



RESEARCH ARTICLE

Study of *in vitro* propagation and acclimatisation in *Polianthes tuberosa* cv. Pink Sapphire

Nguyen Thi My Duyen^{1,2*}, Trinh Thi Thu Hong^{1,2}, Diep Nhut Thanh Hang^{1,2} & Bui Phuoc Tam^{1,2*}

¹Faculty of Agriculture and Natural Resources, An Giang University, An Giang province 90 000, Vietnam

²Vietnam National University, Ho Chi Minh City 71 309, Vietnam

*Correspondence email - phuoctam1987@gmail.com; ntmduyen@agu.edu.vn

Received: 15 November 2025; Accepted: 01 January 2026; Available online: Version 1.0: 28 January 2026; Version 2.0: 05 February 2026

Cite this article: Duyen NTM, Hong TTT, Hang DNT, Tam BP. Study of *in vitro* propagation and acclimatisation in *Polianthes tuberosa* cv. Pink Sapphire. Plant Science Today. 2026; 13(1): 1-10. <https://doi.org/10.14719/pst.12743>

Abstract

Polianthes tuberosa cv. Pink Sapphire is one of the beautiful commercial flower varieties newly imported into Vietnam. However, detailed studies on the micropropagation and acclimatisation of this flower species to the local environment are lacking. To meet the production and commercial demand of this flower variety in Vietnam's An Giang province, the study was conducted to select optimal media for *in vitro* propagation and suitable environments for seedling acclimatisation under greenhouse conditions. Five experiments were encompassed in this study, consisting of sterilisation of initial explants, *in vitro* shoot regeneration from bulb scales, *in vitro* shoot multiplication, complete plantlet generation and acclimatisation of seedlings in the greenhouse. The results demonstrated that the most effective sterilisation method was using 0.2 % $HgCl_2$ for 15 min and then 10 % $Ca(OCl)_2$ for 10 min. Four-scaling bulbs cultured on MS media containing 2.5 mg/L BAP and 0.5 mg/L NAA were recommended for *in vitro* shoot regeneration. The best medium for *in vitro* shoot multiplication was MS medium supplemented with 2 mg/L BAP and 0.5 mg/L NAA. The suitable medium for complete plantlet regeneration was MS medium. To acclimatisate Pink Sapphire in the greenhouse, the optimal substrate was a mixture of rice husk ash, coconut coir and sand in equal parts (1:1:1). The findings of this study provide a foundation for the rapid development of the *P. tuberosa* cv. Pink Sapphire variety in An Giang province of Vietnam.

Keywords: acclimatisation; *in vitro*; medium; Pink Sapphire; *Polianthes tuberosa*; propagation

Introduction

Tuberose (*Polianthes tuberosa* L.) belongs to the genus *Polianthes*, is native to Mexico and is popularly used as a fresh-cut flower in tropical and subtropical countries. The *P. tuberosa* cv. Pink Sapphire is a newly bred flower from a maternal plant (*P. tuberosa* × *P. howardii*) and a paternal plant (*P. tuberosa* 'Double') (1). It has beautiful double florets, pale pink and a nice fragrance. There are two main types of tuberose flowers. Genotypes of single-flowered plants are typically utilised for extracting essential oils, as well as for loose flowers and floral arrangements; in contrast, double types of tuberoses are employed for cut flowers and garden displays (2). *Polianthes tuberosa* cv. Pink Sapphire flower is not yet widely cultivated in Vietnam, as it is a newly introduced variety. *Polianthes tuberosa* cv. Pink Sapphire is not yet widely cultivated in Vietnam because it is a newly introduced variety. Currently, in An Giang province, the demand for this flower is high, but its supply is limited and prices are elevated due to the fact that the bulbs are primarily imported from Taiwan. Therefore, research on the mass propagation of Pink Sapphire bulbs is essential to ensure a timely supply of seedlings, reduce investment costs and satisfy the increasing demands of flower enthusiasts.

Compared to traditional propagation methods such as dividing tubers and cuttings, *in vitro* protocols greatly enhanced the propagation rate and allowed the production of disease-free seedlings in large quantities (3). The micropropagation effectiveness of plantlets is affected by various factors, such as genotype, explant kind, position of explants on the medium, different culture media, plant growth regulators and substrates for plantlet acclimatisation under greenhouse conditions (2-5). Tuberose is usually propagated through vegetative bulbs or bulblets instead of using seeds (3). In addition, the use of *in vitro* protocols involving different components of the whole plant for the generation of new tuberose plants is gaining popularity (6). Many studies on propagation by tissue culture have been published; however, there is limited information regarding the parameters that influence the *in vitro* efficiency of tuberose (2). This study was conducted to develop and optimise a process for the *in vitro* propagation and bulb acclimatisation of *P. tuberosa* cv. Pink Sapphire in Vietnam's An Giang province. This will facilitate the production of a large quantity of high-quality plantlets to satisfy the demands of flower growers.

Materials and Methods

Place and time

The experiments were conducted at Nguyen Nhu Experimental Garden and An Giang University, belonging to Vietnam National University Ho Chi Minh City in Long Xuyen Ward, An Giang Province, Vietnam, from April 2024 to March 2025.

Materials

Plant materials

The *P. tuberosa* cv. Pink Sapphire bulbs were collected from the Nguyen Nhu Experimental Garden (Long Xuyen Ward, An Giang Province, Vietnam), originally sourced from Taiwan. Bulbs with a diameter of 1.0–1.5 cm were selected for experiments.

Chemicals

The study utilised Murashige and Skoog (MS) medium as the nutrient medium in tissue culture and plant growth regulators (PGRs) such as α -naphthaleneacetic acid (NAA), 6-Benzylaminopurine (BAP) and Thidiazuron (TDZ). These chemicals were purchased from Duchefa Biochemie B.V., Netherlands. Calcium hypochlorite or chlorine, Ca(OCl)_2 70 %, was from Mindy Materials (India) and mercuric chloride, HgCl_2 98 %, was from Xilong Chemical Co. Limited (China).

Methods

Experiment 1 - Sterilisation of initial Pink Sapphire explants

Pink Sapphire tuberosa bulbs were removed of all excess leaves and washed under running water for 20 min to remove soil and adhesive substances on the bulb surface. Next, in a sterile chamber, bulb samples were dipped into 70 % alcohol for about one min and then washed with sterile distilled water 3–4 times. After that, bulbs were treated with disinfectants (Ca(OCl)_2 and/or HgCl_2) according to the treatments designed specifically in Table 1. Finally, the samples were

washed with sterile distilled water 4–5 times. After sterilising, the damaged parts were trimmed and then transplanted into the prepared MS medium. The experiment was conducted in a tissue culture room according to a randomised complete block design (RCBD) with six treatments (A_1 – A_6), each treatment had four replications, each replication included 10 bulb samples and each bulb was cultured in a glass vessel. The culture samples were evaluated at one, two and three weeks after culturing with the following indicators:

$$\text{Infected sample rate (\%)} = \frac{F}{N} \times 100 \quad (\text{Eqn. 1})$$

$$\text{Dead sample rate (\%)} = \frac{D}{N} \times 100 \quad (\text{Eqn. 2})$$

$$\text{Surviving sample rate (\%)} = \frac{(N) - (D+F)}{N} \times 100 \quad (\text{Eqn. 3})$$

Where, F- Number of infected samples; D- Number of dead samples; N- Total number of cultured samples

Experiment 2 - *In vitro* shoot regeneration from bulb scales

This experiment applied three kinds of explants, whole, double-scaling and four-scaling bulbs, to evaluate *in vitro* shoot regeneration ability (Fig. 1). These explants were cultured on MS media supplemented with BAP (0–2.5 mg/L) and NAA (0–0.5 mg/L) for 56 days (8 weeks). The experiment was carried out in an RCBD with nine treatments (B_1 – B_9) shown in Table 2. Each treatment had four replications, with each replication consisting of two culture vessels and each sample was cultured in a separate vessel. Indicators were recorded at 2, 4, 6 and 8 weeks after culturing, including the number of regenerated shoots per explant, shoot height and number of leaves per explant.

Table 1. Treatments of sterilisation of Pink Sapphire tuberose explants

Treatment	HgCl_2		Ca(OCl)_2	
	Concentration (%)	Time (min)	Concentration (%)	Time (min)
A_1	0.2	15	10	10
A_2	0.2	20	-	-
A_3	0.1	20	-	-
A_4	0.1	15	10	10
A_5	-	-	10	20
A_6	-	-	10	25

HgCl_2 : Mercury(II) chloride; Ca(OCl)_2 : Calcium hypochlorite

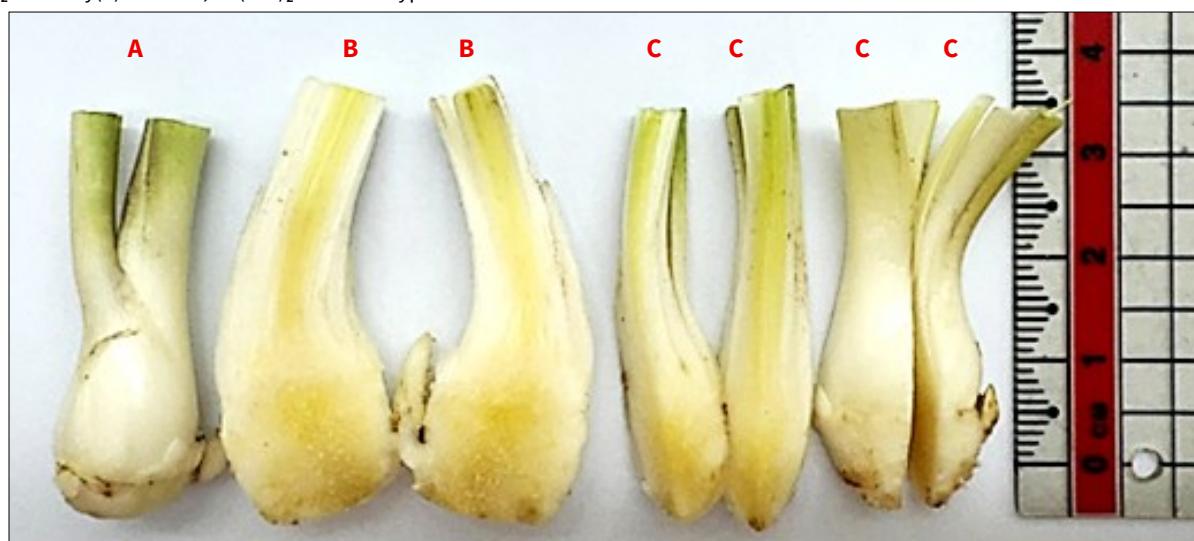


Fig. 1. Three kinds of explants. A. Whole, B. Double-scaling, C. Four-scaling used in *in vitro* shoot regeneration.

Table 2. Treatments of explant kinds and PGRs in *in vitro* shoot regeneration

Treatment	Different explants utilised			Plant growth regulators (mg/L)	
	Whole bulb	Twin-scaling bulb	Four-scaling bulb	BAP	NAA
B ₁	✓	-	-	0	0
B ₂	✓	-	-	2.5	0
B ₃	✓	-	-	2.5	0.5
B ₄	-	✓	-	0	0
B ₅	-	✓	-	2.5	0
B ₆	-	✓	-	2.5	0.5
B ₇	-	-	✓	0	0
B ₈	-	-	✓	2.5	0
B ₉	-	-	✓	2.5	0.5

PGR: Plant growth regulator; BAP: 6-Benzylaminopurine; NAA: Naphthaleneacetic acid

Experiment 3 - *In vitro* shoot multiplication

Explants collected from healthy shoots obtained from the experiment of *in vitro* shoot regeneration from bulb scales were cut off their leaves. Stem sections of Pink Sapphire tuberose, approximately 1.5 cm in length, were prepared and transplanted into MS shoot multiplication medium supplemented with 0.5 mg/L NAA, combined with one of two cytokinins, BAP or TDZ, at varying concentrations. The experiment was carried out in an RCBD with six treatments (C₁-C₆) shown in Table 3. Each treatment had four replications, with each replication consisting of two culture vessels and each sample was cultured in a separate vessel. Indicators were recorded at 2, 4 and 6 weeks after culturing, including the number of shoots, shoot height and number of leaves per explant.

Table 3. Different PGR treatments for *in vitro* shoot multiplication

Treatment	Plant growth regulators (mg/L)		
	BAP	TDZ	NAA
C ₁	4	-	0.5
C ₂	3	-	0.5
C ₃	2	-	0.5
C ₄	-	1.5	0.5
C ₅	-	1.0	0.5
C ₆	-	0.5	0.5

Notes: PGR: Plant growth regulator; BAP: 6-Benzylaminopurine; NAA: Naphthaleneacetic acid; TDZ: Thidiazuron

Experiment 4 - Complete plantlet generation

The strong shoots from the experiment of *in vitro* shoot multiplication were collected for the rooting experiment. Shoot samples were placed in different rooting media of MS and NAA. The experiment was conducted in an RCBD with five treatments (D₁-D₅) described in Table 4. Each treatment had four replications, with each replication consisting of two culture vessels and each sample was cultured in a separate vessel. Indicators were recorded at 1, 2, 4 and 6 weeks after culturing, including the number of roots, root length, shoot height and number of leaves per explant.

Table 4. Treatments of MS media and NAA in complete plantlet generation

Treatment	Nutrient media	NAA (mg/L)
D ₁	MS	0
D ₂	½MS	0
D ₃	¼MS	0
D ₄	½MS	1
D ₅	¼MS	1

MS: Murashige and Skoog medium; ½MS: MS medium reduced mineral content by half; ¼MS: MS medium reduced mineral content by three-quarters; NAA: Naphthaleneacetic acid

Experiment 5 - Acclimatisation of Pink Sapphire in the greenhouse

Completely generated plantlets approximately 6 cm in height from experiment 4 were pruned to retain three leaves near the apex and transferred to grow in greenhouse conditions. They were grown in the C5 plastic pot (10.5 × 11.0 × 7.5 cm) containing sand, soil, coconut coir and rice husk ash. The experiment was conducted in an RCBD with five treatments (E₁-E₅) described in Table 5. Each treatment had four replications, with each replication consisting of two plants and each plant was grown in a separate pot. Fertiliser was applied every two weeks with the formula-Dau Trau HCMK organic mineral fertiliser (6 g/plant) + NPK chemical fertiliser (1.8 g/plant) (7). Water was sprayed in mist once a day in the morning. The temperature inside the greenhouse was maintained at 24–32 °C. Observation criteria were recorded four weeks after transplanting, consisting of the survival plant rate (%); plant height (cm); number of leaves/plant; and stem diameter (mm).

Survival plant rate (%) =

$$\frac{\text{number of survival plants}}{\text{total number of plants}} \times 100 \quad (\text{Eqn. 4})$$

Table 5. Treatments of substrate components for acclimatisation of *Polianthes tuberosa* cv. Pink Sapphire in the greenhouse

Treatment	Ratio of substrate components (x:x:x)		
	Rice husk ash	Coconut coir	Sand
E ₁	1	-	-
E ₂	1	1	-
E ₃	1	-	1
E ₄	-	1	1
E ₅	1	1	1

Data analysis

Data processing was performed using Microsoft Excel. Analysis of variance (ANOVA) and pairwise mean comparison of treatments by Tukeys' honest significant difference (HSD) test were then conducted using SAS 9.1 software.

Results and Discussion

Sterilisation of initial Pink Sapphire explants

Different concentrations of disinfectants and sample handling times affected the number of infected, dead and surviving bulbs at one, two and three weeks of *in vitro* culture, resulting in differences in the rates of these outcomes at the 5 % statistical significance level (Table 6). The A treatment, which sterilised the Pink Sapphire bulbs using HgCl_2 0.2 % for 15 min, combined with $\text{Ca}(\text{OCl})_2$ 10 % for 10 min, gave the highest rate of surviving bulbs. Bulbs survived completely (100 %), nearly one-third (65.0 %) and more than half (57.5 %) after 1 week, 2 weeks and 3 weeks of culture, respectively.

Table 6. Rate (%) of the infected, dead and surviving samples at one, two and three weeks after culturing

Treatment	One week after culturing			Two weeks after culturing			Three weeks after culturing		
	Infected	Dead	Surviving	Infected	Dead	Surviving	Infected	Dead	Surviving
A₁	0 ^d	0 ^c	100.0 ^a	15.0 ^d	20.0 ^a	65.0 ^a	20.0 ^d	22.5 ^a	57.5 ^a
A₂	27.5 ^c	5.0 ^b	67.5 ^b	37.5 ^c	10.0 ^b	52.5 ^b	45.0 ^c	12.5 ^c	42.5 ^b
A₃	42.5 ^b	10.0 ^a	47.5 ^c	67.5 ^b	10.0 ^b	22.5 ^c	77.5 ^b	10.0 ^c	12.5 ^c
A₄	25.0 ^c	10.0 ^a	65.0 ^b	37.5 ^c	17.5 ^a	45.0 ^b	47.5 ^c	17.5 ^b	35.0 ^b
A₅	85.0 ^a	0 ^c	15.0 ^d	92.5 ^a	0 ^c	7.5 ^d	100.0 ^a	0 ^b	0 ^d
A₆	77.5 ^a	0 ^c	22.5 ^d	87.5 ^a	0 ^c	12.5 ^d	100.0 ^a	0 ^b	0 ^d
P-value	*	*	*	*	*	*	*	*	*
CV (%)	9.67	12.82	8.75	8.67	6.12	7.49	7.58	8.87	8.80

Notes: A₁–A₆: Treatments of disinfectants for sterilisation of Pink Sapphire tuberose; DAC: Days after culturing; CV: Coefficient of variation; Within the same group of average values, means followed by the same letter were not significantly different from each other; *: Significance at the 5 % level.

A previous study investigated the sterilisation stage of *in vitro* propagation in the mulberry plant and concluded that shoot tips and auxiliary buds sterilised with mercuric chloride 0.2 % for 10 min were the best to get sterilised and survive explants (8). While another study showed that the combined disinfectant, 70 % ethanol (20 sec) and Ca(OCl)₂ 10 % (15 min), was proposed as the best surface sterilisation protocol as it gave 100 % survival in explants of *Solanecio biafrae* (9). A study of *in vitro* culture in tuberose (*P. tuberosa* L.) found that treatments of single sterilant either by Ca(OCl)₂ or HgCl₂ were not effective for the percentage of survival (10). The combination of chlorox (sodium/calcium hypochlorite) and mercuric chloride helps to reduce bacterial contamination in *in vitro* culture of lily and tuberose species (11, 12).

In vitro shoot regeneration from bulb scales

The results of this experiment showed that PGRs such as BAP and NAA had a significant effect on shoot regeneration, e.g., the number of regenerated shoots, shoot height and number of leaves, in *P. tuberosa* cv. Pink Sapphire (Fig. 2, 3). PGRs like cytokinin and auxin are introduced to stimulate the initiation of shoot and root growth (13). BAP, one of the cytokinins, typically facilitates shoot growth and is applied in initiating shoot growth within plant culture. Meanwhile, auxins, e.g., NAA, are utilised to promote the development of roots (14, 15). In this study, the number of regenerated shoots in treatments with PGRs tended to be more than in treatments without PGRs. After eight weeks of culture, the treatments supplemented with BAP and NAA in all three bulb scales (whole, twin and four-scaling bulbs) had the highest number of shoots, followed by the treatments supplemented with only BAP and the lowest number in the treatments without growth regulators. The B₉ treatment, four-scaling bulbs cultured on MS media supplemented with 2.5 mg/L BAP and 0.5 mg/L NAA, had the highest shoot regeneration, reaching 9, 9, 10 and 14 shoots/bulb after two, four, six and eight weeks of culture, respectively (Fig. 3A). Shoot height in treatments without PGRs was often higher than in treatments with PGRs and treatments B₁ and B₇ had the tallest shoots (Fig. 3B). A previous finding demonstrated that

the MS medium without NAA and BAP was best for the formation of roots and shoots and the addition of BAP and NAA in the medium decreased shooheight in tissue culture of potato and basil species (16, 17). However, the mechanism of these results has not been studied. After eight weeks of culture, the number of leaves in treatment B₃ was the most, followed by treatments B₈ and B₉ (Fig. 3C). Therefore, the treatment of four-scaling bulbs on MS media with 2.5 mg/L BAP and 0.5 mg/L NAA was proposed as the best treatment for *in vitro* shoot regeneration in *P. tuberosa* cv. Pink Sapphire.

In vitro shoot multiplication

Through 6 weeks of *in vitro* culture, shoot multiplication showed significant differences among six treatments (C₁–C₆) of PGRs (Fig. 4). The number of shoots and shoot height started to increase from the 2nd week and gradually rose until the 6th week, while the number of leaves began later, forming from the 4th week onwards (Fig. 5). During the culture weeks, the C₃ treatment stimulated the largest number of shoots to arise and had a statistically significant difference compared to the other treatments (Fig. 5A). Treatment C₅ gave the best shoot height (7.66 cm, 10.56 cm and 12.40 cm at the 2nd, 4th and 6th week, respectively). Shoot height in treatment C₃ was lower than in treatments C₅, C₄ and C₁ (Fig. 5B); however, shoots in treatment C₃ were stronger and more sturdy. Leaves began to appear from the 2nd week of culture. In the 2nd week, leaves only appeared in the C₃ and C₁ treatments. In the following weeks, the number of leaves in the C₃ treatment developed rapidly and was significantly larger than in the other treatments (Fig. 5C). Therefore, the C₃ treatment (MS medium supplemented with 2 mg/L BAP and 0.5 mg/L NAA) was the optimal treatment for *in vitro* shoot multiplication in Pink Sapphire tuberose. The previous study of *in vitro* propagation of *P. tuberosa* flowers demonstrated that MS medium supplemented with BAP and NAA increased multiple shoot rates (18). Another finding found that MS medium supplemented with 0.5 mg/L NAA combined with 1.0–2.0 mg/L BAP gave the highest number of shoots in *Stevia rebaudiana* (19).

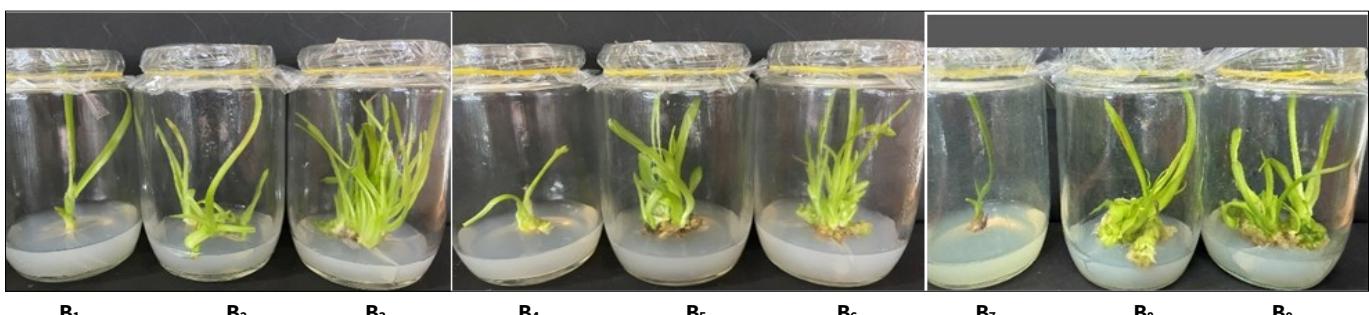
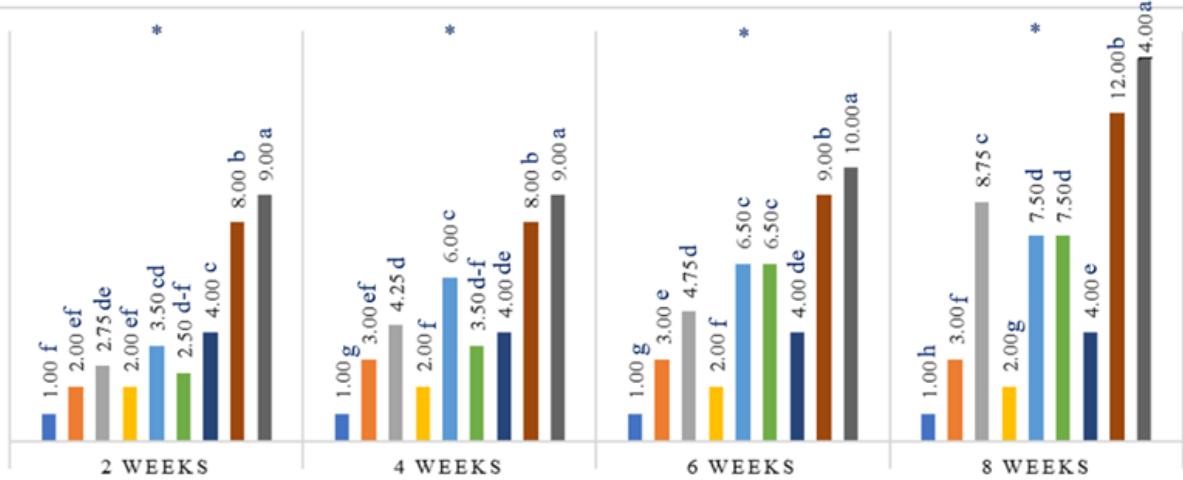


Fig. 2. The differences in explant growth at the 8th week in bulb kinds and PGRs in *in vitro* shoot regeneration. B₁–B₉: Treatments of explant kinds and PGRs.

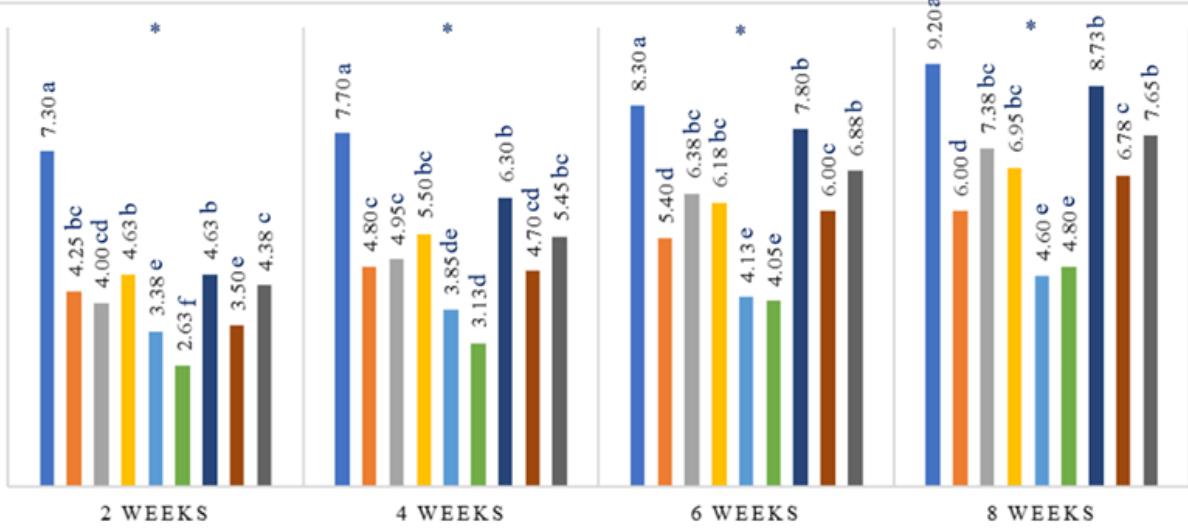
NUMBER OF REGENERATED SHOOTS



A

TREATMENTS: ■ B1 ■ B2 ■ B3 ■ B4 ■ B5 ■ B6 ■ B7 ■ B8 ■ B9

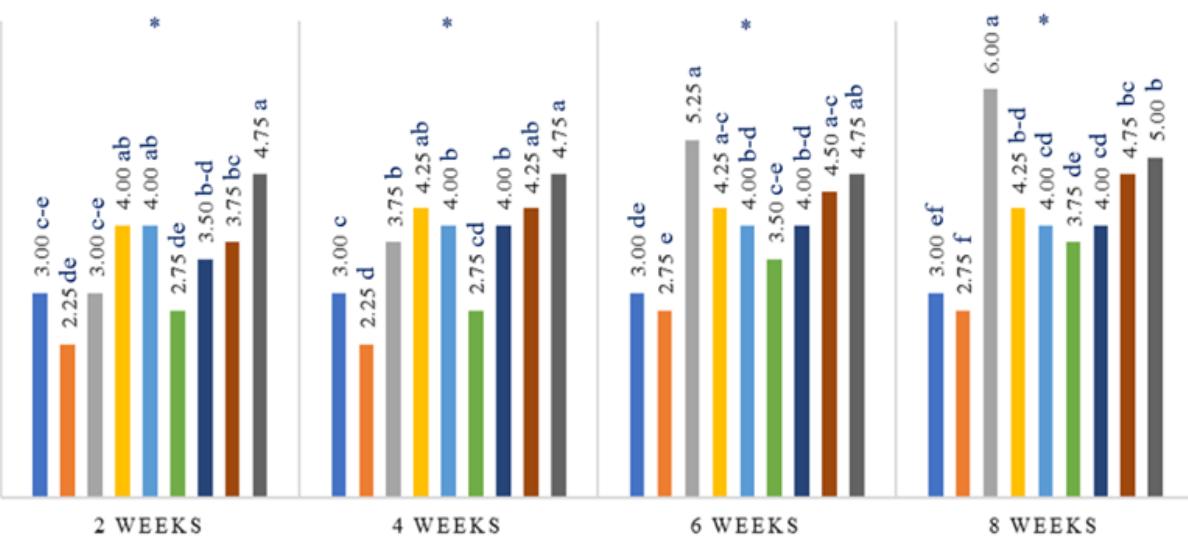
SHOOT HEIGHT (CM)



B

TREATMENTS: ■ B1 ■ B2 ■ B3 ■ B4 ■ B5 ■ B6 ■ B7 ■ B8 ■ B9

NUMBER OF LEAVES PER EXPLANT



C

TREATMENTS: ■ B1 ■ B2 ■ B3 ■ B4 ■ B5 ■ B6 ■ B7 ■ B8 ■ B9

Fig. 3. Bulb scales in the different treatments of *in vitro* shoot regeneration. A. Number of regenerated shoots, B. Shoot height, C. Number of leaves per explant. B₁-B₉: Treatments of explant kinds and PGRs.

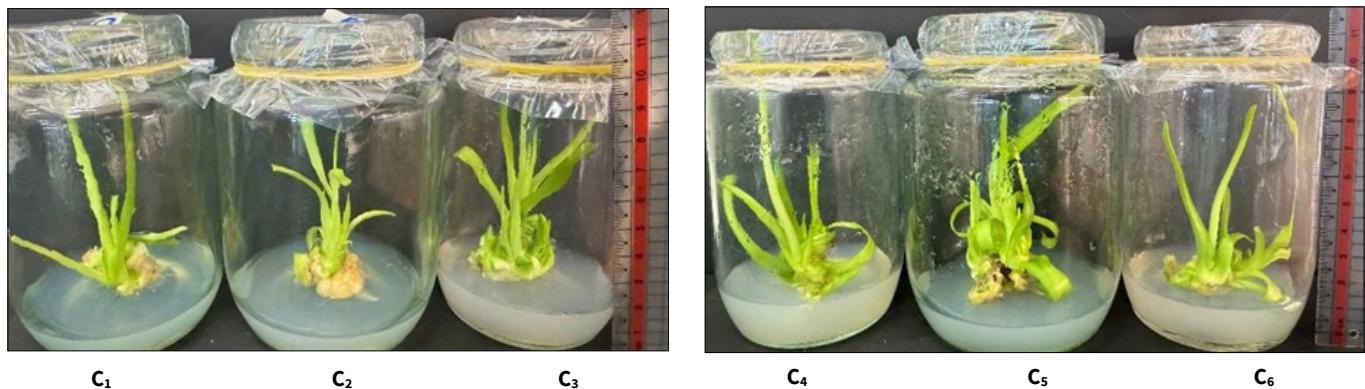


Fig. 4. The differences in shoot growth at the 6th week in six treatments of PGRs. C₁–C₆: Treatments of PGRs in *in vitro* shoot multiplication.

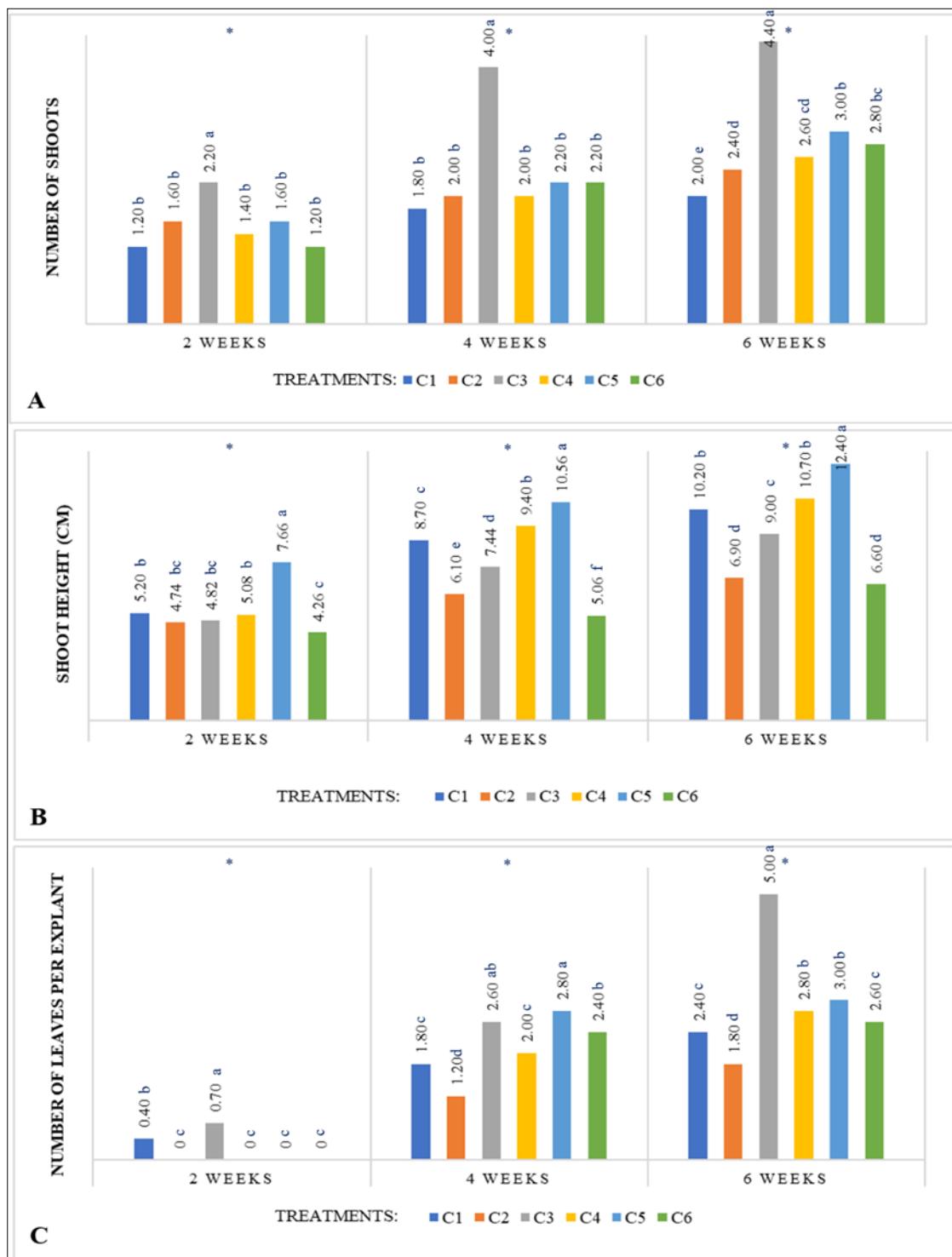


Fig. 5. A. Number of shoots, B. shoot height, C. Number of leaves of explants in the different treatments of *in vitro* shoot multiplication. C₁–C₆: Treatments of PGRs in *in vitro* shoot multiplication.

Complete plantlet generation

Over the weeks of culture, there were statistical differences among the environmental treatments in the formation of the number of roots and leaves and the growth in root length and shoot height (Fig. 6, 7). The highest number of roots and leaves was recorded in treatments D₁ and D₂ and there was no statistical difference between these two treatments in most weeks of culture, especially in the 4th and 6th weeks (Fig. 7A, B). Root length and shoot height in treatment D₁ were the highest and significantly different from those in other treatments (Fig. 7C, D). Thus, treatment D₁, MS medium without

NAA, was the optimal medium for complete plantlet regeneration, followed by D₂, 1/2MS medium without NAA. This also showed that NAA was not effective in complete plantlet generation. Previous tissue culture studies also suggested that MS medium was more suitable for the growth of *in vitro* plantlets than other MS media strengths, such as 1/2MS and 1/4MS (20–22). Furthermore, previous findings reported that plantlet growth, especially in shoot height, in *in vitro* culture was notably influenced by the MS media without growth regulators (13, 23).

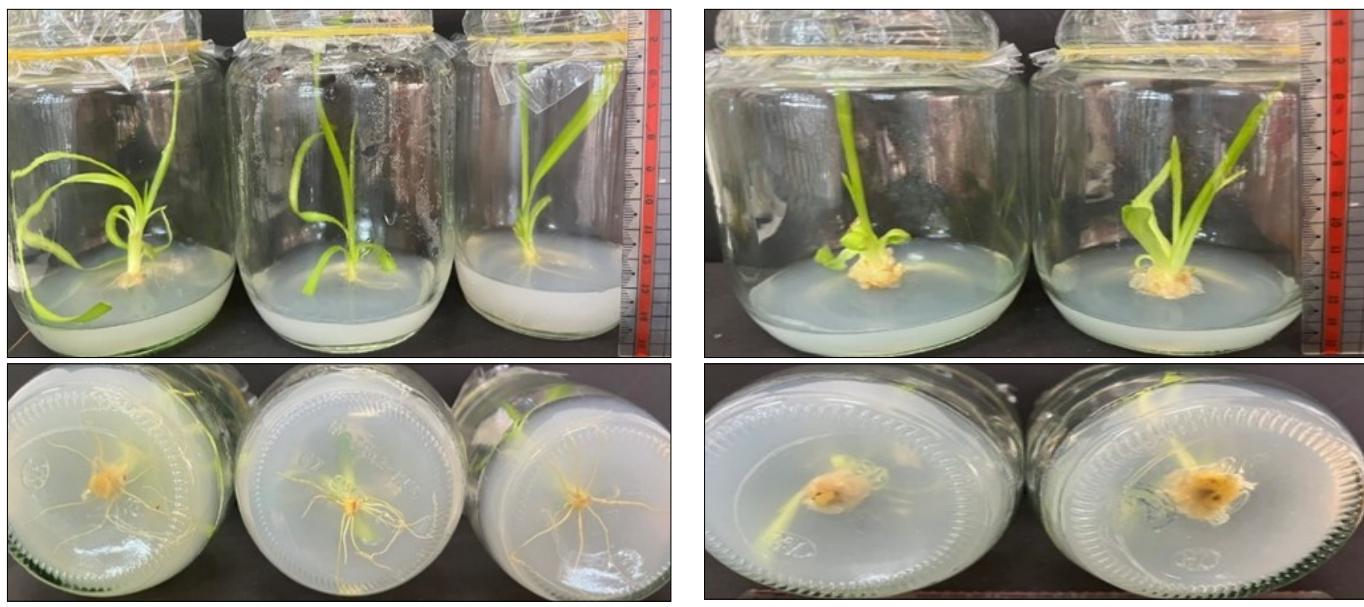
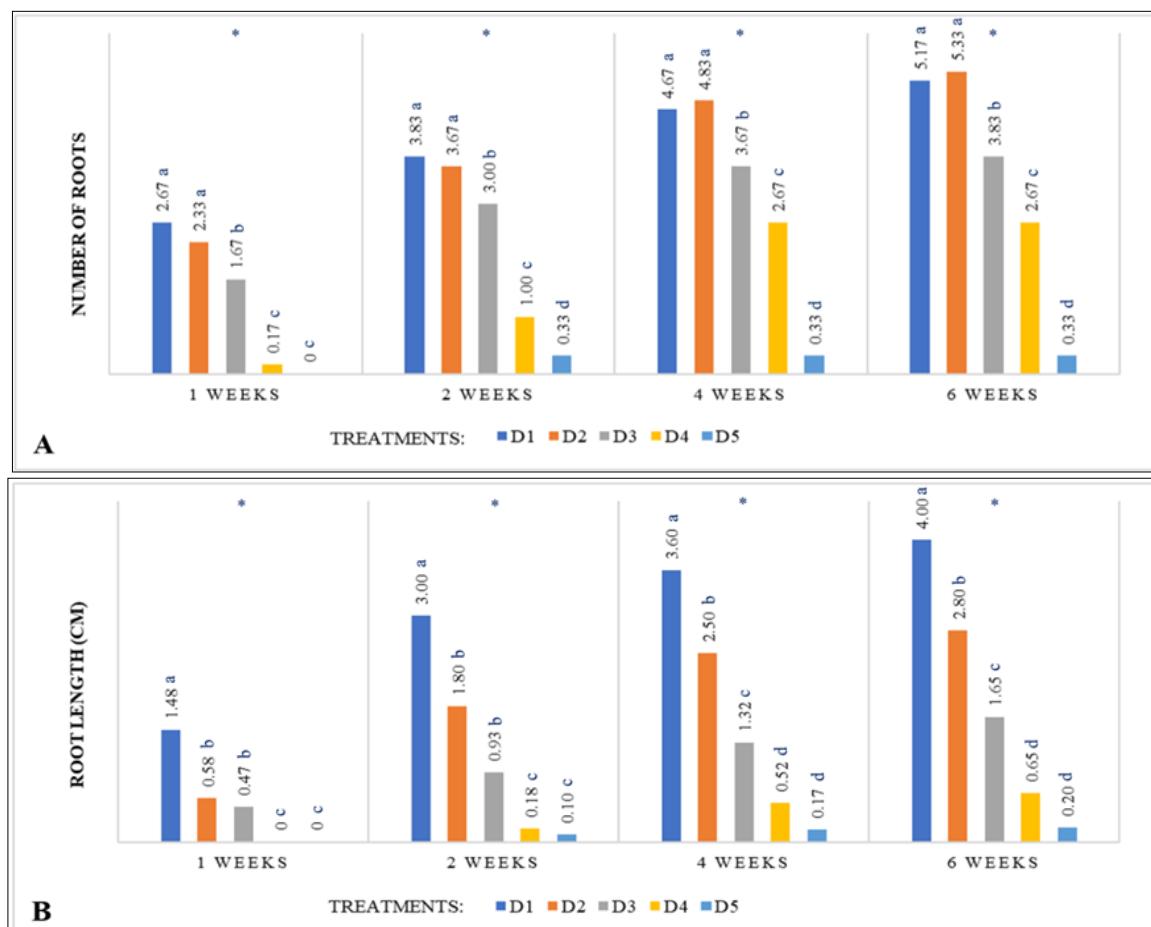


Fig. 6. The differences in shoot and root growth at the 6th week in treatments of complete plantlet generation. D₁–D₅: Treatments of complete plantlet generation.



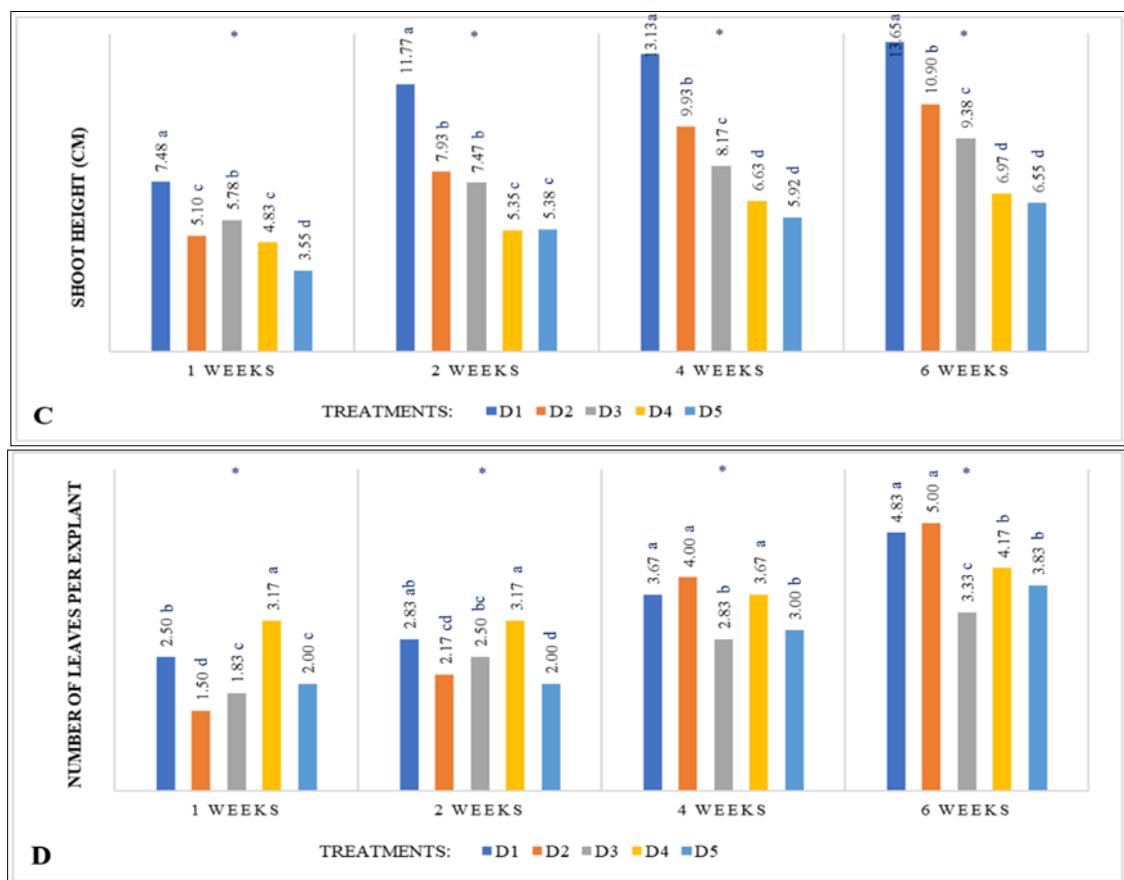


Fig. 7. A. Number of roots, B. Root length, C. Shoot height, D. Number of leaves of explants in the different treatments of complete plantlet generation. D₁-D₅: Treatments of complete plantlet generation.

Acclimatisation of *Polianthes tuberosa* cv. Pink Sapphire in the greenhouse

Healthy Pink Sapphire seedlings were grown in different substrates under greenhouse conditions. The results showed that seedling survival and growth among treatments were statistically significant at the 5 % level (Table 7, Fig. 8). Plants in treatments E₃ and E₅ were recorded as surviving completely for 4 weeks after transplanting; meanwhile, the survival of seedlings in other treatments only reached 62.5–87.5 %. Plant height in treatment E₅ was highest, followed by treatments E₃ and E₄ and the height in these treatments was significantly higher than in the other treatments. The number of leaves formed among the treatments exhibited minor differences, ranging from 6.38 to 7.75 leaves/plant and treatment E₅ had the highest number of leaves/plant. There were differences in stem diameter between the substrate treatments. The plants in treatment E₅ had the largest stem diameter, followed by E₃ and the diameter in these two treatments was significantly higher than in the other treatments. Therefore, treatment E₅, which consists of rice husk ash, coconut coir and sand in a 1:1:1 ratio, is the most optimal substrate for the

survival and growth of Pink Sapphire seedlings under greenhouse conditions. Previous studies pointed out that the combined substrate of rice husk ash and coconut fibre is suitable for the survival and growth of *in vitro* seedlings of *Anthurium scherzerianum* and *Oncidium baueri* in greenhouse conditions (24, 25).

Conclusion

The study proposed the optimal media for *in vitro* propagation and the best substrate for acclimatisation in *P. tuberosa* cv. Pink Sapphire in the condition of An Giang province, Vietnam. The combination of HgCl₂ and Ca(OCl)₂ disinfectants helps achieve the highest sterilisation efficiency for the culture explants and the concentration (HgCl₂ 0.2 % for 15 min combined with Ca(OCl)₂ 10 % for 10 min) resulted in the best survival rate for Pink Sapphire bulbs. PGRs enhanced shoot regeneration about the quantity of shoots and leaves, but limited the shoot height. In *in vitro* shoot regeneration, MS media with 2.5 mg/L BAP and 0.5 mg/L NAA assisted four-scaling bulbs to reach the best number of shoots per explant. MS medium

Table 7. Survival and growth of Pink Sapphire seedlings in treatments of substrate components in the greenhouse

Treatment	Survival plant rate (%)	Plant height (cm)	Number of leaves/plant	Stem diameter (mm)
E ₁	62.5 ^d	11.88 ^b	7.13 ^a	5.63 ^b
E ₂	87.5 ^b	9.13 ^c	6.38 ^b	4.75 ^c
E ₃	100.0 ^a	14.13 ^a	7.38 ^a	6.19 ^a
E ₄	75.0 ^c	13.89 ^a	7.25 ^a	5.69 ^b
E ₅	100.0 ^a	15.33 ^a	7.75 ^a	6.31 ^a
P-value	*	**	*	*
CV (%)	5.15	8.64	6.64	5.34

Notes: E₁-E₅: Treatments of substrate components; CV: Coefficient of variation; Within the same group of average values, means followed by the same letter were not significantly different from each other; *: Significance at the 5 % level; **: Significance at the 1 % level.



Fig. 8. Growth of seedlings in different substrate treatments under greenhouse conditions after 4th weeks after transplanting: A. Samples of five treatments were collected to evaluate, B. Plants in five treatments in the greenhouse.

combined with 2 mg/L BAP and 0.5 mg/L NAA was the optimal medium for *in vitro* shoot multiplication. The suitable medium for complete plantlet regeneration is MS medium without NAA. The most optimal substrate for acclimatisation of Pink Sapphire in the greenhouse is a mixture of rice husk ash, coconut coir and sand in a 1:1:1 ratio. These findings contribute to improving the *in vitro* culture process of *P. tuberosa* cv. Pink Sapphire. This will enable its application in the mass production of this species, resulting in higher yields and reduced costs.

Acknowledgements

This research is funded by Vietnam National University HoChiMinh City (VNU-HCM) under a project within the framework of the Program titled “Strengthening the capacity for education and basic scientific research integrated with strategic technologies at VNU-HCM”, aiming to achieve advanced standards comparable to regional and global levels during the 2025–2030 period, with a vision toward 2045.

Authors' contributions

NTMD conceived of the study and participated in its design and coordination. TTH and DNTH carried out the experimental work in the laboratory and greenhouse. BPT participated in the sequence alignment and drafted the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Shen TM, Huang KL, Shen RS, Du BS. Breeding of dwarf tuberose (*Polianthes tuberosa* L.). *Acta Hortic.* 2003;624:73–6. <https://doi.org/10.17660/ActaHortic.2003.624.9>
2. Kumar M, Sirohi U, Malik S, Kumar S, Ahirwar GK, Chaudhary V, et al. Methods and factors influencing *in vitro* propagation efficiency of ornamental tuberose (*Polianthes* species): A systematic review of recent developments and future prospects. *Horticulturae.* 2022;8:998. <https://doi.org/10.3390/horticulturae8110998>
3. Mandal R, Singh NP, Mukopadayay S. A review on ethnomedicinal properties on *Polianthes tuberosa* L. *Int J Health Sci.* 2022;6:S3:9728–43. <https://doi.org/10.53730/ijhs.v6nS3.8550>
4. Cheesman L, Finnie JF, Van-Staden J. *Eucomis zambesiaca* Baker: Factors affecting *in vitro* bulblet induction. *South Afr J Bot.* 2010;76:543–9. <https://doi.org/10.1016/j.sajb.2010.04.004>
5. Nalousi AM, Hatamzadeh A, Azadi P, Mohsenpour M, Lahiji HS. A procedure for indirect shoot organogenesis of *Polianthes tuberosa* L. and analysis of genetic stability using ISSR markers in regenerated plants. *Sci Hortic.* 2019;244:315–21. <https://doi.org/10.1016/j.scienta.2018.09.066>
6. Ahmad MS, Ahmad T, Zaidi N, Nasir IA. High frequency *in vitro* propagation of *Polianthes tuberosa*. *Pak J Sci Ind Res.* 2006;49:344–8.
7. Duyen NTM, Phong TT, Tam BP. Effects of bulb size and fertilizers on growth, yield and color of *Polianthes tuberosa* Pink Sapphire. *Asian J Plant Sci.* 2025;24:60–72. <https://doi.org/10.3923/ajps.2025.60.72>

8. Taha H, Ghazy UM, Gabr AMM, EL-Kazzaz AAA, Ahmed EAMM, Haggag KM. Optimization of *in vitro* culture conditions affecting propagation of mulberry plant. *Bull Natl Res Cent*. 2020;44:60. <https://doi.org/10.1186/s42269-020-00314-y>
9. Bello OA, Esan EB, Obembe OO. Establishing surface sterilization protocol for nodal culture of *Solanecio biafrae*. *IOP Conf Ser: Earth Environ Sci*. 2018;210:012007. <https://doi.org/10.1088/1755-1315/210/1/012007>
10. Gajbhiye SS, Tripathi MK, Vidya-Shankar M, Singh M, Baghel BS, Tiwari S. Direct shoot organogenesis from cultured stem disc explants of tuberose (*Polianthes tuberosa* Linn.). *J Agric Technol*. 2011;7:695–709.
11. Aslam F, Naz S, Tariq A, Ilyas S, Shahzadi K. Rapid multiplication of ornamental bulbous plants of *Lilium orientalis* and *Lilium longiflorum*. *Pak J Bot*. 2013;45:2051–5.
12. Patil M, Bharathi TU, Usharani TR, Kumar R, Kulkarni BS. Standardization of sterilization protocol for explants and its suitability for direct organogenesis in tuberose cv. Arka Vaibhav. *J Hortic Sci*. 2023;18:173–80. <https://doi.org/10.24154/jhs.v18i1.2160>
13. Nugrahani P, Purnobasuki H, Ansori ANM, Anuchai J, Priyanto AD. Effect of different strengths of MS media and BAP on banana plantlet growth *in vitro*. *Sarhad J Agric*. 2024;40:1110–7. <https://doi.org/10.17582/journal.sja/2024/40.4.1110.1117>
14. Sugiyono, Dewi PS, Prasetyo R. Banana cultivars microshoot introduction and plantlet formation using cytokinin and auxin. *Caraka Tani J Sustain Agric*. 2021;36:249–58. <https://doi.org/10.20961/carakatani.v36i2.50425>
15. Justine AK, Kaur N, Savita, Pati PK. Biotechnological interventions in banana: Current knowledge and prospects. *Helion*. 2022;8:e11636. <https://doi.org/10.1016/j.heliyon.2022.e11636>
16. Sanavy SAMM, Moeini MJ. Effects of different hormone combinations and planting beds on growth of single nodes and plantlets resulted from potato meristem culture. *Plant Tissue Cult Biotechnol*. 2003;13:145–50.
17. Wiendi NMA, Putri DD. *In vitro* adventitious shoot proliferation of three basil species (*Ocimum* sp. L.) by addition of naphthalene acetic acid (NAA) and benzyl amino purine (BAP). *J Trop Crop Sci*. 2017;4:108–15. <https://doi.org/10.29244/jtcs.4.3.108-115>
18. Naz S, Aslam F, Ilyas S, Shahzadi K, Tariq A. *In vitro* propagation of tuberose (*Polianthes tuberosa*). *J Med Plants Res*. 2012;6:4107–12. <https://doi.org/10.5897/JMPR12.647>
19. Ashrafi K, Iqrar S, Saifi M, Khan S, Qamar F, Quadri SN, et al. Influence of plant growth regulators on glandular trichome density and steviol glycosides accumulation in *Stevia rebaudiana*. *ACS Omega*. 2022;7:30967–77. <https://doi.org/10.1021/acsomega.2c02957>
20. Rezali NI, Sidik NJ, Saleh A, Osman NI, Adam NAM. The effects of different strength of MS media in solid and liquid media on *in vitro* growth of *Typhonium flagelliforme*. *Asian Pac J Trop Biomed*. 2017;7:151–6. <https://doi.org/10.1016/j.apjtb.2016.11.019>
21. Dönmez D, Erol HM, Biçen B, Şimşek Ö, Kaçar-Aka Y. The effects of different strength of MS media on *in vitro* propagation and rooting of *Spathiphyllum*. *Anadolu J Agric Sci*. 2022;37:583–92. <https://doi.org/10.7161/omuanajas.1082219>
22. Rodboot N, Te-chato S, Yenchan S. Influence of MS medium strengths and types on *in vitro* shoot multiplication and development of *Nymphaea colorata*. *ASEAN J Sci Tech Report*. 2025;28:e258176. <https://doi.org/10.55164/ajstr.v28i4.258176>
23. Asmono SL, Rahmawati, Sjamsijah N. The effect of Murashige and Skoog (MS) modified medium and several types of auxins on the growth of *Stevia rebaudiana* Bertoni *in vitro*. *IOP Conf Ser: Earth Environ Sci*. 2021;672:012001. <https://doi.org/10.1088/1755-1315/672/1/012001>
24. Khiem DV, Huyen PX, Hang NTT, Hoang NTP. *In vitro* regeneration and acclimatization of *Anthurium scherzerianum* Schott plants. *AJB*. 2022;44:99–109. <https://doi.org/10.15625/2615-9023/16548>
25. Nadal MC, de Assis AM, Schuch MW, de Faria RT. Grape-based residue as a substrate in *Oncidium baueri* Lindl. acclimation. *Ornam Hortic*. 2022;28:239–45. <https://doi.org/10.1590/2447-536x.v28i2.2477>

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting

Copyright: © The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium; provided the original author and source are credited (<https://creativecommons.org/licenses/by/4.0/>)

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.