakham 44150, Thailand

First page 688
Publication year 2023
Publication date 2023
Publisher MDPI AG
e-ISSN 23117524
Source type Scholarly Journal
Language of publication English
DOI

https://doi.org/10.3390/horticulturae9060688

ProQuest document ID 2829808333