Jurnal Ilmu Pertanian Indonesia (JIPI), January 2026
(Indonesian Journal of Agricultural Sciences)
ISSN 0853-4217 EISSN 2443-3462

Vol. 31 (1): 92‒99
http://journal.ipb.ac.id/index.php/JIPI
DOI: 10.18343/jipi.31.1.92

Effect of Seed Size and Kombucha Soaking on Soursop Germination and Seedling Growth

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(Received January 2024/Accepted October 2025)

ABSTRACT

The purpose of this study was to look into the influence of long-term soaking seeds in kombucha and seed sizes on seed viability and seedling growth of soursop. The experiment was place between March and July 2024 at Screenhouse and the Undip Plant Physiology and Breeding Laboratory. The experiment followed a completely randomized factorial design with three replications. The first factor was the duration of seeds soak in kombucha (quick dipping, 2 h, 4 h, and 6 h). The second factor was varying seed sizes according on diameter. Seeds from local fruit varieties were removed, picked, and steeped in kombucha according to treatment, before being planted in a germination box and put into polybags for seedling growth. Germination time, vigor index, germinability, germinating speed, sprout wet and dry weight, seedling height, number of leaves, stem diameter, and seedling wet and dry weight were the parameters measured. The data were analyzed using ANOVA, with an honest significance difference at the 5% level. The results showed an interaction between the treatment and sprout dry weight parameter. Soaking seeds in kombucha with a quick dipping approach influenced germination speed and number of leaves; soaking seeds in kombucha for 4 h produced the maximum sprout dry weight. Different seed size had a substantial influence, with large seeds showing the greatest values for sprout wet and dry weight and stem diameter. Large seeds steeped in kombucha for 4 h produced the highest viability and growth of soursop seedlings.

Keywords: kombucha, seed size, seed soaking time, seedling, soursop

INTRODUCTION

Soursop was commonly planted in Indonesia due to its medicinal chemicals, such as vitamin C and annonaceous acetogenin, as well as its antibacterial and antiviral qualities. However, according to BPS statistics (2024), national soursop output fell from 142.39 metric tons in 2022 to 140.41 tons in 2023. One of the underlying factors is the difficulties of plant multiplication, notably seedling failure and soursop seed dormancy. Soursop is typically reproduced from seeds since it has a well-established root system. Seed size selection is regarded as a vital aspect in the successful development of soursop seedlings. Chima et al. (2017) described thay seed size influences soursop germination and seedling growth significantly. Large seeds have more endosperm reserves and larger embryos, increasing the potential for optimal seedling growth when compared to medium- and small-sized seeds.

Soursop seeds experience physical dormancy, which is caused by an impenetrable seed covering that limits imbibition, lowers seed quality, and causes physiological changes within the seed. Several scarification procedures have been used to break soursop seed dormancy. Mechanical scarification with sandpaper (Noflindawati 2014), seed soaking in KNO_3 for 30 min (Simanjutak *et al*. 2015), and treatments with 90% H_2SO_4 and gibberellin for 24 h have all been shown to be ineffectual in significantly enhancing seed germination. Furthermore, high-concentration chemical treatments have the potential to alter seed metabolism and reduce seedling quality.

Kombucha, a fermented tea beverage, has surfaced as a potential natural scarifier due to its organic content, which includes citric acid (0.112%), lactic acid (0.003%), and acetic acid (1.6%), for a total acid content of 1.83% (Apriyadi 2017). Kombucha fermentation involves bacteria such as *Acetobacter xylinum* and *Saccharomyces* spp. (Puspitasari *et al*. 2022). These bacteria have been shown to produce bioactive compounds as well as enzymes including cellulase and protease (Dewi 2013). These enzymes help to break down cellulose in impermeable seed coats, allowing for easier imbibition and germination. Pozzobom (2022) found that soaking *Piatta* grass seeds in 100% kombucha enhanced germination rates by up to 43% compared to the control. Daniel *et al*. (2020) reported similar results, observing substantial impacts in kombucha-soaked vegetable seeds (pea, cucumber, lettuce, and radish). Pea seeds steeped in 1% kombucha for 12 h resulted in the highest germination rate, reaching 100%. However, no study

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has precisely looked into the combined influence of seed size and kombucha soaking length on the physiological response of soursop seeds. The purpose of this study was to look at how seed size and kombucha soaking length affected soursop germination rate and seedling growth.

The successful implementation of adaptive farming practices is only possible if farmers have a thorough understanding of peatland characteristics and the importance of protecting them, as well as the ability to use peatlands in their natural state, which has undergone rewetting as they are now. This concept is based on the reality that existed prior to the restoration program, in which peatlands were managed and exploited without consideration for their inherent ecological qualities, resulting in declining productivity (Pangaribuan 2019). However, rewetting might have unforeseen consequences such as flooding or persistent waterlogging, which can result in large losses for farming firms (Arifudin *et al*. 2018). Furthermore, when peatlands have been degraded and burned, the peat surface and water table levels often fall (Afriyanti *et al*. 2021, Nusantara *et al*. 2023), making them highly susceptible to flooding during rewetting attempts. As a result, it is critical to strategically tailor the height of canal blocks and overflow structures to the unique characteristics of each peat conservation region.

In accordance with the preservation concept, the government has mandated that peatlands designated for cultivation must maintain a maximum water table level of 40 cm below the soil surface. Furthermore, the success of peatland restoration necessitates adaptive farming management, which can be achieved, among other strategies, by selecting appropriate crop commodities and implementing land-use practices that are consistent with the ecological characteristics of peatlands and the goals of their protection. Thus, the notion of biodiversity-smart farming is predicted to be achieved, in which technical or institutional options align with farmers' socioeconomic goals through conservation-oriented practices (Daum *et al*. 2023). Farmers in the research area, notably in many peat care villages in Terentang and Sungai Raya Districts, Kubu Raya Regency, have progressively come to recognize the need of peatland restoration. Currently, many forms of adaptation are being implemented based on farmers' own initiatives. For example, some farmers have begun building canal blocks called locally as *pagung* to keep water at the required level. The introduction of such techniques suggests that farmers are beginning to comprehend and accept the concept of peatland protection. Based on restoration efforts and various forms of adaptation, this study aims to quantify aspects of sustainability in terms of economic, social, and environmental dimensions, utilizing empirical data collected at both the farmer and farm levels.

Economic sustainability can be measured by the amount of direct farm revenue earned, as any conservation-oriented solution must still provide economic advantages or secure the livelihoods of farmers and their families. This theory underscores the idea of economically viable agriculture. Furthermore, such methods are projected to yield indirect economic advantages, notably in the form of ecosystem services like carbon sequestration and soil and water conservation. Meanwhile, social sustainability can be assessed by determining whether the implementation of the peat protection concept promotes broad-based engagement within farmer communities, such as by increasing participation in local groups. To examine this social dimension, farmers' engagement in organizations and various institutional characteristics that enable farming can be used as indicators.

Understanding the presence of direct and indirect economic benefits as well as social dimensions, the desired development idea has included three interrelated pillars of sustainable development: social, economic, and environmental. According to the sustainable development paradigm, development must be economically and environmentally viable, socially and environmentally acceptable, and socially and economically equitable in the sense that it can raise welfare over time. Based on these considerations, the purpose of this study is to assess the sustainability of small-scale peatland farming in regions that have been restored through rewetting.

METHODS

This experiment was carried out from March to July 2024 at the Screenhouse and Laboratory of Plant Physiology and Breeding, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang. Green tea leaves (5 g/L), sugar (70 g/L), a kombucha culture obtained from Diponegoro University's Food Technology Laboratory, local variety soursop seeds, and a growth medium made up of equal parts soil, sand, and manure (1:1:1). The experimental design was a completely randomized 3 × 4 factorial layout with two factors. The first factor was soursop seed size, as measured by diameter: K1 = small (3.3−4.9 mm), K2 = medium (5−5.5 mm), and K3 = large (5.6−7.6 mm). The second factor was kombucha soaking time: M1 = quick (1 min), M2 = 2 h, M3 = 4 h, and M4 = 6 h. Each treatment combination was done in triplicates, fresulting a total of 36 experimental units.

Kombucha Preparation

Kombucha was prepared by boiling 1 L of water, then steeping 5 g of green tea leaves for 15 min. The infusion was then filtered, and 70 g of sugar was added, stirring until completely dissolved. Tea was coated with a porous fabric and sterilized in an autoclave at 121 °C for 10 min before cooling to 20−25 °C. The Food Technology Laboratory at Diponegoro University provided a 10% (b/v) kombucha microbe culture (containing *Acetobacter* and *Saccharomyces* spp.) for inoculation purposes. The combination was then incubated for 14 days at 23−30 °C (Apriyadi 2017).

Seed Selection and Soaking in Kombucha

The soursop seeds utilized in this study were extracted from physiologically mature fruits of a local variety from Semarang, which have a greenish-brown skin, soft texture, and a smooth surface. Seeds were manually taken from the fruit and soaked in water for 1 min to distinguish full and empty seeds. Seeds that sank were deemed viable and were stripped of their seed coverings. The seeds were sorted by diameter size in accordance with the treatment and were then steeped in 100% kombucha for the duration specified.

Planting

The nursery growing media was created by combining soil, sand, and manure in a 1:1:1 ratio and then placed in germination trays (60 cm × 40 cm). Soursop seeds were sown at a density of 25 seeds per experimental unit, 3 cm apart, with a planting depth of 1−2 cm. The transplanting media was created by combining soil and manure in a 2:1 ratio and placing it in 45 cm × 45 cm polybags. Seedlings were transplanted 32 days after sowing (DAS), with the two most vigorous seedlings per unit (each having 2−3 leaves). Fertilizing, weeding, watering, and pest and disease management were all part of the maintenance process.

Observing Parameters

First day of germination (DAS). The initial day of germination was examined from day 1 to 32 after sowing (DAS) by visually seeing cotyledon emergence on the growth medium's surface.

Vigor Index (%). Seed vigor was determined by calculating the proportion of normally germinated seeds on the first count (16 DAS) using the following formula:

$$VI = = \frac{\text{NS I}}{\text{number of seed sown}} \times 100\%$$

where:
VI : Vigor index
NS I : Normally germinated seeds on first count (16 DAS)

Germinability (%). The germination percentage was calculated by counting typically germinated seeds at the initial (16 DAS) and final counts (32 DAS) (Musthofhah 2019). The percentage was computed with the following formula:

$$GR = \frac{\text{NS I} + \text{NS II}}{\text{total number of seed sown}} \times 100\%$$

where:
GR : Germinable rate
NS I : Normally germinated seed on first count (16 DAS)
NS II : Normally germinated seed on second count (32 DAS)

Germination Speed (%/ethmal). Germination speed was observed daily for 16 days by recording the number of normally germinated seeds that emerged each day. The rate was calculated using the following formula:

$$GS = (\% \frac{NS}{etmal}) = \sum_0^{tn} \frac{N}{t}$$

where:
GS : Germination speed
NS : Normally germinated seed
Etmal : 1 day (24 h)
tn : Final observation time of germination speed
N : Normal sprout percentage each observation time

Sprout Wet and Dry Weight. Five samples of normal seedlings with cotyledons removed were collected from each experimental unit and weighed to determine the fresh weight at 32 DAS. The samples were then oven-dried for 24 h at 80 °C before being weighed again to establish their dry weight.

Seedling growth parameters. Plant height, leaf count, and stem diameter were among the metrics measured for soursop seedlings. Observations were made 1 to 12 weeks after transplantation (WAT). Plant height was measured with a ruler, and stem diameter was measured with a caliper. The number of leaves was counted from beginning to finish of the observation period. Wet weight of the seedling was determined by weighing the entire plant at 12 WAT. The dry weight of the seedlings was determined after oven-drying the samples at 100 °C for 24 h.

The acquired data were subjected to analysis of variance (ANOVA). If the estimated F_{value} surpassed the F_{table} value, it indicated a significant effect, and the differences between treatments were determined using the honest significant difference (HSD) test at the 5% significance level.

RESULTS AND DISCUSSION

First Day of Germination (DAS)

The investigation revealed that changing the seed size, soaking period in kombucha, or their interaction (Table 1) had no significant effect on the parameters of the first day of germination. The 6-hour soaking treatment had the earliest average germination day (14.44 DAS), followed by the small seed size treatment (14.75 DAS); nevertheless, neither treatment differed substantially from the others. This study implies that kombucha may not be the most effective way to reduce germination time. This finding is reinforced by Daniel *et al*. (2020), that the first day of germination of numerous types of vegetable seeds after soaking in 25% kombucha for 12 h was not substantially different from average germination at 2 DAS. The ineffectiveness of the treatment is related to physiological dormancy and the impermeable structure of soursop seeds, which prevents imbibition (Hayati *et al*. 2019). Musthofhah (2019) also found that soursop seeds take 13−29 DAS to germinate. Thus, kombucha treatment needs to be modified in order to properly remove soursop seed dormancy.

Vigor Index (%)

The effect of seed size and soaking duration in kombucha on soursop vigor index was not significant (Table 2). The greatest mean was obtained after 4 h of soaking (8.45%) and for small seed sizes (7.67%). Although not significantly different, these data show that tiny seeds have a decent initial response to all soaking conditions, even if the values are quite modest. It is believed that the kombucha acid level is insufficient to permeate the seed coat structure. Daniel (2020) found that soaking vegetable seeds in kombucha at modest concentrations (1−5%) for 12 h resulted in considerable germination. Thus, 100% kombucha with a shorter soaking time has potential as a scarifying agent, but it must be studied to determine the appropriate percentage so that it does not have any negative effects and can promote plant growth. Furthermore, seed degeneration contributes to reduced vigor, resulting in slow, synchronous, and irregular seed growth (Rori *et al.* 2018). In general, the vigor index ranges between 4 and 13.33%, which is still lower than the required seed quality level of more than 40% (Wahyuni 2023).

Germination Rate (%)

The period of soaking in kombucha had no significant influence on germination (Table 3). It was assumed that the concentration of kombucha was too high, resulting in reduced germination. Daniel *et al.* (2020) found that soaking pea seeds in 25% kombucha for 12 h caused mold and seed damage, inhibiting germination. Lower concentrations (1%, 3%, and 5%) boosted the germination rate. The size of the soursop seeds had no significant impact on germination. Chima *et al.* (2017) found that small seeds have the same germination capacity as medium-sized seeds. The germination percentage was 64−77.33%, which is still lower than the ISTA (2018) quality criterion of 80% or higher.

Germination Speed (%/etmal)

The quick dipping treatment (1 min) did not differ substantially from the 4- and 2-hour soaking treatments, however it did significantly better than the 6-hour soaking treatment (Table 4). Sprout growth rate represents the percentage of typical sprouts that grow in a 24-hour period. Soursop seeds soaked in kombucha grew faster than other treatments, most likely because the seeds did not need to soak in the kombucha solution for long enough. Kombucha contains organic acids that impact soursop germination. Wiranata (2022) reported that EM4 (containing 0.008% lactic acid) and *Trichoderma* sp. had a substantial influence on soursop germination. Soursop seeds treated with hard coat seed types sprouted at the same rate as usual. According to

Table 1 First day of germination of soursop with different seed sizes and soaking duration in kombucha treatment

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	13.33	15.00	16.33	14.33	14.75
Medium	17.00	16.00	14.33	15.00	15.58
Large	17.00	14.00	15.00	14.00	15.00
Mean value	15.78	15.00	15.22	14.44	15.11

Table 2 Vigor index with different seed sizes and soaking duration in kombucha treatment (%)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	13.33	6.67	6.67	4.00	7.67
Medium	5.33	8.00	10.67	2.67	6.67
Large	1.33	4.00	8.00	4.00	4.33
Mean value	6.66	6.22	8.45	3.56	6.22

Table 3 Germination rate with different seed sizes and soaking duration in kombucha treatment (%)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	69.33	66.67	77.33	64.00	69.33
Medium	72.00	64.00	74.67	68.00	69.67
Large	70.67	73.33	73.33	77.33	73.67
Mean value	70.67	68.00	75.11	69.78	70.89

Azahra and Suharto (2022), the size of tembesu seeds with hard seed type has no significant effect on the rate of germination.

Sprout Wet Weight (g/sprout)

Seed size has a substantial effect on the wet weight of sprouts; large seeds yield more wet weight than small seeds, but the difference is not statistically significant when compared to medium seeds (Table 5). Surya *et al*. (2020) found a favorable association between seed size and plant wet weight. Large seeds contain dissolved sugar reserves, which aid in the development of embryos, cotyledons, meristems, and apicals. Sprout wet weight is a good measure of early plant growth. High wet weight values suggest excellent imbibition and biomass synthesis, which can enhance plant physiological growth at an early stage. The treatment of kombucha soaking duration had no significant effect on the wet weight of the sprouts. This was most likely owing to the hard soursop seed skin, which prevented simultaneous imbibition and resulted in inadequate growth. Junita *et al.* (2023) stressed the importance of adjusting the solution concentration and soaking time during the seed scarification process to improve imbibition and prevent seed damage.

Sprout Dry Weight (g/sprout)

There was a relationship between seed size treatment and soaking time in kombucha with varying seed sizes (Table 6). Large seeds immersed in kombucha for 4 h produced the most dry weight of sprouts and differed considerably from large seeds submerged in fast dipping and for 2 h, but not from soaking for 6 h. The interaction shows that combining big seeds with a 4-hour soak can boost initial growth and germination rates. The increased dry weight of sprouts is assumed to be due to the action of enzymes released during the kombucha fermentation process, such as protease and cellulase, which can degrade proteins into amino acids and cellulose into glucose complex molecules. Dissolved sugar can provide an energy source for bacteria, allowing them to create protein and CO_2 (Wiranata 2022). Physiologically, the dry weight of sprouts represents the accumulation of photosynthesis and respiration activities by plants. An efficient photosynthetic mechanism enhances CO_2 absorption, whereas respiration adds to CO_2 release, reducing plant dry weight (Pranata & Barus 2018).

Seedling Height (cm)

Different soursop seed sizes showed no significant effect on seedling height (Table 7), which is consistent with Chima *et al*. (2017)'s findings. The mean value was highest in the rapid dipping procedure, and the lowest in the 6-hour method. High temperature changes caused by solar radiation are likely to accelerate evapotranspiration, limiting water availability in plant tissues and interfering with metabolic processes. The soursop seedling height in the study ranged from 35.67 to 41.00 cm, and all treatments fulfilled the minimum soursop seedling

Table 4 Germination speed with different seed sizes and soaking duration in kombucha treatment (%/etmal)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	7.07	4.57	6.03	3.73	5.35
Medium	7.45	5.46	6.25	5.10	6.06
Large	5.19	4.37	4.61	5.41	4.90
Mean value	6.57 a	4.80 ab	5.63 ab	4.75 b	5.44

Remark: Different superscripts on the mean value indicate significant differences according to HSD(5%)

Table 5 Sprout wet weight with different seed sizes and soaking duration in kombucha treatment (g/sprout)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	0.66	0.61	0.65	0.62	0.64 b
Medium	0.71	0.61	0.74	0.74	0.70 ab
Large	0.74	0.70	0.81	0.71	0.74 a
Mean value	0.71	0.64	0.73	0.69	0.69

Remark: Different superscripts on mean value indicate significant differences according to HSD(5%)

Table 6 Sprout dry weight with different seed sizes and soaking duration in kombucha treatment (g/sprout)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	0.14 bc	0.13 c	0.13 c	0.15 bc	0.14 b
Medium	0.15 bc	0.14 bc	0.15 ab	0.15 bc	0.15 ab
Large	0.15 bc	0.15 bc	0.20 a	0.16 ab	0.17 a
Mean value	1.15 ab	0.14 b	0.16 a	0.15 a	0.15

Remark: Different superscripts in the row or column mean, and interaction matrix shows significant differences according to HSD (5%)

height standard of 30 cm or more (Ministry of Agriculture of the Republic of Indonesia 2019).

Stem Diameter

According to Table 8, large seeds had a considerably longer stem diameter parameter than medium seeds, however there was no significant difference between small seeds. These insignificant figures highlight the importance of other factors like seed quality and growing conditions. According to Chima *et al*. (2017), seed size impacts soursop stem diameter since it contains more endosperm, protein, fat, and minerals. Wu *et al*. (2015) exhibited that large seeds resulted in larger stem diameters than small or medium seeds. The time of kombucha soaking had no significant influence on stem diameter, possibly because the active chemicals in kombucha did not reach the seed embryo in sufficient quantities to drive stem tissue synthesis. The vigor index and stem diameter are connected. High-vigor seeds can more effectively translocate nutrients to the growth point and encourage stem expansion, whereas low-vigor seeds impede the translocation process (Ernawati 2017).

Number of Leaves

Seed size had no significant effect on the number of soursop leaves (Table 9). According to Arifin *et al*. (2020), large seeds contain higher food reserves and cotyledons, which have the potential to enhance vegetative growth, such as increased leaf number. However, in this investigation, these advantages were not found to be significant. These findings indicate that additional factors, such as seed vigor homogeneity or environmental conditions, influence the number of leaves. Meanwhile, the duration of kombucha soaking had drastically different outcomes. The 4-hour immersion produced more leaves than the 6-hour soak, but the difference was not statistically significant when compared to the quick dip and 2-hour soak. This is most likely due to the activity of kombucha bioactive compounds, which can boost nutrient availability in the root zone, particularly phosphorus release, hence improving plant assimilation and growth (Abdillah & Setiawati 2023).

Seedling Wet Weight (g/plant)

The soursop seed size had no significant effect on seedling wet weight (Table 10). This conclusion is

Table 7 Seedling high of soursop in 12 WAT with different seed sizes and soaking duration in kombucha treatment (cm)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	35.67	37.25	39.58	38.00	37.63
Medium	40.08	37.92	38.08	35.73	37.95
Large	41.00	38.17	38.42	38.20	38.95
Mean value	38.92	37.78	38.69	37.31	38.18

Table 8 Stem diameter in 12 WAT with different seed sizes and soaking duration in kombucha treatment (mm)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	4.23	4.60	4.52	4.63	4.50 [ab]
Medium	4.57	4.45	4.42	4.07	4.38 [b]
Large	4.88	4.82	4.75	4.45	4.73 [a]
Mean Value	4.56	4.62	4.56	4.38	4.53

Remark: Different superscripts on mean value indicate significant differences according to HSD(5%)

Table 9 Number of leaves in 12 WAT with different seed sizes and soaking duration in kombucha treatment (leaf)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	18.67	17.83	19.17	18.33	18.50
Medium	19.33	18.00	18.50	17.33	18.29
Large	18.83	18.67	19.17	17.67	18.58
Mean value	18.94 [a]	18.17 [ab]	18.94 [a]	17.78 [b]	18.46

Remark: Different superscripts on mean value indicate significant differences according to HSD(5%)

Table 10 Seedling wet weight with different seed sizes and soaking duration in kombucha treatment (g/plant)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	11.48	12.70	14.80	14.46	13.36
Medium	14.12	14.04	11.30	13.69	13.29
Large	15.02	14.46	15.08	14.18	14.69
Mean value	13.54	13.73	13.73	14.11	13.78

consistent with the findings of Chima *et al*. (2017), that seed size had no significant effect on the wet weight of shoots and roots in soursop seedlings. Physiologically, seedling wet weight indicates the plant's fresh weight from root to shoot before water loss caused by respiration. Siregar *et al*. (2022) mentioned that the moist weight of soursop seedlings indicates metabolic activity throughout plant development. The length of kombucha soaking had no significant effect on the wet weight of seedlings. It is hypothesized that imbibition is suboptimal, resulting in insufficient support for the plant's metabolic processes (Satya *et al.* 2015). Optimal water absorption can help with photosynthesis and biomass development. Prasetion (2023) stated that the availability of water in plant tissues is critical for photosynthetic activity and determines plant wet weight.

Seedling Dry Weight (g/plant)

Soursop seed size had no significant effect on the dry weight of soursop seedlings (Table 11). In line with Chima *et al*. (2017), soursop seed size had no significant effect on the dry weight of plant shoots and roots. When compared to other treatments, soaking in kombucha showed no meaningful benefit. Plant dry weight represents the amount of assimilates accumulated throughout the photosynthetic translocation process from the roots to the rest of the plant. Asisyah (2023) revealed that plant dry weight represents the results of plant metabolism, specifically the process of converting inorganic substances, water, and CO_2 into organic compounds.

CONCLUSION

This experiment found that soursop seedlings can germinate and grow better when the seeds are medium to large in size. The quick dipping treatment (1 min) was more effective, resulting in the highest germination rate and quantity of leaves. Meanwhile, soaking for 4 h increased the yield of sprouts' dry weight. The interaction between treatments with large seed size soaking in kombucha for 4 h produced the best outcomes in terms of dry weight of sprouts. To assess the effectiveness of scarification, further research into the usage of kombucha with lower concentrations and shorter soaking times is required.

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Table 11 Seedling dry weight with different seed sizes and soaking duration in kombucha treatment (g/plant)

Seed size	Soaking duration				Mean value
	Quick dipping	2 hours	4 hours	6 hours	
Small	2.61	2.81	3.63	3.50	3.14
Medium	3.07	3.55	3.27	2.98	3.22
Large	3.10	3.12	3.22	2.53	2.99
Mean value	2.92	3.16	3.37	3.00	3.11

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