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Growth of porang (*Amorphopallus muelleri*) seedlings as influenced by seed maturity and the presence of sarcotesta

Abstract. Porang seed maturity based its position on spadix position significantly impacts germination. The presence of the seed coat (sarcotesta) also influenced germination and initial seedling growth. This study aimed to explore the effect of seed maturity and the presence of sarcotesta to the seedling growth. The experiment was conducted from January to June 2023. A two factor Randomized Complete Block Design was employed, examining three maturity levels based on spadix position (physiological maturity seed from the tip spadix (red colour), half physiological maturity seed from the middle spadix (orange colour), and immature seed from the base spadix (green colour)), and the presence of sarcotesta (seed with sarcotesta, and seed without sarcotesta). Every treatment replicated six times, each experimental unit consisted of five seeds, resulting in a total of 180 seeds used in the experiment. The observation parameters were seed germination capacity, seedling height, leaf canopy, seedling fresh weight, seedling dry weight, number of seedling roots, and tuber diameter. The result showed that physiologically mature seeds produce the highest germination capacity and seedling dry weight compared to others. No significant correlation was found between the level of seed maturity including the presence of sarcotesta on all observed parameters. Seeds obtained from the top of the spadix (red fruit) showed higher germination capacity compared to others The removal of sarcotesta significantly enhanced all growth parameters, resulting in the highest seedling height, leaf canopy area, fresh and dry seedling weight, number of seedling roots, and tuber diameter in porang.

Keywords: Base spadix · Middle spadix · Morphophysiological dormancy · Tip spadix

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Introduction

Porang was found in tropical areas, from Africa expanded to Asia, including Indonesia (Turhadi & Indriyani, 2015). Porang plants are characterized by their elevated glucomannan content found in their tubers. Glucomannan is a hemicellulose-type polysaccharide that is water-soluble, operates as a hydrocolloid, and is low in calories. Additionally, it is gluten-free, which renders it highly suitable for application as both an industrial raw material and a food ingredient (Yanuriati et al., 2017). The higher glucomannan content in porang than other tubers make the exports of porang as food and industrial raw materials have increased in recent years (Hidayah et al., 2022)

Porang is commonly propagated through the use of small tubers, bulbils (referred to as frogs), and seeds. However, the propagation by small tubers or bulbils tends to be less efficient and may incur higher costs (Palupi et al., 2024). Among the three propagation materials, seeds are particularly advantageous because each plant generally produce approximately 300 seeds (Harijati & Widoretno, 2018). The limited availability of rare porang seeds poses a significant constraint on the propagation of porang through generative seeds, as it takes approximately four to five years for porang to produce seeds (Gusmalawati et al., 2023).

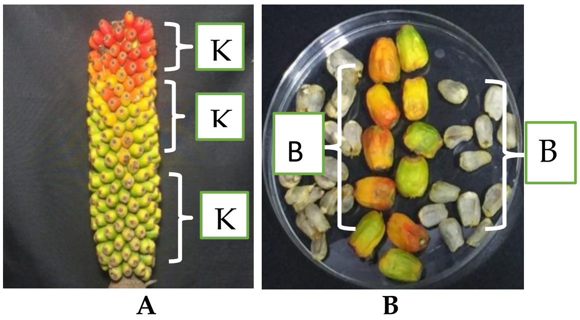
Numerous factors significantly influence seed quality, including seed genotype, habitat of origin, local variety, seed purity, morphology, dimensions, and maturity (Yan & Chen, 2020). The successful cultivation of porang relies heavily on the availability of seeds that exhibit the necessary physiological characteristics and are present in adequate quantities (Riptanti et al., 2023). One notable challenge in porang cultivation is the issue of immature seeds, as the maturity level of these seeds directly impacts their germination rates. The maturity of seeds influences the activity of the endophytic microbiome in A. muelleri seeds. During the mid to late stages of seed development, microbial functional genes that contribute to the production of resistant compounds like phenols, flavonoids, and alkaloids become significantly enriched, thereby boosting the resistance and environmental adaptability of A. muelleri seeds (Yang et al., 2022). Endophytic bacteria can enhance plant adaptability by improving nutrient mobilization, nitrogen fixation, and phosphate solubilization, as well as by providing resistance against pathogens (Wang et al., 2021).

Furthermore, the presence of the seed coat is also an essential factor in seed development. Porang seeds are characterized by a thick testa, a thin tegmen, and a rafid sac (Dewi et al., 2015). The seed coat comprises an outer layer known as the testa and an inner layer referred to as the tegmen, both of which play crucial roles in supporting seed development. *Amorphophallus muelleri* tubers and seeds are rich in glucomannan, which is known for its high viscosity, solubility, and swelling properties, as well as its excellent film-forming and gel characteristics in water-based solutions. The substantial glucomannan content in the seeds prevents germination. Raising the germination temperatures can decrease the elasticity and strength of glucomannan, thereby facilitating germination (Herranz et al., 2013). According to Fadhilah et al. (2025), subjecting seeds to dry preheating at 35°C for four weeks can disrupt seed dormancy by causing the seed coat to fracture and tear, thus speeding up the germination of *A. muelleri* seeds. This research aims to investigate how seed maturity and the presence of the sarcotesta, along with their interaction, affect germination results.

Materials and Methods

This experiment was conducted from January to June 2023 at the Seed Technology Laboratory and Greenhouse of Agronomy Study Program, Faculty of Agriculture, University of Jember. The seed material used 3-4 months old porang seed with the differences in maturity and physical condition. This research used Randomized Complete Block Design with two factors. The first factor was seed maturity in three level based on Figure 1A, the second factor is the presence of sarcotesta (Figure 1B). Every treatment replicated six times, each experimental unit consisted of five seeds, resulting in a total of 180 seeds used in the experiment.

Seed selection. Porang seeds were harvested from healthy, well-developed plants that possessed seed-bearing spadixs. The seeds were obtained from various maturity stages, ranging from green to orange and red (Figure 2). Red seeds were collected from the spadix tip, indicating that the seeds had reached physiological maturity. Orange seeds were collected from the middle of the spadix, representing the half-physiological maturity phase. Meanwhile green seeds were obtained from the basal of the spadix, signifying an immature stage. Subsequently, the collected seeds were peeled and selected based on health criteria, ensuring they were free from diseases like mold and decay.



A B

Figure 1. A) Maturity level of porang seeds; K1= Physiological maturity seed from the tip spadix (red); K2= Half physiological maturity seed from the middle spadix (orange); K3= Immature seed from the base spadix (green). B) The presence of sarcotesta; B1= Seed with sarcotesta; B2= Seed without Sarcotesta

Figure 2. Maturity stages from green, orange, and red (left to the right)

Seed cleaning. The selected porang seeds were subsequently washed and soaked in distilled water for 24 hours in an Erlenmeyer flask. Seed separation using common separation methods include to remove lightweight and foreign material to separate seeds by weight. Clearing sarcotesta was done for the treatment only.

Germinating Seed. The germination media consisted of a 1:1 mixture of soil and rice husk ash, which was previously sterilized using an autoclave. There are 6 treatments, every treatment replicated 6 times, so total of the treatment was 36 unit. Each experimental unit consisted of 5 seeds, resulting in a total of 180 seeds used in the experiment. Seeds were then sown in germination trays (72 holes), measuring 4.5 cm x 4.5 cm x 4.2 cm, received one seed.

Seedling maintenance. The germination trays were sprayed daily with distilled water to maintain adequate moisture and prevent desiccation during the germination period. Throughout this process, non-viable seeds, those that were moldy and soft were eliminated. Seeds that were moldy but remained firm were rinsed with distilled water before being returned to the tray.

Observation Variable. Seed Germination (%). Germination data was carried out to determine the initial quality of the seeds before used. Germination percentage (GP) was assessed 35 days after planting (DAP) or 5 weeks after planting. Gusmalawati et al. (2023) reported that the porang seed dormancy lasted for 4-8 weeks (1-2 months). Since the International Seed Testing Association (ISTA) has not established specific criteria for normal porang seedlings, Hamdi et al. (2022) defined seed as a normal seedling if its plumule emergence reached 1 cm (Figure 3).

Figure 3. Normal seedling in porang

The germination rate was subsequently calculated using the following formula:

$$\text{GP (\%)} = \frac{number\ of\ normal\ seedling}{number\ of\ seeds\ tested} \times 100\%$$

Seedling height (cm). Seedling height was measured using a ruler, from the base of the stem to the tip of the coleoptile. This measurement was taken once at 50 DAP (Figure 4A), based on the experiment of Fadhilah et al. (2025) which observed the final count of germination at 57 DAP.

Leaf canopy (cm^2). Leaf canopy diameter, which reflects the spread of the crown, was measured using a ruler. The diameter was assessed by measuring the widest horizontal spread of the leaves at 50 DAP (Figure 4B).

Seedling fresh weight (g). Seedling fresh weight was measured at 50 DAP immediately after harvest. This measurement, which reflects the plant's metabolic activity, was recorded using a digital scale (Figure 4C).

Seedling dry weight (g). Seedling dry weight, reflecting the accumulation of biomass and net CO_2 assimilation, was determined at 50 DAP. Samples were dried in an oven until a constant weight was achieved, and the final weight was the recorded using a digital scale.

Number of seedling roots. The number of seedling roots indicates the growth of the seedling, measured mechanically by counting the number of roots that have formed on the 50 DAP (Figure 4D).

Tuber diameter (cm). The diameter of the porang tuber was early harvested from the seedling using a ruler on the 50 DAP (Figure 4E).

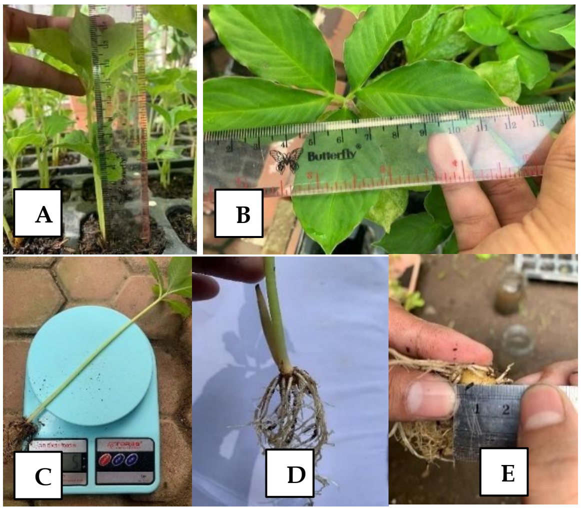


Figure 4. The measurement of A) plant height, B) leaf area, C) seedling fresh weight, D) root number, E) tuber diameter

Data Analysis. Data were analyzed using Analysis of Variance (ANOVA). When significant differences were detected, further comparisons among treatment means were performed using Duncan's Multiple Range Test (DMRT) at α 5% significance level (α = 0.05).

Results and Discussion

The ANOVA analysis indicated no significant interaction between seed maturity and the presence of sarcotesta for any of the observed parameters, which included seedling height, leaf canopy, seedling fresh and dry weight, number of seedling roots and tuber diameter of porang. Only the single factors demonstrated a significant influence of these parameters.

Seed Germination (%). Seeds collected from the spadix tip (red) resulted in the highest total number of normal seedlings (17.5 seedlings) (Figure 5A) and germination of 70% (Figure 5B). This suggests that seeds at the spadix tip (red) reached physiological maturity earlier than those in the middle (orange) and base sections (green) of the spadix. Physiologically mature seeds tend to have a higher dry weight resulting from embryo ripening. However, this germination capacity is considered low because it is still below the standard for good seed quality, which is 80%. The existence of sarcotesta is thought to inhibit germination, resulting in an initial germination below 80%. These findings are consistent with the results of (Gusmalawati et al., 2023), which also reported that seeds harvested from the spadix tip at 4 weeks after planting exhibited a faster germination rate compared with orange and green spadix. This attributed to the sequential maturation of seeds along the porang spadix, where the seeds located at the tip attain physiological maturity earlier, thus resulting in faster germination. The viability of porang seeds originating from the spadix base was the lowest (31.0±19.92%) relative to seeds from the middle (81.7±32.5%) and tip of the porang spadix (77.7±25.5%).

Wardani et al. (2019) reported that seed germination was directly correlated with fruit maturity. Seeds derived from red fruit showed the highest germination rate, measuring 92±7.71%. This was followed by seeds from yellow fruit (64.5±5.86%) and lastly the seeds from the green fruit (37.77±8.2%) at 130 DAP. The lower germination observed in yellow and green seeds is due to they had not yet reached physiological maturity at the time of harvest. Consequently, these immature seeds resulted in lower germination uniformity and required longer time for first shoot emergence and 60% germination. This difference is attributed to the incomplete formation of food reserves stored within the embryo of seeds harvested before full physiological maturity.

Yang et al. (2022) speculate that fully mature *Amorphopallus muelleri* seeds and their coats contained an abundance of plant growth promoting microorganisms, which may enhance resistance and facilitate the robust seedling establishment. There were strong correlation between seed maturity, indicated by fruit color and germination rate. Red seeds exhibited the highest germination to 100%, significantly outperforming yellow seeds (8.33%) and green seeds (0%). The superior performance of red seeds is linked to the microbial community within the seed coat. The relative abundance of genus *Streptomyces*, *Bradyrhizobium*, *Pseudomonas*, *Bacillus* and *Burkholderia* were markedly higher in the red seed coats. Since the seed coat acts as the primary protective layer, this microbial community enhanced the higher seed resistance against plant pathogens.

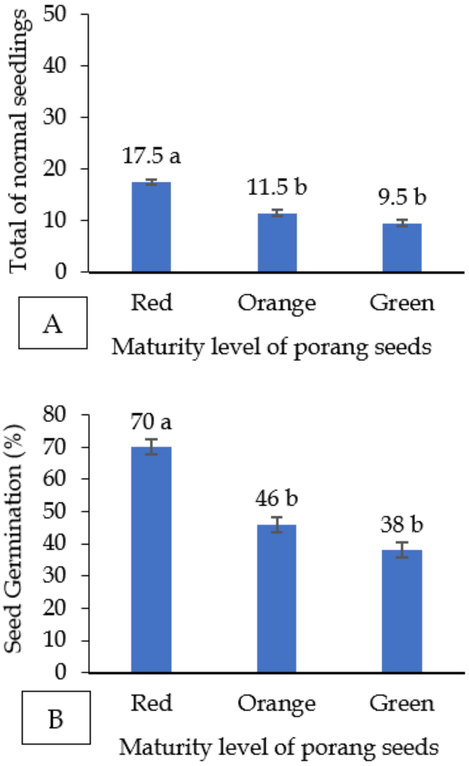


Figure 5. A) Total of normal seedlings and B) germination percentage of porang seeds in different maturity levels

Seedling Height (cm) and Leaf Canopy (cm^2). The presence of sarcotesta significantly inhibited early porang seedling growth. At 50 DAP, seedlings from seeds with the sarcotesta removed exhibited a significantly greater height (10.48 cm) and leaf canopy (9.25 cm^2) compared to intact seeds (9.00 and 6.93 cm^2, respectively) (Figure 6A, Figure 6B). This inhibition by the thick sarcotesta layer resulted in dwarfed seedling and reduced leaf size. This result aligned with the seedling height range (10.97 – 16.47 cm) reported by Gusmalawati et al. (2023) for extracted porang seeds. Meanwhile the seedling height observed for intact seeds at 50 DAP (9.00 cm) was also considerably higher than the 6.43 cm reported by Wardani et al. (2019) for intact seeds at 130 DAP. Hamdi et al. (2022) reported that porang seedling growth from seed without sarcotesta was considerably slower than that from bulbil. Seedlings from seed without sarcotesta reached only 4.8 cm at 50 DAP and 8.0 cm at 70 DAP.

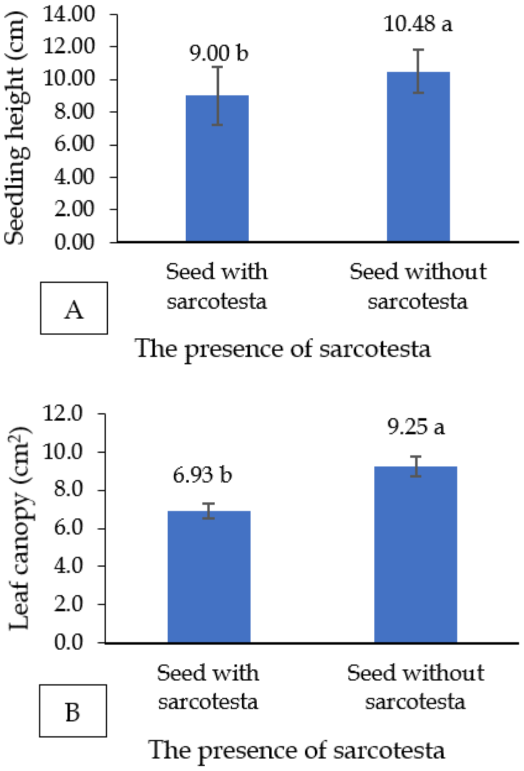


Figure 6. A) Seedling height and B) leaf canopy of porang seedlings in the presence of sarcotesta treatments

The sarcotesta acts as a physical barrier, impeding the uptake of water and oxygen essential for germination, consequently delaying the emergence of vegetative organs. Porang seed is hypothesized to exhibit morphophysiological dormancy, where its embryo requires a period post-harvest development, followed by a physical dormancy phase imposed by the thick sarcotesta. Indriyani & Widoretno (2016) further explained that physiological dormancy in porang prevents the formation of new shoots, requiring tubers, bulbils, or seeds to pass a specific seasonal cycle before growth resumes. The duration of this seed dormancy was reported by Gusmalawati et al. (2023) to last for 4-8 weeks post-harvest. To overcome this, Fadhilah et al. (2025) successfully demonstrated that dry heat treatment (25 or 30 °C) applied for four weeks significantly reduced the time of physical dormancy, accelerating germination from 57 DAP to 37 DAP.

Seedling Fresh and Dry Weight (g). Porang seedlings derived from seed without sarcotesta exhibited significantly more fresh and heavier than seed with sarcotesta. The absence of the sarcotesta likely removed barrier to growth, which at 50 DAP resulted in a greater mean seedling fresh weight of 7.38 g (Figure 7A) and a higher mean seedling dry weight of 2.79 g (Figure 7B). Seedling weight is a key indicator of seed potential in developing biomass, where high-quality seed yields greater seedling dry weight. The increasing in seedling weight is inline with enhanced seedling height and leaf canopy, indicating that sarcotesta elimination promoted more vigorous and rapid growth.

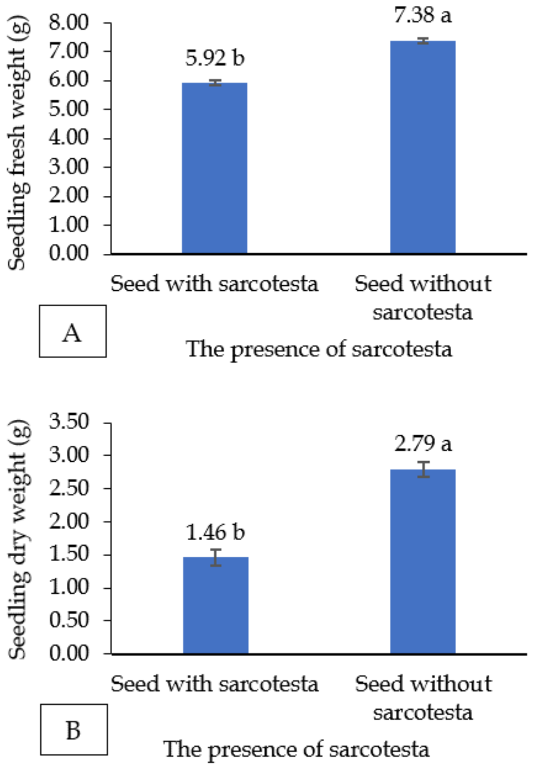


Figure 7. A) Seedling fresh weight and B) seedling dry weight of porang in the presence of sarcotesta treatments

Many seed coats including sarcotesta contain chemical compounds, such as germination inhibitors, which prevent premature germination. The elimination of the sarcotesta effectively removes this inhibitor. This facilitates the optimal action of endogenous growth hormones like gibberellins, consequently accelerating the rate of seedling growth and resulting in significantly higher biomass at 50 DAP. Chenyin et al. (2023) reported that several common germination inhibitors such as phenols, flavonoids, aldehydes, aromatic oils, alkaloids, and amides are frequently detected in diverse plant organs, including the seed, fruit, leaf, stem, and root. Isnaini et al. (2025) detailed the presence of secondary metabolites specifically alkaloids, flavonoids, saponins, tannins, and steroids in porang tuber and leaves, though the study did not directly address the role of these compounds as germination inhibitors within the sarcotesta. As the porang seed matures, the sarcotesta undergoes a chromatic transition from green through orange to red. This shift strongly suggests the accumulation of anthocyanins, which are flavonoid-group pigments known to impart red, pink, purple, and blue. Zhao et al. (2025) reported that porang seeds also contained *p*-coumaric acid, an compound known to inhibit germination and classified as a germination destructor by Chenyin et al. (2023).

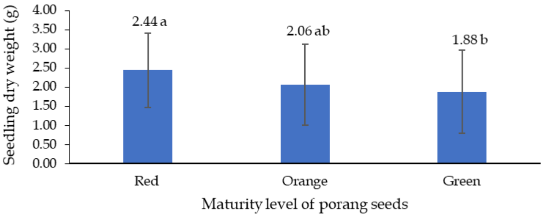


Figure 8. Seedling dry weight of porang seeds in different maturity levels

The seedling dry weight for seedlings derived from red and orange fruits was not significantly different, measuring 2.44 and 2.06 g, respectively (Figure 8). Seeds collected from the tip and middle portions of the spadix were confirmed to have already attained the physiological maturity phase at three to four months after planting. However, subsequent analysis showed that seeds harvested from red fruits generally resulted in a higher seedling dry weight also total number of normal seedlings and germination percentage. This observation suggests that if the harvest period is prolonged, red seeds likely achieve a more advanced stage of maturity compared to seeds from orange fruits, thereby enhancing their overall vigor. Seed harvesting is not performed at the phase of physiological maturity (the agronomic yield harvest), but rather several weeks after, when viability and vigor had reached their optimum. During physiological maturity, the seed are still undergoing the seed-filling process, resulting in an increasing dry weight. In contrast, at harvest maturity, the grain-filling process had reached its maximum, the seed protection mechanism is fully developed, and the seed desiccation is complete. Sari et al. (2019) explained that seed harvesting should be performed gradually when the fruit turns red, specifically at 10-11 months after plating or 8-9 months after anthesis. Wardani et al. (2019) added that seed from red fruit planted in soil and cocopeat media resulted in the higher seedlings (8 cm), larger petiole diameter (8 cm), and wider canopy diameter (3 mm). This is likely to the sufficient availability of food reserves within the seed, which are utilized to accelerate shoot and root growth.

Number of Seedling Roots and Tuber diameter (cm). Seeds without the sarcotesta resulted in a higher number of seedling roots (13.79) (Figure 9A) and a greater tuber diameter (1.70 cm) (Figure 9B). The elimination of sarcotesta removes both of physical and chemical dormancy, which allows for faster absorption of water and oxygen also frees the seed from inhibiting agents. This optimal condition facilitates radicle protrusion and the efficient allocation of energy from food reserves to develop a stronger seedling structure, as evidenced by the higher number of roots formed at 50 DAP or 7 weeks after sowing. Consistent with these findings, Sari et al. (2019) reported that seeds with eliminated sarcotesta showed an increase in the number of seedling roots, from 3.0 to 12.0 roots, between 3 and 6 weeks after sowing. Furthermore, Hamdi et al. (2022) found that seedlings grown from seeds produced a root length of 12.08 cm, which was not significantly different from seedlings grown from bulbil (16.36 cm). This suggests that both seeds and bulbils possess a comparable total amount of food reserves capable of supporting vegetative growth, particularly root elongation and maturation. With sufficient energy derived from these food reserves, the roots are able to undergo maturation and form lateral roots, which ultimately maximizes the absorption of water and nutrients essential for overall plant health and tuber development.

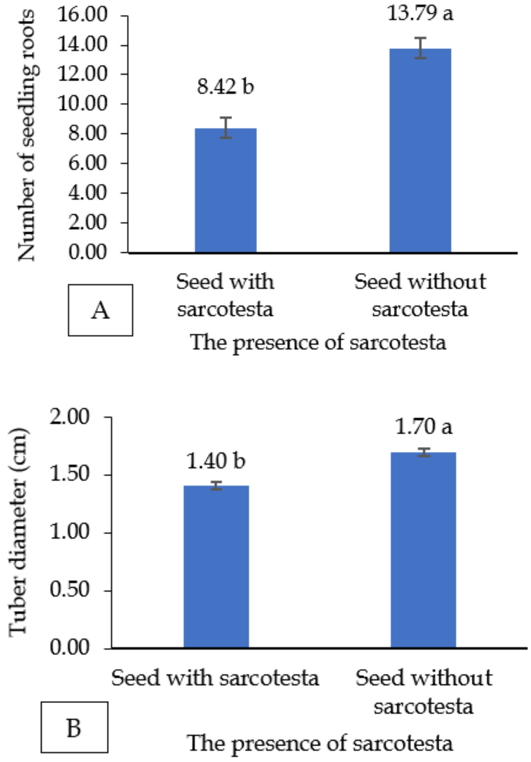


Figure 9. A) Number of seedling roots and B) tuber diameter of porang in the presence of sarcotesta treatments

The average tuber diameter harvested at 27 months after planting from spadixs developed from seeds without sarcotesta was 1.53 cm (Gusmalawati et al., 2023), whereas this study found a slightly higher average of 1.7 cm (Figure 9B) at 1.6 months after planting (50 DAP). Sarcotesta removed from seeds also yielded greater fresh and dry seedling weights, indicating higher seed vigor. This suggests an enhanced capacity for efficient and effective transport of food reserves to growth organs, such as the roots and leaves. Furthermore, the resulting larger leaf canopy area allows for greater light interception, leading to maximum carbohydrate accumulation in the porang tuber. Previous research reported that porang seeds exhibit physiological dormancy primarily due to the sarcotesta barrier (Harijati & Widoretno, 2018). Removing the seed coat or fruit flesh significantly increased the average germination percentage to over 90%. The removal of sarcotesta enhances seed permeability to water and oxygen, consequently accelerating seedling growth and promoting higher accumulation of food reserves in the developing tuber.

Conclusion

There is no correlation between the level of seed maturity and the presence of sarcotesta on all observed parameters. Seeds obtained from the top of the spadix (red fruit) showed higher germination capacity compared to others. The removal of sarcotesta eliminate the causes of dormancy and germination inhibitors, thereby facilitating optimal growth in seedling height (10.48 vs 9.00 cm), leaf canopy area (9.25 vs 6.93 cm^2), fresh and dry seedling weight (7.38 and 2.79 g, respectively), number of seedling roots (13.79 vs 8.42), and tuber diameter (1.7 vs 1.4 cm). Future research on causes of seed dormancy and chemical compounds contained in sarcotesta is needed to identify growth inhibitors in porang.

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