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Optimizing Clorox Concentration and Soaking Time for In Vitro Sterilization of Porang (*Amorphophallus muelleri* Blume) Bulbil Explants

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Abstract:
Porang (*Amorphophallus muelleri* Blume) is an export-oriented tuber crop valued for its glucomannan, but its propagation is constrained by slow, season-dependent multiplication and by heavy contamination during in vitro culture initiation. This study aimed to determine the optimal combination of Clorox (commercial sodium hypochlorite) concentration and soaking time for the in vitro sterilization of porang bulbil explants. A 3 × 3 factorial completely randomized design was used, combining Clorox concentrations of 20%, 30%, and 40% (v/v) with soaking times of 10, 15, and 20 minutes, each replicated three times. Explants were cultured on hormone-free Murashige and Skoog medium and evaluated for sterile and viable explants, time to shoot emergence, number of shoots, and shoot height. Data were analyzed by two-way ANOVA followed by Duncan's multiple range test. Soaking time significantly affected the percentage of sterile and viable explants, which was highest at 15 minutes (77.05%) and statistically similar at 10 minutes (68.29%). Clorox concentration significantly affected shoot emergence and shoot height, with 30% Clorox giving the earliest emergence (9.00 days after planting) and the tallest shoots (0.950 cm). No interaction was detected. Therefore, 30% Clorox for 10 minutes is recommended as an efficient sterilization protocol for porang bulbils.

Keywords:
amorphophallus muelleri, bulbil explant, micropropagation, sodium hypochlorite, surface sterilization

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INTRODUCTION

Porang (*Amorphophallus muelleri* Blume) is a tuberous aroid native to the forests of Indonesia and has become one of the country's fastest-growing export commodities. Its corms are rich in glucomannan, a highly viscous soluble dietary fiber used as a gelling and thickening agent in the food industry and as a functional ingredient with hypoglycemic, cholesterol-lowering, prebiotic, and anti-obesity effects (Devaraj et al., 2019). Rising demand from importing countries, together with national export programs, has encouraged rapid expansion of porang cultivation (Riptanti et al., 2022). However, the supply of high-quality planting material has not kept pace. Farmers still rely mainly on bulbils, corms, and seeds, which have long dormancy periods, low multiplication rates, and uneven availability in terms of quantity, quality, and continuity (Dermoredjo et al., 2021; Hardjo et al., 2023).

Micropropagation offers a practical route to overcome this bottleneck because it can produce large numbers of uniform, pathogen-free plantlets year-round, regardless of the growing season

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(Cardoso et al., 2018). Several in vitro systems have already been developed for porang, including direct shoot organogenesis, callus-mediated regeneration, and somatic embryogenesis from bulbil and leaf explants (Hardjo et al., 2023; Oktavia et al., 2024; Restanto et al., 2024a, 2024b). All of these systems, however, depend on a first step that is often overlooked: obtaining explants that are both free from microorganisms and still physiologically alive. Bulbils and corms develop in close contact with soil and leaf litter, so they carry a dense surface population of fungi and bacteria, and they may also harbor endophytic microorganisms inside their tissues (Quambusch and Winkelmann, 2018; Abdalla et al., 2022). As a result, contamination during culture initiation remains one of the main causes of failure in porang tissue culture, and the reported proportions of clean explants are frequently modest (Adawiyah et al., 2021; Irawati et al., 2023).

Sodium hypochlorite (NaOCl), commonly used as diluted commercial bleach such as Clorox®, is the most widely used surface sterilant in plant tissue culture because it is inexpensive, readily available, and active against a broad spectrum of microorganisms. In water, NaOCl forms hypochlorous acid (HOCl) and hypochlorite ions, which oxidize proteins, membrane lipids, and nucleic acids and rapidly kill microbial cells (da Cruz Nizer et al., 2020). This oxidative action, however, is not selective. The same reactive chlorine species can injure plant cells, trigger phenolic oxidation and browning, and reduce the explant's regenerative capacity (Amente and Chimdessa, 2021). Both the antimicrobial efficacy and the phytotoxicity of NaOCl are governed by two adjustable variables, namely concentration and exposure time. Studies on chrysanthemum, Melia azedarach, apple rootstocks, Castanopsis argentea, breadfruit, and kepel consistently show that insufficient treatment leaves contaminants alive, whereas excessive treatment kills or weakens the explant, and that the optimal window differs among species and explant types (Asni Setiani et al., 2018; Hesami et al., 2019; Ahmadpoor et al., 2022; Chika et al., 2022; Handayani et al., 2022; Lal et al., 2023).

A further complication is that contamination and viability do not always respond in the same direction to a given treatment. In Melia azedarach, adjusting the pH of NaOCl lowered microbial contamination but reduced explant viability and subsequent callus growth (Ahmadpoor et al., 2022), and in chrysanthemum, contamination frequency and explant viability showed different sensitivities to the sterilant and immersion time (Hesami et al., 2019). An explant that is merely free from contaminants is therefore not necessarily good starting material; it must also retain the capacity to resume growth quickly. For this reason, a sterilization protocol should be judged not only by the percentage of clean cultures but also by early developmental responses, such as the timing and vigor of shoot emergence. Such an integrated evaluation is particularly important for propagules with large storage tissues, such as porang bulbils, in which surface injury may delay bud activation without causing visible death of the explant.

For porang, the available evidence is still fragmented. Khoirunnisa and Mercuriani (2022) obtained the lowest tuber explant contamination (3.7%) with a graded treatment of 20% Clorox for 10 minutes, followed by 10% Clorox for 7 minutes. Adawiyah et al. (2021) compared five sterilization sequences and concluded that bulbils were more suitable explants than tubers, while Irawati et al. (2023) reported that bulbils responded best to a combination of cefotaxime, mercuric chloride, and NaOCl. These studies compared fixed, multi-step protocols rather than systematically varying NaOCl concentration and soaking time, and most evaluated contamination alone without following the explant's subsequent growth. Consequently, it remains unclear how each factor, and their possible interaction, affects both asepsis and the early development of porang bulbils. To our knowledge, no study has yet optimized these two variables simultaneously in a factorial design for porang bulbils.

This study therefore aimed to determine the optimal combination of Clorox concentration and soaking time for the in vitro sterilization of porang bulbil explants. Specifically, it examined the main

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and interactive effects of the two factors on (i) the percentage of sterile and viable explants and (ii) early explant growth, expressed as time to shoot emergence, number of shoots, and shoot height. We hypothesized that an intermediate concentration combined with a moderate soaking time would provide the best balance between sterilization efficacy and explant vitality.

METHOD

Study Site and Experimental Design

The experiment was conducted from June to September 2025 at the Plant Tissue Culture Laboratory, Politeknik Negeri Jember, East Java, Indonesia. A factorial experiment arranged in a completely randomized design (CRD) was used with two factors. The first factor was Clorox concentration (S), consisting of three levels: S1 = 20%, S2 = 30%, and S3 = 40% (v/v), prepared by diluting the commercial product with sterile distilled water. The second factor was soaking time (D), also consisting of three levels: D1 = 10 minutes, D2 = 15 minutes, and D3 = 20 minutes. The combination of the two factors produced nine treatments (S1D1 to S3D3). Each treatment was replicated three times, giving 27 experimental units. The number of replicates satisfied Federer's criterion, $(t - 1)(r - 1) \geq 15$, where t is the number of treatments and r is the number of replicates; with t = 9, the minimum value of r is 3. Treatments were allocated to experimental units at random, and culture bottles were placed randomly on the culture racks to avoid positional bias.

The observations were analyzed according to the linear model of a two-factor CRD: $Y_{ijk} = \mu + S_i + D_j + (SD)_{ij} + \varepsilon_{ijk}$, where Y_{ijk} is the observed value for the k-th replicate receiving the i-th Clorox concentration and the j-th soaking time, μ is the general mean, Si is the effect of the i-th concentration, Dj is the effect of the j-th soaking time, (SD)ij is the interaction effect, and ε_{ijk} is the random error.

Plant Material

Bulbils of porang (Amorphophallus muelleri Blume) were obtained from farmers in Situbondo Regency, East Java, Indonesia. The bulbils were first-generation propagules harvested one week before use. Only intact and healthy bulbils, 10–45 mm in diameter, with a light to dark brown skin and free from visible wounds, rot, or insect damage, were selected as explant sources. Selecting propagules of a similar age and physiological condition was intended to reduce variation in microbial load and in regeneration capacity among experimental units.

Explant Pre-treatment and Sterilization Treatments

Sterilization was performed according to the method of Adawiyah et al. (2021), with modifications. The complete sequence is summarized in Table 1. Bulbils were first rinsed under running tap water for 10 minutes to remove soil particles, then soaked in a detergent solution (4 mL/200 mL) for 30 minutes and in a 5% fungicide–bactericide mixture for 12 hours. They were then immersed in 30% Clorox containing Tween-20 (20 drops/200 mL) for 15 minutes, followed by 70% ethanol for 15 minutes. At this stage, the bulbils were exposed to the experimental treatment, namely the assigned Clorox concentration (20%, 30%, or 40%) and soaking time (10, 15, or 20 minutes). After treatment, the bulbils were immersed in 0.1% mercuric chloride ($HgCl_2$) for 10 minutes and rinsed three times with sterile distilled water to remove residual sterilant. The final steps were carried out under aseptic conditions in a laminar airflow cabinet. Because all explants received the same pre-treatment and post-treatment steps, differences among treatments can be attributed to the Clorox concentration and soaking time applied in step 6.

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Table 1. Sequence of explant sterilization applied to porang bulbils

Step	Procedure	Agent / concentration	Duration
1	Washing under running tap water	–	10 min
2	Soaking in detergent solution	4 mL/200 mL	30 min
3	Soaking in fungicide–bactericide mixture	5%	12 h
4	Soaking in Clorox with Tween-20	30% + 20 drops/200 mL	15 min
5	Soaking in ethanol	70%	15 min
6	Treatment: Clorox (factor S × D)	20%, 30%, or 40% (v/v)	10, 15, or 20 min
7	Soaking in mercuric chloride ($HgCl_2$)	0.1%	10 min
8	Rinsing with sterile distilled water	–	3 times

Note: Step 6 is the experimental treatment; all other steps were identical for every experimental unit.

Culture Medium, Inoculation, and Incubation

Hormone-free Murashige and Skoog medium (MS0) was used as the culture medium. The medium was supplemented with 30 g/L sucrose, solidified with 8 g/L agar, and adjusted to pH 5.8 before sterilization in an autoclave at 121 °C for 15 minutes. A growth-regulator-free medium was deliberately chosen so that the observed responses reflected the effects of the sterilization treatments and the intrinsic regenerative capacity of the bulbils, rather than the influence of exogenous hormones. Sterilized explants were inoculated individually, one explant per culture bottle, under aseptic conditions in the laminar airflow cabinet. Cultures were incubated in the culture room at 25 ± 2 °C under a 16-hour light and 8-hour dark photoperiod.

Observed Variables

Cultures were observed from 7 to 30 days after planting (DAP). Four variables were recorded. (1) The percentage of sterile and viable explants was calculated as the number of explants that showed no visible fungal or bacterial growth on the explant or medium and remained alive (green or fresh, not necrotic), divided by the total number of explants cultured in the experimental unit, multiplied by 100. (2) Time to shoot emergence was recorded as the number of days from planting until the first shoot bud became visible on the explant. (3) The number of shoots was counted as the number of shoots formed per explant at the end of the observation period. (4) Shoot height was measured in centimeters from the base to the tip of the shoot at the end of the observation period.

Statistical Analysis

Data were subjected to a two-way analysis of variance (ANOVA) in a factorial CRD to test the main effects of Clorox concentration and soaking time, as well as their interaction. The calculated F values were compared with tabulated F values at the 5% and 1% significance levels. When a factor had a significant effect, differences among its levels were separated using Duncan's multiple range test (DMRT) at the corresponding significance level. With nine treatments and three replicates, the error term had 18 degrees of freedom; the critical F values were therefore 3.55 and 6.01 for the main effects (2 and 18 degrees of freedom) and 2.93 and 4.58 for the interaction (4 and 18 degrees of freedom) at the 5% and 1% levels, respectively. Means followed by the same letter were considered not significantly different. The recommended protocol was selected by considering all variables together: priority was given to treatments with the highest percentage of sterile and viable explants and the best early growth, and, where two levels did not differ significantly, the shorter exposure was preferred because it reduces both processing time and the risk of tissue injury.

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RESULT

The ANOVA results for all observed variables are summarized in Table 2. Soaking time significantly affected the percentage of sterile and viable explants, whereas Clorox concentration significantly affected time to shoot emergence and shoot height. Neither factor affected the number of shoots, and no significant interaction between Clorox concentration and soaking time was found for any variable.

Table 2. Recapitulation of ANOVA results for in vitro sterilization of porang bulbil explants

Parameter	Source of Variation	F-count	F-table 5%	F-table 1%	Sig.
Sterile & Viable Explants (%)	Concentration (S)	2.47	3.55	6.01	ns
	Soaking Duration (D)	5.37	3.55	6.01	*
	Interaction (S×D)	1.20	2.93	4.58	ns
Shoot Emergence (DAP)	Concentration (S)	9.74	3.55	6.01	**
	Soaking Duration (D)	0.38	3.55	6.01	ns
	Interaction (S×D)	0.58	2.93	4.58	ns
Number of Shoots	Concentration (S)	0.23	3.55	6.01	ns
	Soaking Duration (D)	0.67	3.55	6.01	ns
	Interaction (S×D)	1.18	2.93	4.58	ns
Shoot Height (cm)	Concentration (S)	4.34	3.55	6.01	*
	Soaking Duration (D)	2.34	3.55	6.01	ns
	Interaction (S×D)	2.67	2.93	4.58	ns

Note: ** = highly significant; * = significant (F-count > F-table 5%); ns = not significant

Sterile and Viable Explant Percentage

Soaking time had a significant effect on the percentages of sterile and viable explants (F = 5.37 > F-table at 5% = 3.55), whereas Clorox concentration and the interaction were not significant (Table 2). The DMRT showed that the 15-minute soak (D2) produced the highest percentage of sterile and viable explants (77.05%), followed by the 10-minute soak (D1; 68.29%) and the 20-minute soak (D3; 57.45%) (Table 3). D2 differed significantly from D3, but not from D1. Thus, extending the soak from 10 to 15 minutes did not give a statistically meaningful gain, while extending it to 20 minutes reduced the proportion of usable explants by about 20 percentage points compared with D2.

Table 3. DMRT results for the percentage of sterile and viable explants

Treatment	Mean	Notation
D3 (20 minutes)	57.45%	a
D1 (10 minutes)	68.29%	ab
D2 (15 minutes)	77.05%	b

Note: Values followed by the same letter are not significantly different at DMRT 5%

Shoot Emergence Time

Clorox concentration had a highly significant effect on the time to shoot emergence (F-count = 9.74 > F-table 1% = 6.01). As shown in Table 4, explants sterilized with 30% Clorox (S2) produced shoots earliest, at 9.00 DAP, followed by those sterilized with 20% Clorox (S1; 11.00 DAP) and 40% Clorox (S3; 12.22 DAP). S2 differed significantly from S3, whereas S1 was intermediate and did not differ from either S2 or S3. The highest concentration, therefore, delayed shoot emergence by about 3 days compared with 30% Clorox.

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Table 4. DMRT results for time to shoot emergence (DAP)

Treatment	Mean	Notation
S2 (Clorox 30%)	9.00	a
S1 (Clorox 20%)	11.00	ab
S3 (Clorox 40%)	12.22	b

Note: Values followed by the same letter are not significantly different at DMRT 1%

Number of Shoots

Clorox concentration, soaking time, and their interaction had no significant effect on the number of shoots (Table 2). The main effect means were consistent across treatments, ranging from 1.45 to 1.58 shoots per explant. Among the treatment combinations, S2D1 (30% Clorox for 10 minutes) produced the highest number of shoots (1.76 shoots per explant), followed by S3D1 (1.59), although these differences were not statistically significant.

Shoot Height

Clorox concentration had a significant effect on shoot height (F-count = 4.34 > F-table 5% = 3.55), whereas soaking time and the interaction were not significant. The DMRT at the 5% level (Table 5) showed that 30% Clorox (S2) produced the tallest shoots (0.950 cm), followed by 40% (S3; 0.825 cm) and 20% (S1; 0.775 cm). S2 differed significantly from S1, while S3 was intermediate and did not differ from either S1 or S2.

Table 5. DMRT results for shoot height (cm)

Treatment	Mean	Notation
S1 (Clorox 20%)	0.775	a
S3 (Clorox 40%)	0.825	ab
S2 (Clorox 30%)	0.950	b

Note: Values followed by the same letter are not significantly different at DMRT 5%

Summary of Treatment Responses

Table 6 integrates the responses of all variables. The two factors influenced different aspects of explant performance: soaking time mainly determined whether an explant became a clean and living culture, whereas Clorox concentration mainly determined how quickly and vigorously the surviving explant developed. The 30% concentration was the optimal level for both concentration-affected growth variables, and the 10- and 15-minute soaking times were statistically equivalent for sterility and viability.

Table 6. Summary of significant factors and best treatment levels for each observed variable

Variable	Significant factor	Best level	Mean (DMRT)	Practical meaning
Sterile and viable explants (%)	Soaking time (*)	D2 (15 min)	77.05 b	D1 (68.29 ab) is statistically equal; 20 min reduces viable explants
Time to shoot emergence (DAP)	Concentration (**)	S2 (30%)	9.00 a	40% delays emergence by about 3 days
Number of shoots	None (ns)	–	1.45–1.58	Not influenced by sterilization; highest combination S2D1 (1.76)
Shoot height (cm)	Concentration (*)	S2 (30%)	0.950 b	30% supports the best shoot elongation

Note: * = highly significant; = significant; ns = not significant. Means followed by the same letter within a variable are not significantly different according to DMRT.

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The significant main effects are visualized in Figure 1. The figure highlights the contrasting response patterns: the percentage of sterile and viable explants peaked at the intermediate soaking time and declined sharply at 20 minutes, whereas both growth variables were most favorable at the intermediate Clorox concentration of 30%.

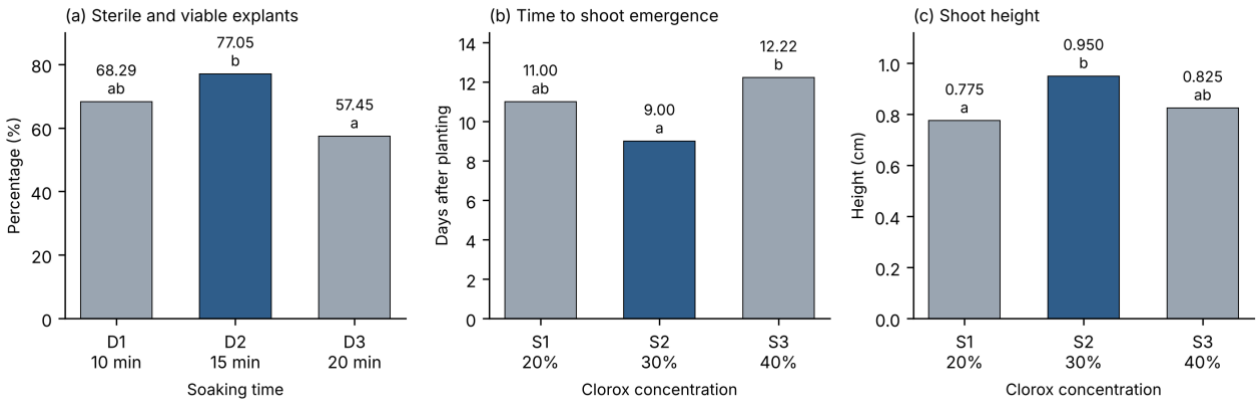


Figure 1. Means of the variables significantly affected by the treatments: (a) percentage of sterile and viable explants by soaking time; (b) time to shoot emergence and (c) shoot height by Clorox concentration. Dark bars indicate the best level; means followed by the same letter are not significantly different according to DMRT.

DISCUSSION

This study showed that Clorox concentration and soaking time act on different stages of culture establishment in porang bulbils. Soaking time determined the proportion of explants that became clean, viable cultures, whereas concentration determined how quickly and how well the surviving explants grew. No interaction was found between the two factors. These results support the general principle that surface sterilization is a trade-off between killing contaminants and preserving the explant, and they show that, for porang bulbils, the two sides of this trade-off are controlled largely by separate variables.

The significant effect of soaking time on sterile and viable explants agrees with the view that exposure duration is one of the most sensitive variables in surface sterilization. Using a neural network model, Hesami et al. (2019) found that both contamination frequency and explant viability in chrysanthemum were more sensitive to immersion time than to the type of sterilant, and their predicted optimum (about 14 minutes in NaOCl) is very close to the 10–15-minute window identified here. Because the variable measured in this study combines sterility and survival, the 20-minute decline (57.45%) most likely reflects tissue injury rather than a failure to eliminate microorganisms. Longer contact allows more HOCl to penetrate the outer cell layers, where it oxidizes membrane lipids and proteins (da Cruz Nizer et al., 2020), potentially leading to browning and necrosis of the explant. Similar losses of viability with prolonged NaOCl exposure have been reported for breadfruit leaves, which turned brown after extended soaking (Asni Setiani et al., 2018), and for apple rootstock explants (Lal et al., 2023). The 10-minute soak did not differ significantly from the 15-minute soak, indicating that most of the sterilizing benefit is achieved within the first 10 minutes.

Clorox concentration had a highly significant effect on the time to shoot emergence. Explants treated with 30% Clorox produced shoots about three days earlier than those treated with 40%. A plausible explanation is that the higher concentration caused sub-lethal oxidative stress in the

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meristematic tissues of the bulbil. Such explants survive and are counted as viable, but they first need to repair damaged membranes and neutralize oxidized phenolic compounds before cell division and bud outgrowth can resume (Amente and Chimdessa, 2021). The 20% treatment was intermediate and did not differ significantly from 30%, which is consistent with earlier porang work in which 20% Clorox was effective for tuber explants (Khoirunnisa and Mercuriani, 2022), and with the graded 10–30% NaOCl treatment that successfully controlled contamination and browning in Castanopsis argentea (Chika et al., 2022). The slightly later emergence at 20% compared with 30% may be related to a residual, sub-visible microbial load that competes with the explant during the first days of culture, although this possibility was not tested directly.

The number of shoots was unaffected by either factor and remained low (about 1.5 shoots per explant) across all treatments. This indicates that, once the explant survives, its capacity to form shoots is determined mainly by intrinsic factors rather than by the sterilization procedure. Porang bulbils contain substantial carbohydrate reserves and an apical bud with strong apical dominance, so on a hormone-free medium they usually develop one or two shoots. In porang, shoot multiplication is driven primarily by exogenous cytokinins. Hardjo et al. (2023) obtained about 15 shoots per explant on MS medium containing 5.0 mg/L BAP and 0.2 mg/L NAA, and other studies have shown similar dependence on BAP and auxin balance (Oktavia et al., 2024; Restanto et al., 2024a). From a practical standpoint, this means that the sterilization stage only needs to deliver clean, healthy explants, while shoot multiplication should be handled in a subsequent stage with an appropriate growth regulator regime.

Shoot height followed the same pattern as shoot emergence, with 30% Clorox producing the tallest shoots. Two mechanisms probably contribute to this result. First, explants with less tissue injury maintain normal metabolism, cell division, and cell elongation. Second, because shoot height was measured at a fixed point in time, shoots that emerged earlier had more days to elongate before measurement. The advantage of 30% Clorox for shoot height is therefore partly a consequence of its advantage for emergence time. At 40%, shoots were shorter than at 30% but not significantly different from either of the other concentrations, suggesting that this concentration approaches, but does not clearly exceed, the phytotoxicity threshold for porang bulbils.

The absence of an interaction between concentration and soaking time indicates that, within the tested ranges, the two factors acted independently and their effects were additive. In practice, this means that the best level of each factor can be chosen separately. It should also be noted that all explants passed through a strong common sterilization sequence, including a fungicide–bactericide soak, a preliminary 30% Clorox treatment, 70% ethanol, and 0.1% $HgCl_2$. This intensive background treatment probably reduced the microbial load so much that the additional Clorox step had limited room to change sterility, which may explain why concentration did not affect the percentage of sterile and viable explants. Under these conditions, the main contribution of the experimental Clorox step was to modify the level of stress experienced by the explant, as reflected in the growth variables.

Based on these results, the combination of 30% Clorox and a 10-minute soak (S2D1) is recommended. The 30% concentration gave the earliest emergence and the tallest shoots, and the 10-minute soak was statistically equivalent to the 15-minute soak for sterility and viability while shortening exposure and reducing the risk of tissue injury. S2D1 also produced the highest number of shoots. Compared with earlier porang protocols that relied on longer or more complex sequences (Adawiyah et al., 2021; Irawati et al., 2023), the present protocol is simple and uses an inexpensive, widely available sterilant, which is valuable for commercial laboratories that need to initiate large numbers of cultures. However, the reliance on mercuric chloride in the common sequence is a

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concern because of its toxicity and environmental persistence. Future protocols should test safer alternatives, such as hydrogen peroxide, nano-silver, or plant preservative mixtures, which have shown promising results in other species (Hesami et al., 2019; Ahmadpoor et al., 2022; Abdalla et al., 2022).

From an operational perspective, the choice between 10 and 15 minutes is not trivial. In a production laboratory that initiates hundreds of cultures, a shorter soaking step reduces the total sterilization cycle and the time each batch of explants spends in the sterilant, thereby reducing both labor time and the risk of cumulative tissue injury. Because the statistical evidence did not favor the longer exposure, the shorter exposure is expected to yield a similar proportion of usable explants in less processing time. This efficiency-oriented choice is consistent with the broader need to reduce the cost of micropropagation, which remains a main barrier to its wider adoption (Cardoso et al., 2018; Abdalla et al., 2022).

This study has several limitations. The experiment used three replicates, bulbils from a single source, and a 30-day observation period, so the long-term stability of the cultures was not assessed. No contaminants were identified, and fungal and bacterial contamination were not recorded separately. In addition, latent endophytic bacteria may emerge only during later subcultures as shoots grow and the bulbil surface cracks; such endophytes can remain undetected in the initial culture and may even modify shoot growth (Quambusch and Winkelmann, 2018; Tamošiūnė et al., 2018). Future studies should therefore include longer observation periods, molecular identification of contaminants, separate scoring of contamination, browning, and survival, and comparisons with other explant types, such as leaf petioles and meristems. Evaluating the protocol on bulbils from different regions and genotypes would also strengthen its general applicability for the mass propagation of porang.

CONCLUSION

Clorox concentration and soaking time independently affected the in vitro sterilization of porang bulbil explants, with no interaction between them. Soaking time governed the percentages of sterile and viable explants, which were highest at 15 minutes (77.05%) and were statistically similar at 10 minutes, whereas Clorox concentration governed early growth, with 30% Clorox giving the earliest shoot emergence (9.00 DAP) and the tallest shoots (0.950 cm). The number of shoots was not affected by either factor. Therefore, 30% Clorox for 10 minutes (S2D1) is recommended as a simple and efficient sterilization protocol for the in vitro propagation of porang.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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