

# In Vitro Seed Germination and Seedling Development of a Rare Indonesian Native Orchid *Phalaenopsis amboinensis*

J.J.Sm

*by* Edy Setiti Wida Utami

---

**Submission date:** 06-Feb-2019 08:43PM (UTC+0800)

**Submission ID:** 1073888113

**File name:** seedling\_germination\_of\_P.\_amboinensis\_Scientifica,\_HINDAWI.pdf (2.2M)

**Word count:** 5143

**Character count:** 26019

## In Vitro Seed Germination and Seedling Development of a Rare Indonesian Native Orchid *Phalaenopsis amboinensis* J.J.Sm

Edy Setiti Wida Utami  and Sucipto Hariyanto

Department of Biology, Faculty of Science and Technology, Universitas Airlangga, Surabaya 60115, Indonesia

Correspondence should be addressed to Edy Setiti Wida Utami; edy-s-w-u@fst.unair.ac.id

Received 9 October 2018; Revised 8 December 2018; Accepted 31 December 2018; Published 3 February 2019

Academic Editor: Shamsul Hayat

Copyright © 2019 Edy Setiti Wida Utami and Sucipto Hariyanto. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Phalaenopsis amboinensis*, an epiphytic orchid, has a great potential for commercial exploitation in the cut-flower industry. It is difficult to propagate vegetatively as it naturally grows slowly. Therefore, there is a need to improve the propagation methods to avoid endangering its natural populations. The objective of this study was to identify the best medium and organic supplements for seed germination and plantlets development of *P. amboinensis*. Seeds from 4-month-old hand-pollinated orchids were sown on different strengths of MS and VW culture media: Murashige and Skoog (MS), 1/2 MS, Vacin and Went (VW), and 1/2 VW. Optimum seed germination, i.e., 90.7%, was achieved on VW medium. VW medium was suitable for seedling formation and allowed 51.4% of seedling development from protocorm within 10 weeks of culture. When 15% (v/v) coconut water was added together with banana homogenate (10 g·L<sup>-1</sup>) to the VW medium, the plantlets grew to the highest length and had the highest dry weight (62.1 mm and 15.5 g, respectively). The roots and leaves of the plantlets grew vigorously in this medium. Plants regenerated via *in vitro* seed germination processes were successfully acclimatized in greenhouse conditions, and the survival rate was more than 85%.

### 1. Introduction

*Phalaenopsis*, the moth orchid, has been recognized as one of the most beautiful flowers in the world [1]. This genus has economic value for pot plant and cut-flower production. However, it is difficult to propagate vegetatively as it naturally grows slowly [2]. *P. amboinensis* is an epiphytic monopodial orchid of tropical origin and is found at an elevation of 500–700 m. *P. amboinensis* from Sulawesi has yellow flowers with brown fine lines, whereas the white-based flowers with brown or reddish brown thick lines are found in Maluku.

*Phalaenopsis amboinensis* is a native species from Indonesia which has a great potential for commercial exploitation in cut-flower industry and is a parent for orchid breeding. The product of plant breeding of *P. amboinensis* with *P. amabilis* could potentially produce a greater flower and prettier color than both parents. The plant breeding of *P. amboinensis* with *P. violacea* produced the hybrid *P. Princess*

Kaiulani, whereas *P. amboinensis* and *P. fasciata* generated the hybrid *P. Golden Pride*. Furthermore, *P. amboinensis* with *P. venosa* produced the hybrid *P. Ambonosa*, whereas breeding of *P. amboinensis* and *P. mannii* generated the hybrid *P. Mambo*. However, the existence of this orchid in native habitat is endangered due to the overexploitation and deforestation. *P. amboinensis* is one of the endemic orchid species protected by the government of Indonesia to conserve the endemic orchid from extinction. The techniques could be conducted by *in situ* or *ex situ* conservation. *Ex situ* conservation could be executed in a botanical garden, orchid nursery, and university. *In vitro* seed culture is a proper method to propagate the endemic or threatened plant species for conservation in order to maintain variability of plant genetics.

Lots of propagation techniques were developed for *Phalaenopsis* species and their hybrids through the *in vitro* culture from various explants, including leaf segments/tissue [3], flower stalk nodes [4], callus and protocorm-like bodies

[5], flower stalks [6], and seeds [7, 8]. However, propagation through *in vitro* seed culture has not yet been achieved in *P. amboinensis* orchid.

The success of seed germination through *in vitro* culture is influenced by several factors, including the types of culture media [9, 10], seed maturity [11, 12], plant growth regulators [13, 14], carbohydrates [15], and organic amendments [16].

In the present study, we evaluated the effects of different strengths of MS and VW media on seed germination and supplementation of coconut water with various concentrations of banana homogenate on the plantlet development of *P. amboinensis*. The reproducible protocol for the production of seedlings from seeds by *in vitro* culture of this species has been established.

## 2. Materials and Methods

**2.1. Plant Material, Surface Sterilization of Capsules, and Collection of Seeds.** *Phalaenopsis amboinensis* J.J.Sm. (Maluku) (Figure 1) was kindly provided by Handoyohardjo Orchids Nursery, East Java, Indonesia. The yellowish green capsules, which are four-month old from hand pollinating, were washed with soapy solution (10 v/v) of Sunlight (commercial detergent, Unilever, Indonesia) for 5 minutes to eliminate the dust, and then it was rinsed 3 times with sterile-distilled water and put on a Petri dish in a laminar flow hood followed by flaming 3 times. The surface-sterilized capsules were slit longitudinally into two sections with a sterile surgical blade in a sterile Petri dish to isolate the seeds.

**2.2. In Vitro Germination on Different Basal Media.** To evaluate the influence of different strengths of MS and VW media on seed germination and protocorm development, the seeds were sown on four media: (1) Vacin and Went (VW) [17], (2) Murashige and Skoog (MS) [18], (3) half-strength MS (1/2 MS macro- and micronutrients), and (4) half-strength VW (1/2 VW macro- and micronutrients). All media were supplemented with 30 g·L<sup>-1</sup> sucrose (Merck, made in Germany) and 3 g·L<sup>-1</sup> peptone (Difco Laboratories Detroit, USA) and solidified with 2 g·L<sup>-1</sup> gellan gum (Phytigel; Sigma Chemical Co., St. Louis, MO). The pH was adjusted to 5.6 with 0.1 M KOH or HCl before the addition of gellan gum. Media were sterilized at 120°C for 15 minutes. Each treatment contained approximately 300 seeds, which were cultured in culture tube loaded with 25 mL of medium. All experiments consisted of three independent replicates with four culture tubes per replicate. All the cultures were maintained under a 16 and 8 h light and darkness, respectively, at 23 ± 2°C.

**2.3. Seed Morphological Observation.** The samples (seeds) were fixed in 2% (v/v) glutaraldehyde in 0.1 M phosphate buffer (pH 7.0) at 4°C for 12 h. The samples were washed in the phosphate buffer at 4°C for 3 times and dehydrated in the ethanol series followed by drying at critical point, affixing to aluminium stubs, and finally coating with gold palladium. The prepared samples were examined and photographed



FIGURE 1: Flowering plant of *Phalaenopsis amboinensis* J.J.Sm. Scale bars: 3 cm.

with a JSM-T100 scanning electron microscope (Jeol, Tokyo, Japan).

**2.4. Histological Analysis.** The seeds were fixed in FAA (70% ethyl alcohol : glacial acetic acid : formaldehyde, 90 : 5 : 5 v/v/v) and dehydrated in ethyl alcohol series, and it was then embedded in paraffin wax for 24 h. Followed by the use of a rotary microtome (Shibuya, Japan) to make longitudinal sections at 10 μm thickness, stain with 1.0% safranin and 1.0% fast green and then mounted with Canada Balsam Synthetic in Xylene (Aldon, USA). Seed histology was observed in light microscope (Olympus FSX100, Japan). Seed and embryo size (length and width) were measured (at the longest and widest axis) using a light microscope with a micrometer. The data length and width were collected in 30 replicates.

**2.5. In Vitro Plantlet Development.** After 10 weeks of culture, seedlings (0.5 cm long with 1-2 leaves and one root) obtained from the *in vitro* seed germination were cultured individually on the fresh VW medium, supplemented with CW 15% (v/v) at various BH concentrations (0, 5, 10, and 15 g·L<sup>-1</sup>), and medium without BH and CW supplementation was used as the control treatment. Each treatment (4 seedlings) was planted in culture tube loaded with 25 mL of medium. All experiments consisted of three independent replicates with five culture tubes per replicate. All the cultures were maintained under a 16 and 8 h light and darkness, respectively, at 23 ± 2°C. After 10 weeks, the number and length of leaves, roots, and plantlet, the max width of leaves, and dry weight of plantlet were recorded.

**2.6. Ex Vitro Plant Acclimatization.** The healthy *in vitro* plantlets with well-developed roots were removed from the culture tube, washed under running tap water, and transplanted to the plastic pots containing a mixture of coal pieces : tree fern roots : sphagnum moss at 1 : 1 : 1 ratio. Potted plants were grown in the green house under 30%–40% natural light and sprayed twice a day with water for



acclimatization. In this experiment, 250 plantlets were transplanted in plastic pots. Every plastic pot was loaded with 5 plantlets. The percentage of plantlets survival was recorded 12 weeks after transplanting, and plantlets survival percent was calculated using the following formula:

$$\frac{\text{no. of plantlets survival}}{\text{no. of plantlets transplanted}} \times 100. \quad (1)$$

**23**  
**2.7. Experimental Design, Data Collection, and Analysis.** The experimental units were set up in a completely randomized design (CRD). Data were subjected to analysis of variance (ANOVA), and the mean values were separated using Duncan's multiple range test (DMRT) with level of significance at  $\alpha = 0.05$  [19]. The statistical package SPSS (Version 20) was used for analysis. Seed germination and protocorm development were observed at 10 weeks after inoculation by a Tension stereomicroscope (Nikon SMZ-1, Japan). The process of seed germination to seedling formation was classified into six groups of embryos development stages (Table 1), which were adapted from Steward and Zettler [20]. Seeds were considered germinated only if the swollen embryo occurred (stage 1, Figure 2(C)). Percentage of seed germination and protocorm development for each treatment were calculated by dividing the amount of seeds in each developmental stage by the total amount of seeds  $\times 100$ .

### **39** **3. Results and Discussion**

**3.1. Seed Germination and Seedling Formation.** The morphological development stages of *P. amboinensis* from embryo to seedling were documented (Figures 2(A)–2(G)). Seed germination of *P. amboinensis* started with swelling embryo and rounding up at about 3 weeks after sowing (WAS) (Figure 2(C)). Six WAS, embryos were discharged from the testa and developed into a round, yellow form protocorm (Figure 2(D)). A shoot apex became visible at one side of the protocorm (Figure 2(E)). When the size of the protocorm became bigger about 3.6 mm, the protocorm developed into elongated shape and the color changed into green, followed by the absorbing hair and first and second leaves formation, respectively (Figure 2(F)). Finally, the roots emerged from the seedling 9 WAS (Figure 2(G)). We found that, during the developmental process, protocorm has changed from round to perfectly round and finally to elongated shape.

**3.2. Seed Morphological Observation and Histological Analysis.** The mature seeds of *P. amboinensis* which were used as explant source of this study are fusiform in shape and dark brown in color (Figures 2(A) and 2(C)). The seeds were very small,  $0.349 \pm 0.006$  mm in length and  $0.058 \pm 0.001$  mm in width. Cellular organization of seed was also simple. It consisted only of an undifferentiated mass of embryo cells, without endosperm, covered by testa (Figure 2(B)). According to Molvray and Chase [21] and Arditti and Ghani [22], the size of very small seeds was one of the most distinctive characteristics in the family of Orchidaceae, so it was

TABLE 1: Seed germination and seedling formation stages of *P. amboinensis* (modified from [20]).

Stage	Description
0	No growth of embryo occurs and testa was found intact
1	Swollen embryo (=germination)
2	Embryo is completely discharged from the testa (=protocorm)
3	Embryo with pointed shoot apex
4	Absorbing hairs are formed on the protocorm surface and one or more leaves emerge
5	Embryo with evident root and two or more leaves (=seedling)

called “dust seeds.” Like seeds, the embryos were also minutes in *P. amboinensis*. Embryo size was  $0.202 \pm 0.004$  mm in length,  $0.048 \pm 0.001$  mm in width, located in centre, and elliptical in shape. Arditti and Ghani [22] and Arditti and Ernst [23] reported that orchid embryo was simple and generally oval or spherical in shape; some consisted of only few cells and most of them had no endosperm.

The embryo in the seeds of orchids generally occupies a very small portion of the seed, but in this study, *P. amboinensis* had the large embryo and it occupied a major part of the seed (Figure 2(B)). The large embryo occupying a major part of the seed was also discovered in *Bulbophyllum rothschildianum* [24].

**18**  
**3.3. Effect of Different Strengths of MS and VW Media on Seed Germination and Protocorm Development of *P. amboinensis* J.J.Sm.** The result of seed germination (Table 2) showed that *P. amboinensis* seed could germinate in all tested media. VW medium gave the highest percentage of germination (97.3%) compared with 1/2 VW (90.7%), 1/2 MS (89.3%), and MS (85.3%).

The result of protocorm growth (Table 2) showed that all tested media supported the protocorm growth. The VW medium was the best for protocorm growth, giving rise to 51.4% protocorm development to stage 5 of seedling significantly higher than those of 1/2 VW (35.3%), 1/2 MS (23.9%), and MS (12.9%). Therefore, the VW medium was the most effective for seed germination and protocorm growth of *P. amboinensis*. The result showed that the VW medium contained higher P level (3.77 mM) than other media 1/2 VW (1.88 mM), MS (1.26 mM), and 1/2 MS (0.63 mM), respectively. This is in conformity with the previous reports that high P concentration in VW medium promoted seed germination in *Vanda teres* [25] and seedling development in *Bulbophyllum nipondhii* [26]. The medium type and strengths influenced significantly toward germination and growth of *P. amboinensis* protocorm. Suzuki et al. [12] also reported that the germination and protocorm development were greatly influenced by different culture media among different species. It should be noted that, different orchid might prefer different types of nutritional support. Mahendran et al. [27] reported a higher percentage of germination in epiphytic orchids

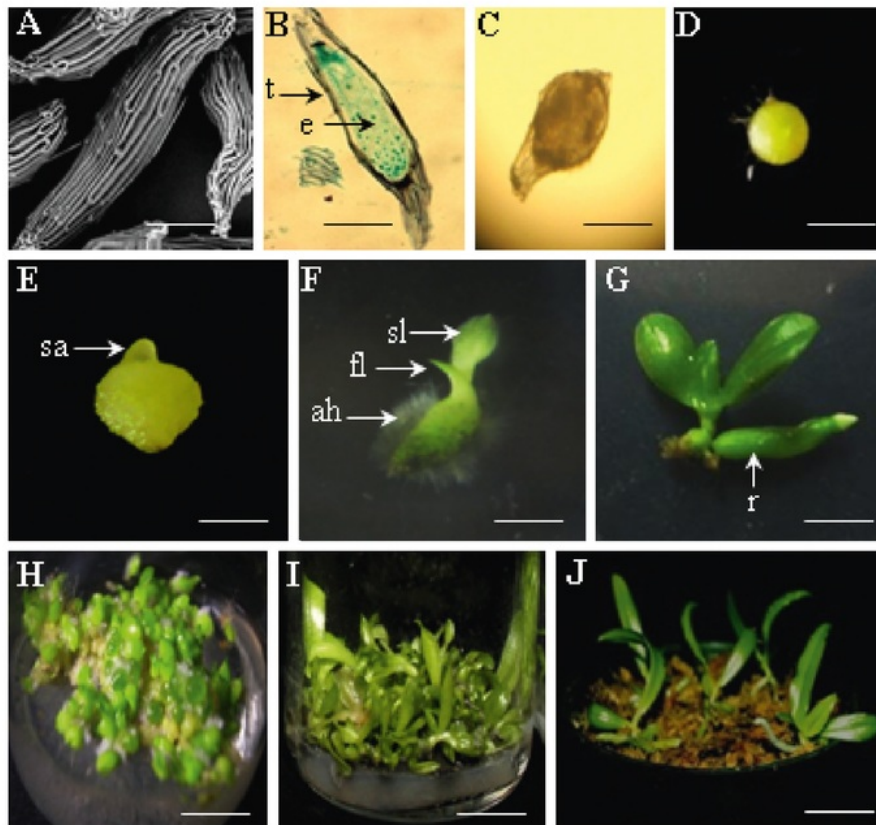


FIGURE 2: *In vitro* seed culture and propagation of *P. amboinensis* J.J.Sm. (A) Mature seed under scanning electron microscopy; (B) stage 0, no germination, long section of viable seed in elliptical embryo shape; (C) stage 1, germination, swollen embryo; (D) stage 2, embryo is completely discharged from the testa; (E) stage 3, embryo with pointed shoot apex; (F) stage 4, appearance of absorbing hair and emergence of leaves; (G) stage 5, seedling stage, root with leaves; (H) *in vitro* seed culture and protocorm development on VW medium eight weeks after inoculation; (I) seedlings *in vitro* on VW medium supplemented with coconut water 15% (v/v) and banana homogenate 10 g·L<sup>-1</sup>; (J) plantlet development on 12 weeks after transplanted to plastic pots. e: embryo; t: testa; sa: shoot apex; ah: absorbing hair; fl: first leaf; sl: second leaf; r: root. Scale bars: (A, B) 100  $\mu$ m, (C) 140  $\mu$ m, (D) 840  $\mu$ m, (E) 1900  $\mu$ m, (F) 3.6 mm, (G) 0.9 mm, (H, I) 1.2 cm, and (J) 1.4 cm.

36

49

TABLE 2: Effect of different strengths of MS and VW media on seed germination and protocorm development of *P. amboinensis* J.J.Sm. within 10 weeks of culture.

Medium	Stage 0	Stage 1 (germination)	Stage 2 (protocorm)	Stage 3	Stage 4	Stage 5 (seedling)	Germination (stages 1–5)
MS	14.7 ± 2.3 <sup>d</sup>	10.2 ± 1.2 <sup>b</sup>	21.4 ± 2.6 <sup>c</sup>	21.1 ± 2.5 <sup>c</sup>	19.7 ± 2.1 <sup>c</sup>	12.9 ± 1.8 <sup>a</sup>	85.3 ± 2.1 <sup>a</sup>
1/2 MS	10.7 ± 2.3 <sup>c</sup>	9.7 ± 1.4 <sup>b</sup>	19.9 ± 2.1 <sup>b</sup>	15.4 ± 2.1 <sup>b</sup>	20.4 ± 2.3 <sup>c</sup>	23.9 ± 1.6 <sup>b</sup>	89.3 ± 2.1 <sup>b</sup>
VW	2.7 ± 1.5 <sup>a</sup>	5.1 ± 1.6 <sup>a</sup>	12.9 ± 1.4 <sup>a</sup>	13.5 ± 1.2 <sup>a</sup>	14.4 ± 1.8 <sup>a</sup>	51.4 ± 1.5 <sup>d</sup>	97.3 ± 1.5 <sup>c</sup>
1/2 VW	9.2 ± 1.5 <sup>b</sup>	10.5 ± 2.6 <sup>c</sup>	14.1 ± 2.3 <sup>a</sup>	13.7 ± 2.1 <sup>a</sup>	17.1 ± 1.5 <sup>b</sup>	35.3 ± 2.1 <sup>c</sup>	90.7 ± 2.8 <sup>b</sup>

Note. Means ± standard errors followed by the same letter within a column are not significantly different based on Duncan's multiple range test at  $P = 0.05$ .

*Cymbidium bicolor* on LO medium than KCM, KC, and MS media. Pradhan et al. [28] reported that MS was the most suitable for germination of *Cymbidium aloifolium* rather than KC, PM, and VW media, whereas dos Santos et al. [29] working with *Brasiliorchis picta*, an epiphytic orchid, found WPM to be significantly higher than KC, 1/2 MS, and MS media. Roy et al. [30] claimed that Phytamax medium was the most suitable for germination and protocorm development of *Vanda coerulea* than Vacin and Went, MS, and Knudson C media.

6

3.4. Effect of 15% (v/v) CW Supplementation with Various Concentrations of Banana Homogenate (BH) on the Plantlet Development of *P. amboinensis* J.J.Sm. Growth and development of plant tissues, *in vitro*, could be enhanced through the addition of various organic supplements such as apple juice, tomato juice, tryptone, peptone, coconut water, banana homogenate, potato homogenate, corn extract, yeast extract, and casein hydrolysate [31–34]. In this study, the organic supplementations with CW and BH were assayed for their effectiveness in the plantlet development of *P. amboinensis*.



TABLE 3: Effect of 15% (v/v) CW supplementation with various concentrations of banana homogenate (BH) on plantlet development of *P. amboinensis* J.J.Sm. within 10 weeks of culture.

Treatments	Root		Leaf			Plantlet	
	No.	Length (mm)	No.	Length (mm)	Max width (mm)	Length (mm)	Dry weight (g)
Control	6.2 ± 1.4 <sup>a</sup>	24.1 ± 1.2 <sup>a</sup>	3.8 ± 0.7 <sup>a</sup>	24.3 ± 1.7 <sup>a</sup>	10.1 ± 1.9 <sup>a</sup>	41.6 ± 1.4 <sup>a</sup>	11.8 ± 2.2 <sup>a</sup>
CW 15% v/v	7.4 ± 1.2 <sup>ab</sup>	31.2 ± 2.2 <sup>b</sup>	6.5 ± 0.7 <sup>b</sup>	36.3 ± 1.2 <sup>b</sup>	12.2 ± 1.6 <sup>ab</sup>	43.7 ± 1.2 <sup>a</sup>	12.2 ± 1.1 <sup>a</sup>
CW 15% v/v + BH 5 g·L <sup>-1</sup>	8.5 ± 1.1 <sup>b</sup>	32.1 ± 2.1 <sup>b</sup>	6.7 ± 0.8 <sup>b</sup>	38.2 ± 1.3 <sup>b</sup>	14.9 ± 1.2 <sup>b</sup>	61.8 ± 0.9 <sup>b</sup>	14.8 ± 0.9 <sup>b</sup>
CW 15% v/v + BH 10 g·L <sup>-1</sup>	8.7 ± 1.4 <sup>b</sup>	32.4 ± 2.4 <sup>b</sup>	7.1 ± 1.3 <sup>b</sup>	36.7 ± 0.9 <sup>b</sup>	15.1 ± 1.1 <sup>b</sup>	62.1 ± 1.3 <sup>b</sup>	15.5 ± 1.4 <sup>b</sup>
CW 15% v/v + BH 15 g·L <sup>-1</sup>	8.5 ± 1.1 <sup>b</sup>	32.3 ± 2.1 <sup>b</sup>	6.9 ± 1.4 <sup>b</sup>	36.5 ± 0.7 <sup>b</sup>	14.8 ± 0.8 <sup>b</sup>	61.9 ± 1.2 <sup>b</sup>	15.2 ± 1.3 <sup>b</sup>

Note: Means ± standard errors followed by the same letter within a column are not significantly different based on Duncan's multiple range test at  $P = 0.05$ .

We have found that the organic supplementation of CW, together with BH, had profound effects upon the growth and development of *P. amboinensis* in terms of root elongation, leaf size, and plantlet elongation (Table 3). Coconut water contains sugars, amino acids, vitamins, enzymes, and organic acids [35]. It moreover contains kinetin [36] which has a cytokinin function and enhances the explant growth and regeneration by inducing cell division. Banana contains carbohydrate, mineral, amino acids, fatty acids, niacin, vitamins, cellulose, polyols, and sterols which are beneficial for further development of plantlets [37]. Arditti [38] reported that BH was a rich source of natural cytokinins, commonly added to orchid media, to stimulate the differentiation and growth of shoots at later stages. Zeng et al. [39] found that leaf size and shoot height of *Paphiopedilum wardii* increased significantly when 100 g·L<sup>-1</sup> BH and 1 g·L<sup>-1</sup> peptone were added on Hyponex NO26 medium. Moreover, Wu et al. [40] observed that the growth of plantlet of *Renanthera imschootiana* increased when 100 g·L<sup>-1</sup> BH, 10% (v/v) CW, and 1 g·L<sup>-1</sup> peptone were added to 1/4 MS medium during the culture period. Chen et al. [41] found that the addition 10 g·L<sup>-1</sup> BH and 1 mg·L<sup>-1</sup> NAA to a medium during the culture period was the most effective toward the seedling formation of *Paphiopedilum spicerianum*.

3.5. *Ex Vitro Plant Acclimatization.* After 12 weeks of transplantation, plantlets were successfully acclimatized to greenhouse conditions, and the survival rate was more than 85%.

#### 4. Conclusion

The results of this study allow the establishment of a protocol for *in vitro* propagation of *P. amboinensis* J.J.Sm. Vacin and Went medium is recommended for the *in vitro* germination and protocorm development. The seedlings exhibited vigorous growth and root development on VW medium with the addition of CW 15% (v/v) + BH 10 g·L<sup>-1</sup>. This protocol is an efficient means for the large-scale propagation of *P. amboinensis*, which may be applicable for other *Phalaenopsis* species.

#### Data Availability

The data related of this article are available from the corresponding author upon request.

#### Conflicts of Interest

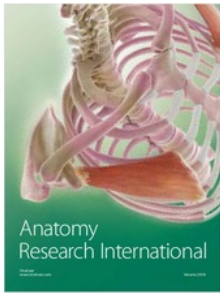
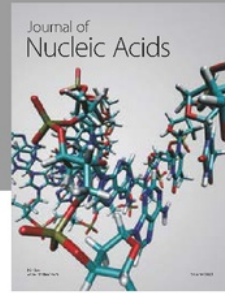
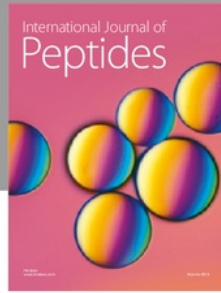
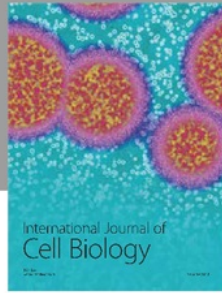
The authors declare that they have no conflicts of interest.

#### References

- Y. T. Wang, "Flourishing market for potted orchids," *Flower Technologies*, vol. 7, no. 5, pp. 2–5, 2004.
- P. Kosir, S. Skof, and Z. Luthar, "Direct shoot regeneration from nodes of *Phalaenopsis* orchids," *Acta Agriculturae Slovenica*, vol. 83, no. 2, pp. 233–242, 2004.
- A. Datta, M. Zahara, P. Boonkorkaev, and A. Mishra, "Effect of plant growth regulators on the growth and direct shoot formation from leaf explants of the hybrid *Phalaenopsis* 'Pink'," *Acta Agriculturae Slovenica*, vol. 111, no. 1, pp. 5–16, 2018.
- K. Balilashaki and G. G. Ghehsareh, "Micropropagation of *Phalaenopsis amabilis* var. 'Manila' by leaves obtained from *in vitro* culturing the nodes of flower stalks," *Notulae Scientia Biologicae*, vol. 8, no. 2, pp. 164–169, 2016.
- A. Niknejad, M. A. Kadir, and S. B. Kadzimin, "In vitro plant regeneration from protocorms-like bodies (PLBs) and callus of *Phalaenopsis gigantea* (Epidendroideae: Orchidaceae)," *African Journal of Biotechnology*, vol. 10, no. 56, pp. 11808–11816, 2011.
- M. Y. Chung, A. H. Naing, K. Khatun, H. G. Ahn, K. B. Lim, and C. K. Kim, "In vitro propagation of phalaenopsis hybrid 'Little gem' by culturing apical part and axillary bud of flower stalk," *Journal of Plant Biotechnology*, vol. 43, no. 4, pp. 438–443, 2016.
- H. Lesa, N. Ceranic, D. Kastelec, and Z. Luthar, "Asymbiotic seed germination of *Phalaenopsis* Blume orchids after hand pollination," *Acta Agriculturae Slovenica*, vol. 99, no. 1, pp. 5–11, 2012.
- K. Balilashaki, S. Gantait, R. Naderi, and M. Vahedi, "Capsule formation and asymbiotic seed germination in some hybrids of *Phalaenopsis*, influenced by pollination season and capsule maturity," *Physiology and Molecular Biology of Plants*, vol. 21, no. 3, pp. 341–347, 2015.
- S. M. Vudala and L. L. F. Ribas, "Seed storage and asymbiotic germination of *Hadrolaelia grandis* (Orchidaceae)," *South African Journal of Botany*, vol. 108, pp. 1–7, 2017.
- M. M. Hossain and R. Dey, "Multiple regeneration pathways in *Spathoglottis plicata* Blume—a study in vitro," *South African Journal of Botany*, vol. 85, pp. 56–62, 2013.
- W. Udomdee, P. J. Wen, C. Y. Lee, S. W. Chin, and F. C. Chen, "Effect of sucrose concentration and seed maturity on *in vitro* germination of *Dendrobium nobile* hybrids," *Plant Growth Regulation*, vol. 72, no. 3, pp. 249–255, 2013.
- R. M. Suzuki, V. C. Moreira, R. Pescador, and F. W. Melo, "Asymbiotic seed germination and *in vitro* seedling

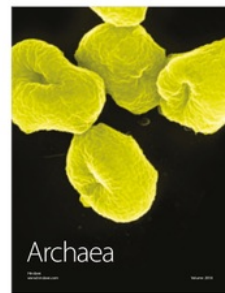
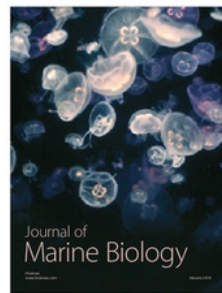
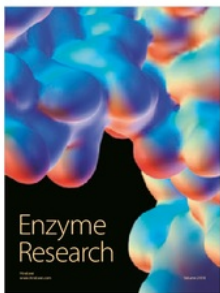
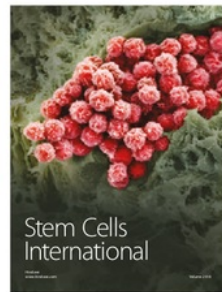
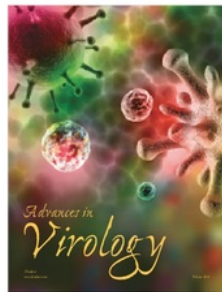
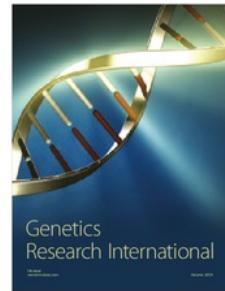
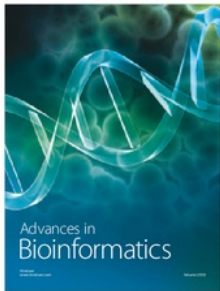
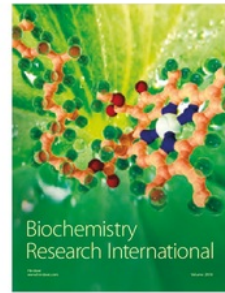
- development of the threatened orchid *Hoffmannseggella cinnaberina*," *Vitro Cellular and Developmental Biology-Plant*, vol. 48, no. 5, pp. 500–511, 2012.
- [13] M. Paudel, S. Pradhan, and B. Pant, "In vitro seed germination and seedling development of *Esmeralda clarkei* Rchb.f. (Orchidaceae)," *Plant Tissue Culture and Biotechnology*, vol. 22, no. 2, pp. 107–111, 2012.
- [14] I. N. Vogel and A. F. Macedo, "Influence of IAA, TDZ, and light quality on asymbiotic germination, protocorm formation, and plantlet development of *Cyrtopodium glutiniferum* Raddi, a medicinal orchid," *Plant Cell, Tissue and Organ Culture*, vol. 104, no. 2, pp. 147–155, 2010.
- [15] Y. S. Huh, J. K. Lee, S. Y. Nam, E. Y. Hong, K. Y. Paek, and S. W. Son, "Effects of altering medium strength and sucrose concentration on *in vitro* germination and seedling growth of *Cypripedium macranthos* Sw.," *Journal of Plant Biotechnology*, vol. 43, no. 1, pp. 132–137, 2016.
- [16] S. Zeng, Y. Zhang, J. A. Teixeira da Silva, K. Wu, J. Zhang, and J. Duan, "Seed biology and *in vitro* seed germination of *Cypripedium*," *Critical Reviews in Biotechnology*, vol. 34, no. 4, pp. 358–371, 2013.
- [17] E. F. Vacin and F. W. Went, "Some pH changes in nutrient solutions," *Botanical Gazette*, vol. 110, no. 4, pp. 605–613, 1949.
- [18] T. Murashige and F. Skoog, "A revised medium for rapid growth and bioassays with tobacco tissue culture," *Physiologia Plantarum*, vol. 15, no. 3, pp. 437–497, 1962.
- [19] D. B. Duncan, "Multiple range and multiple F tests," *Biometrics*, vol. 11, no. 1, pp. 1–42, 1955.
- [20] S. L. Stewart and L. W. Zettler, "Symbiotic germination of three semi-aquatic rein orchids (*Habenaria repens*, *H. quinqueveta*, *H. macroceratitis*) from Florida," *Aquatic Botany*, vol. 72, no. 1, pp. 25–35, 2002.
- [21] M. Molvray and M. Chase, "Seed morphology," in *Genera Orchidacearum, Volume 1: General Introduction, Apostosiodaeae, Cypripedioideae*, A. M. Pridgeon, P. J. Cribb, M. W. Chase, and F. N. Rasmussen, Eds., pp. 59–66, Oxford University Press, Oxford, UK, 1999.
- [22] J. Arditti and A. K. A. Ghani, "Tansley review no. 110," *New Phytologist*, vol. 145, no. 3, pp. 367–421, 2001.
- [23] J. Arditti and R. Ernst, "Physiology of germinating orchid seed," in *Orchid Biology Reviews and Perspectives*, J. Arditti, Ed., Vol. I, Cornell University Press, Ithaca, NY, USA, 1984.
- [24] J. Augustine, Yogendrakumar, and J. Sharma, *Orchids of India-II, Biodiversity and Status of Bulbophyllum Thou*, Daya Publishing House, Trinagar, New Delhi, India, 2001.
- [25] P. Sinha and S. K. Roy, "Regeneration of an indigenous orchid *Vanda teres* (Roxb.) Lindl. through *in vitro* culture," *Plant Tissue Culture*, vol. 14, no. 1, pp. 55–61, 2004.
- [26] W. Pakum, S. Watthana, K. O. Srimuang, and A. Kongbangkerd, "Influence of medium component on *in vitro* propagation of Thai's endangered orchid: *Bulbophyllum nipondhii* seidenf.," *Plant Tissue Culture and Biotechnology*, vol. 26, no. 1, pp. 37–46, 2016.
- [27] G. Mahendran, V. Muniappan, M. Ashwini, T. Muthukumar, and V. Narmatha Bai, "Asymbiotic seed germination of *Cymbidium bicolor* Lindl. (Orchidaceae) and the influence of mycorrhizal fungus on seedling development," *Acta Physiologiae Plantarum*, vol. 35, no. 3, pp. 829–840, 2012.
- [28] S. Pradhan, B. Tiruwa, B. R. Subedee, and B. Pant, "In vitro germination and propagation of a threatened medicinal orchid, *Cymbidium aloifolium* (L.) Sw. through artificial seed," *Asian Pacific Journal of Tropical Biomedicine*, vol. 4, no. 12, pp. 971–976, 2014.
- [29] S. A. dos Santos, E. D. C. Smidt, A. A. Padial, and L. L. F. Ribas, "Asymbiotic seed germination and *in vitro* propagation of *Brasiliorchis picta*," *African Journal of Biotechnology*, vol. 15, no. 6, pp. 134–144, 2016.
- [30] A. R. Roy, R. S. Patel, V. V. Patel, S. Sajeev, and B. C. Deka, "Asymbiotic seed germination, mass propagation and seedling development of *Vanda coerulea* Griff ex.Lindl. (Blue Vanda): an *in vitro* protocol for an endangered orchid," *Scientia Horticulturae*, vol. 128, no. 3, pp. 325–331, 2011.
- [31] A. Gupta, "Asymbiotic seed germination in Orchids: role of organic additives," *International Advanced Research Journal in Sciences, Engineering and Technology*, vol. 3, no. 5, pp. 143–147, 2016.
- [32] M. A. S. Prando, P. Chiavazza, A. Faggio, and C. Contessa, "Effect of coconut water and growth regulator supplements on *in vitro* propagation of *Corylus avellana* L.," *Scientia Horticulturae*, vol. 171, pp. 91–94, 2014.
- [33] Y. Zhang, Y.-I. Lee, L. Deng, and S. Zhao, "Asymbiotic germination of immature seeds and the seedling development of *Cypripedium macranthos* Sw., an endangered lady's slipper orchid," *Scientia Horticulturae*, vol. 164, pp. 130–136, 2013.
- [34] S. Kaur and K. K. Bhutani, "Asymbiotic seed germination and multiplication of an endangered orchid *Paphiopedilum venustum* (Wall. Ex Sims.)," *Acta Societatis Botanicorum Poloniae*, vol. 85, no. 2, pp. 1–11, 2016.
- [35] J. W. Yong, L. Ge, Y. F. Ng, and S. N. Tan, "The chemical composition and biological properties of coconut (*Cocos nucifera* L.) water," *Molecules*, vol. 14, no. 12, pp. 5144–5164, 2009.
- [36] L. Ge, J. W. H. Yong, N. K. Goh, L. S. Chia, S. N. Tan, and E. S. Ong, "Identification of kinetin and kinetin riboside in coconut (*Cocos nucifera* L.) water using a combined approach of liquid chromatography-tandem mass spectrometry, high performance liquid chromatography and capillary electrophoresis," *Journal of Chromatography B*, vol. 829, no. 1–2, pp. 26–34, 2005.
- [37] S. Tamura, "Amino acid composition of food in Japan. Japan Agric," *Research Quarterly*, vol. 5, pp. 56–60, 1970.
- [38] J. Arditti, *Micropropagation of Orchids*, Blackwell Publishing, vol. I, 2nd edition, 2008.
- [39] S. Zeng, K. Wu, J. A. Teixeira da Silva et al., "Asymbiotic seed germination, seedling development and reintroduction of *Paphiopedilum wardii* Sumerh., an endangered terrestrial Orchid," *Scientia Horticulturae*, vol. 138, pp. 198–209, 2012.
- [40] K. Wu, S. Zeng, D. Lin et al., "In vitro propagation and reintroduction of the endangered *Renanthera imschootiana* Rolfe," *PLoS One*, vol. 9, no. 10, Article ID e110033, 2014.
- [41] Y. Chen, U. M. Goodale, X.-L. Fan, and J.-Y. Gao, "Asymbiotic seed germination and *in vitro* seedling development of *Paphiopedilum spicerianum*: an orchid with an extremely small population in China," *Global Ecology and Conservation*, vol. 3, pp. 367–378, 2015.





**Hindawi**

Submit your manuscripts at  
[www.hindawi.com](http://www.hindawi.com)





# In Vitro Seed Germination and Seedling Development of a Rare Indonesian Native Orchid *Phalaenopsis amboinensis*

J.J.Sm

---

## ORIGINALITY REPORT

---

21%

SIMILARITY INDEX

13%

INTERNET SOURCES

17%

PUBLICATIONS

0%

STUDENT PAPERS

---

## PRIMARY SOURCES

---

- 1 Songjun Zeng, Jia Wang, Kunlin Wu, Jaime A. Teixeira da Silva, Jianxia Zhang, Jun Duan. "In vitro propagation of *Paphiopedilum hangianum* Perner & Gruss", *Scientia Horticulturae*, 2013  
Publication 2%
  - 2 [banglajol.info](http://banglajol.info)  
Internet Source 1%
  - 3 [www.rroij.com](http://www.rroij.com)  
Internet Source 1%
  - 4 Karla Quiroz, Jessica Saavedra, Hermine Vogel, Gabriela Verdugo, Peter D. S. Caligari, Rolando García-González. " In Vitro Asymbiotic Germination for Micropropagation of the Recalcitrant Terrestrial Orchid (Orchidaceae) ", *Applications in Plant Sciences*, 2017  
Publication 1%
  - 5 [kb.psu.ac.th](http://kb.psu.ac.th)  
Internet Source 1%
-

6	<a href="http://tci-thaijo.org">tci-thaijo.org</a> Internet Source	1%
7	Kunlin Wu, Songjun Zeng, Jaime A. Teixeira da Silva, Zhilin Chen, Jianxia Zhang, Yuesheng Yang, Jun Duan. "Efficient regeneration of <i>Renanthera Tom Thumb</i> 'Qilin' from leaf explants", <i>Scientia Horticulturae</i> , 2012 Publication	1%
8	<a href="http://www.jspcmb.jp">www.jspcmb.jp</a> Internet Source	1%
9	Rajkumar Kishor, P.S. Sha Valli Khan, G.J. Sharma. "Hybridization and in vitro culture of an orchid hybrid <i>Ascocenda</i> 'Kangla'", <i>Scientia Horticulturae</i> , 2006 Publication	1%
10	<a href="http://www.bioone.org">www.bioone.org</a> Internet Source	1%
11	<a href="http://export.arxiv.org">export.arxiv.org</a> Internet Source	<1%
12	<a href="http://www.poultryscience.org">www.poultryscience.org</a> Internet Source	<1%
13	<a href="http://media.neliti.com">media.neliti.com</a> Internet Source	<1%
14	<a href="http://www.press.ntu.edu.tw">www.press.ntu.edu.tw</a> Internet Source	<1%



15

A.R. Roy, R.S. Patel, V.V. Patel, S. Sajeev, Bidyut C. Deka. "Asymbiotic seed germination, mass propagation and seedling development of *Vanda coerulea* Griff ex.Lindl. (Blue Vanda): An in vitro protocol for an endangered orchid", *Scientia Horticulturae*, 2011

Publication

&lt;1%

16

[biosains.mipa.uns.ac.id](http://biosains.mipa.uns.ac.id)

Internet Source

&lt;1%

17

"Thidiazuron: From Urea Derivative to Plant Growth Regulator", Springer Nature, 2018

Publication

&lt;1%

18

Teixeira da Silva, Jaime A., Elena A. Tsavkelova, Tzi Bun Ng, S. Parthibhan, Judit Dobránszki, Jean Carlos Cardoso, M. V. Rao, and Songjun Zeng. "Asymbiotic in vitro seed propagation of *Dendrobium*", *Plant Cell Reports*, 2015.

Publication

&lt;1%

19

VERMA, Jagdeep, SHARMA, Kusum, THAKUR, Kranti, SEMBI, Jaspreet Kaur and VIJ, Suraj Prakash. "Study on seed morphometry of some threatened Western Himalayan orchids", *TÜBİTAK*, 2014.

Publication

&lt;1%

20

[www.locus.ufv.br](http://www.locus.ufv.br)

Internet Source

&lt;1%

21	<a href="http://www.wdc-jp.biz">www.wdc-jp.biz</a> Internet Source	<1%
22	<a href="http://www.lankesteriana.org">www.lankesteriana.org</a> Internet Source	<1%
23	Meutia Zahara, Avishek Datta, Patchareeya Boonkorkaew. "Effects of sucrose, carrot juice and culture media on growth and net CO2 exchange rate in Phalaenopsis hybrid 'Pink'", <i>Scientia Horticulturae</i> , 2016 Publication	<1%
24	Rogério Mamoru Suzuki, Vania Carolina Moreira, Rosete Pescador, Wagner de Melo Ferreira. "Asymbiotic seed germination and in vitro seedling development of the threatened orchid <i>Hoffmannseggella cinnabarina</i> ", <i>In Vitro Cellular &amp; Developmental Biology - Plant</i> , 2012 Publication	<1%
25	<a href="http://www.jircas.affrc.go.jp">www.jircas.affrc.go.jp</a> Internet Source	<1%
26	<a href="http://academicjournals.org">academicjournals.org</a> Internet Source	<1%
27	<a href="http://isb.emnuvens.com.br">isb.emnuvens.com.br</a> Internet Source	<1%
28	"Sampling the Egg Population", <i>Mosquito Ecology</i> , 2008 Publication	<1%



29

[pbsociety.org.pl](http://pbsociety.org.pl)

Internet Source

<1%

---

30

Nanekar, Vikas, Varsha Shriram, Vinay Kumar, and P. B. Kavi Kishor. "Asymbiotic In vitro Seed Germination and Seedling Development of *Eulophia nuda* Lindl., An Endangered Medicinal Orchid", Proceedings of the National Academy of Sciences India Section B Biological Sciences, 2014.

Publication

<1%

---

31

[nopr.niscair.res.in](http://nopr.niscair.res.in)

Internet Source

<1%

---

32

Sonia Abraham. "Asymbiotic seed germination and in vitro conservation of *Coelogyne nervosa* A. Rich. an endemic orchid to Western Ghats", Physiology and Molecular Biology of Plants, 05/30/2012

Publication

<1%

---

33

Pant, Bijaya. "Medicinal orchids and their uses: Tissue culture a potential alternative for conservation", African Journal of Plant Science, 2013.

Publication

<1%

---

34

[portal.koreascience.or.kr](http://portal.koreascience.or.kr)

Internet Source

<1%

---

35

[botanica.uaic.ro](http://botanica.uaic.ro)

Internet Source

<1%

36

[docplayer.net](http://docplayer.net)

Internet Source

<1%

37

[www.tandfonline.com](http://www.tandfonline.com)

Internet Source

<1%

38

[www.scielo.cl](http://www.scielo.cl)

Internet Source

<1%

39

[rdo.psu.ac.th](http://rdo.psu.ac.th)

Internet Source

<1%

40

Mahendran, G., V. Muniappan, M. Ashwini, T. Muthukumar, and V. Narmatha Bai.

"Asymbiotic seed germination of *Cymbidium bicolor* Lindl. (Orchidaceae) and the influence of mycorrhizal fungus on seedling development", *Acta Physiologiae Plantarum*, 2013.

Publication

<1%

41

[vdocuments.site](http://vdocuments.site)

Internet Source

<1%

42

[edoc.ub.uni-muenchen.de](http://edoc.ub.uni-muenchen.de)

Internet Source

<1%

43

[journalarticle.ukm.my](http://journalarticle.ukm.my)

Internet Source

<1%



- 
- 44 [agritrop.cirad.fr](http://agritrop.cirad.fr) Internet Source <1%
- 
- 45 [www.scientific.net](http://www.scientific.net) Internet Source <1%
- 
- 46 SOUZA, JOANNE M.M., STRAHILL BERKOV, and ALBERDAN S. SANTOS. "Improvement of friable callus production of *Boerhaavia paniculata* Rich and the investigation of its lipid profile by GC/MS", *Anais da Academia Brasileira de Ciências*, 2014. Publication <1%
- 
- 47 Bembemcha Pebam, Rajkumar Kishor, V. Narmatha Bai. "In vitro immature embryo germination and propagation of *Vanda stangeana* Rchb. f., an orchid endemic to India", *Horticulture, Environment, and Biotechnology*, 2016 Publication <1%
- 
- 48 Shreeti Pradhan, Tripti Regmi, Bijaya Pant. "Comparative study of encapsulated and non-encapsulated protocorms for the propagation of *Cymbidium aloifolium* (L.) Sw. on two different media", *Botanica Orientalis: Journal of Plant Science*, 2015 Publication <1%
- 
- 49 Sureeporn Nontachaiyapoom, Sawitree Sasirat, <1%

Leka Manoch. "Symbiotic seed germination of Grammatophyllum speciosum Blume and Dendrobium draconis Rchb. f., native orchids of Thailand", Scientia Horticulturae, 2011

Publication

---

50

Methods in Molecular Biology, 2013.

Publication

---

<1%

51

Lin Fu. "Embryology of the dioecious Woonyoungia septentrionalis (Magnoliaceae)", Nordic Journal of Botany, 04/2012

Publication

---

<1%

52

Zeng, Songjun, Weichang Huang, Kunlin Wu, Jianxia Zhang, Jaime A. Teixeira da Silva, and Jun Duan. "In vitro propagation of Paphiopedilum orchids", Critical Reviews in Biotechnology, 2015.

Publication

---

<1%

---

Exclude quotes      Off

Exclude matches      Off

Exclude bibliography      On

# In Vitro Seed Germination and Seedling Development of a Rare Indonesian Native Orchid *Phalaenopsis amboinensis*

J.J.Sm

---

GRADEMARK REPORT

---

FINAL GRADE

**/0**

GENERAL COMMENTS

**Instructor**

---

PAGE 1

---

PAGE 2

---

PAGE 3

---

PAGE 4

---

PAGE 5

---

PAGE 6

---

PAGE 7

---