

Coconut Water and Rice Wash Water as Natural Priming Agents for Enhancing Mung Bean (*Vigna radiata* L.) Germination

Aisha Arista Widiya^a, Inas Luthfiah^a, Mahmud Isma'il Marzuki^a, Rizya Oktavia^a, Dita Purwinda Anggrella^a

^aDepartment of Biology Education, Universitas Islam Negeri Raden Mas Said Surakarta^{1,2,3,4,5}

Article Info	ABSTRACT
Article history: Received 13-01-2026 Revised 13-03-2026 Accepted 04-04-2026	Seed germination is a critical early stage that determines the success of subsequent plant growth. However, seed germination quality is often influenced by suboptimal pre-treatment conditions, including the composition of the soaking solution and soaking duration. This study aimed to determine the effects of different coconut water and rice washing water concentrations and soaking duration on the growth of mung bean (<i>Vigna radiata</i> L.) seedlings, as indicated by radicle length. A factorial experimental design was employed with two factors: coconut water and rice washing water concentrations (10%:90%, 20%:80%, 50%:50%, 80%:20%, 90%:10%, and 100% coconut water) and soaking duration (2, 4, and 6 h). Data were analyzed using analysis of variance (ANOVA), followed by Tukey's HSD test at a 5% significance level. The results showed that soaking solution concentration significantly affected radicle length ($p < 0.001$), whereas soaking duration had no significant effect ($p = 0.285$). However, a significant interaction between the two factors was observed ($p = 0.049$). The treatment with 100% coconut water and a soaking duration of 4 h produced the greatest radicle length (4.71 cm), whereas the treatment with 90% coconut water and 10% rice washing water produced the lowest radicle length. These findings indicate that selecting an appropriate soaking solution composition, particularly the use of coconut water, may provide a natural alternative for enhancing the early growth of mung bean seedlings.
Keywords: Coconut water Rice washing water Soaking duration Germination Mung bean (<i>Vigna radiata</i> L.)	
Corresponding Author: Dita Purwinda Anggrella Departement of Biology Education UIN Raden Mas Said Surakarta Indonesia Email: ditaanggrella11@gmail.com	

1. INTRODUCTION

Mung beans (*Vigna radiata*) are a food crop with relatively high nutritional value, containing protein, vitamins, and minerals that are beneficial to human health. The proximate composition of mung beans per 100 g of dry matter includes approximately 22.5–27.94 g of protein, 32.14–66.33 g of carbohydrates, 0.12–2.31 g of fat, 2.9–17.04 g of crude fiber, 2.91–4.26 g of ash (minerals), and 5.26–9.95 g of moisture (Mekkara & Shekappa, 2021). These nutritional characteristics make mung beans an important crop for meeting nutritional needs and supporting food security; therefore, efforts to increase mung bean production are essential (Uebersax *et al.*, 2023). Seed quality is a critical factor because successful plant growth is strongly influenced by their ability to germinate optimally

(Kameswara Rao *et al.*, 2017). Therefore, the germination process is a crucial early stage that determines mung bean productivity.

Germination is the initial stage of a plant's life cycle and plays a crucial role in determining its subsequent growth and development. This process is characterized by the emergence of the radicle following the resumption of metabolic activity after the seed absorbs water (Bareke, 2018). At this stage, seeds undergo imbibition, which triggers enzyme activity and metabolic processes that support embryo growth until the embryos develop into seedlings. The success of germination is influenced not only by the physiological condition of the seed but also by various environmental factors, including temperature, water availability, light, pH, and seed storage conditions. Optimal temperature supports enzyme activity and metabolism, whereas excessively high or low temperatures can inhibit germination. Water availability is essential for reactivating metabolic processes through imbibition. However, excess water can create oxygen-deficient conditions that inhibit germination. In addition, light and environmental pH influence the physiological activity of seeds as well as the availability of nutrients required during the early stages of seedling growth (Pantović *et al.*, 2024).

Another factor influencing the initial treatment of seeds is pre-planting soaking, which can also affect the rate and success of germination. Soaking is intended to accelerate imbibition, the process by which seeds absorb water, thereby reactivating the metabolic activity required for germination. With sufficient water uptake, enzyme activity and various physiological processes within the seed can proceed more rapidly, triggering the emergence of the radicle as the first visible sign of germination (Nadeem *et al.*, 2017). However, the duration of soaking can influence the rate and percentage of germination. Excessively prolonged soaking may damage the embryo or inhibit seed growth due to waterlogged conditions (Garcia *et al.*, 2014).

Besides soaking duration, the type of solution used for soaking can also affect germination success (Kumar *et al.*, 2024). Various natural substances have the potential to serve as growth promoters that support seed germination. One natural substance that is widely used is coconut water, which contains various natural plant growth regulators, including auxin (IAA), abscisic acid (ABA), gibberellins, and the cytokinin zeatin (Tan *et al.*, 2014), as well as sugars, amino acids, vitamins, and minerals (Mantena *et al.*, 2003), all of which can stimulate plant growth (N. Tuyekar *et al.*, 2021). These compounds can enhance the physiological activity of seeds, thereby supporting the germination process (Fardha, 2024; N. Tuyekar *et al.*, 2021; Srimaulinda *et al.*, 2021). Studies on crops such as okra (Lakmali & Seran, 2022) and jujube (Talpur *et al.*, 2024) have shown that coconut water can improve germination rate and seedling vigor. Therefore, coconut water has the potential to be used as a seed-priming agent to promote faster, more uniform germination and more vigorous early seedling growth.

In addition to coconut water, rice washing water obtained from rice (*Oryza sativa*) also has the potential to serve as a nutrient source for seeds. Rice washing water is known to contain various nutrients required for plant growth and development, including 0.015% nitrogen, 16.306% phosphorus, 0.02% potassium, 2.944% calcium, 14.252% magnesium, 0.027% sulfur, 0.0427% iron, and 0.043% vitamin B1. These nutrients and vitamins can enhance seed metabolic activity and support germination and early plant growth (Carganilla *et al.*, 2025; G.M. *et al.*, 2011). Therefore, the use of these two natural substances offers an easy, inexpensive, and environmentally friendly approach to supporting early plant growth (Srimaulinda *et al.*, 2021).

A study by Srimaulinda *et al.* (2021) showed that different concentrations of coconut water and rice washing water, combined with varying soaking durations, can affect mung bean seed germination. The study found that the mixture of coconut water and rice washing water improved several early growth parameters, including sprout height, radicle number, and radicle length. However, growth responses varied among the different treatment combinations, indicating that the effectiveness of this mixture in promoting mung bean seed germination remains inconsistent.

The physiological condition of the seed, the composition of the soaking solution, and soaking duration can influence the success of imbibition and metabolic activity during germination. Therefore, further research is needed to investigate the effects of different concentrations of coconut water and rice washing water, combined with varying soaking durations, on mung bean sprout growth, using sprout length as an indicator of early plant growth. This study is expected to provide more comprehensive information on the effectiveness of coconut water and rice washing water as

natural agents for enhancing mung bean seed germination while also identifying the most effective treatment for improving germination success.

2. RESEARCH METHOD

2.1. Type and Design of the Study

This study employed a factorial experimental design (Creswell, 2016). The first factor was the concentration of the coconut water and rice washing water mixture, while the second factor was the soaking duration. The study was conducted to determine the effects of each factor, as well as their interaction, on the germination of mung bean (*Vigna radiata* L.) seeds, as indicated by radicle length.

2.2. Materials and Equipment

The equipment used in this study included a graduated cylinder, beakers, soaking containers, tweezers, a ruler, label paper, and germination containers or Petri dishes. The materials used in this study were young coconut water, rice washing water, mung bean (*Vigna radiata* L.) seeds, and clean water. The coconut water was obtained from young green coconuts approximately 3 months old, whereas the rice washing water was collected from the first rinse during the rice washing process.

2.3. Experimental Treatments

This study used two treatment factors: solution concentration (Factor A) and soaking duration (Factor B).

1. Factor A (Solution Concentration):

- A1: 10% coconut water + 90% rice washing water
- A2: 20% coconut water + 80% rice washing water
- A3: 50% coconut water + 50% rice washing water
- A4: 80% coconut water + 20% rice washing water
- A5: 90% coconut water + 10% rice washing water
- A6: 100% coconut water (control)

2. Factor B (Soaking Duration)

- B1: 2 h soaking
- B2: 4 h soaking
- B3: 6 h soaking

2.4. Research Procedure

2.4.1 Preparation of Treatment Solutions

The treatment solutions were prepared by mixing coconut water and rice washing water in volume ratios corresponding to the predetermined concentrations. A total volume of 30 mL of each solution was prepared for each experimental unit. The treatment solutions consisted of A1 (3 mL coconut water + 27 mL rice washing water), A2 (6 mL coconut water + 24 mL rice washing water), A3 (15 mL coconut water + 15 mL rice washing water), A4 (24 mL coconut water + 6 mL rice washing water), A5 (27 mL coconut water + 3 mL rice washing water), and A6 (30 mL coconut water). Rice washing water was obtained from the first rinse of the rice and filtered before use, while coconut water was obtained from fresh coconuts. All solutions were prepared immediately before the soaking treatment to maintain their quality and nutritional content.

2.4.2 Seed Soaking

The mung bean (*Vigna radiata* L.) seeds used in this study were selected based on their physical condition. The seeds were healthy, intact, free of defects, and relatively uniform in size. The study employed a factorial design with two factors, namely solution concentration and soaking duration, with each treatment combination replicated three times. Each experimental unit consisted of five seeds, resulting in a total of 270 seeds (18 treatment combinations $\times$ 3 replicates $\times$ 5 seeds).

The seeds were soaked in the treatment solutions at the specified concentrations for 2 h (B1), 4 h (B2), and 6 h (B3). After soaking, the seeds were drained for approximately 5 min to remove any residual solution adhering to their surfaces before germination.

2.4.3 Seed Germination

The soaked seeds were placed on a germination medium consisting of cotton that had been adequately moistened. Each experimental unit was placed in a separate container according to the assigned treatment. During the germination process, the moisture of the medium was maintained by adding sufficient water daily to keep the medium moist and support seedling growth.

2.4.4 Data Collection

Observations were conducted daily for 7 days to monitor seed germination progress. The parameter observed in this study was radicle length. Radicle length was measured on the seventh day after germination using a ruler with a millimeter scale. Radicle length was measured from the base of the seed to the tip of the longest radicle and expressed in centimeters (cm). Radicle length data from each experimental unit were recorded, and the mean value was calculated for each treatment combination.

2.5. Data Analysis

The data obtained were analyzed using analysis of variance (ANOVA) to determine the effects of the treatments on the observed parameters. If the analysis results showed significant differences, a Tukey HSD post-hoc test was conducted at a 5% significance level to determine differences among treatments.

3. RESULT AND ANALYSIS

The objective of this study was to determine the effects of the concentration of coconut water and rice washing water mixtures, as well as soaking duration, on mung bean sprout growth, as indicated by sprout length for each treatment combination. Observations were made after the soaking process at varying durations of 2 hours, 4 hours, and 6 hours. The data obtained were then expressed as mean values and standard deviations to describe the variation in sprout growth for each treatment. The mean sprout lengths for each concentration and soaking duration treatment are presented in the following table.

Table 1. Mean Sprout Length Based on Coconut Water Concentration and Soaking Duration

Coconut Water : Rice Washing Water Concentration	2 h (Mean $\pm$ SD)	4 h (Mean $\pm$ SD)	6 h (Mean $\pm$ SD)	Mean
10% : 90%	1.43 $\pm$ 0.59	1.61 $\pm$ 0.68	1.59 $\pm$ 1.12	1.54
20% : 80%	1.51 $\pm$ 0.63	2.39 $\pm$ 0.52	2.29 $\pm$ 1.38	2.06
50% : 50%	1.71 $\pm$ 0.49	0.64 $\pm$ 0.48	1.79 $\pm$ 0.67	1.38
80% : 20%	1.56 $\pm$ 0.65	0.79 $\pm$ 0.39	1.60 $\pm$ 0.72	1.31
90% : 10%	0.71 $\pm$ 0.39	0.00 $\pm$ 0.00	1.50 $\pm$ 0.65	0.74
100% Coconut Water	4.46 $\pm$ 2.72	4.71 $\pm$ 1.73	3.60 $\pm$ 1.65	4.26
Mean	1.90	1.69	2.06	1.88

Note: Values are presented as mean $\pm$ standard deviation (n = 3).

Based on **Table 1**, the results of the descriptive statistical analysis show that the treatments involving coconut water concentration and soaking duration resulted in variation in the sprout lengths produced. The 100% coconut water treatment produced the highest average sprout length across all soaking durations, with an overall average of 4.26, while the treatment with 90% coconut water + 10% rice washing water produced the lowest average sprout length of 0.74.

Among the mixed treatments, the 20% coconut water + 80% rice washing water treatment showed relatively higher growth compared with the other mixed treatments, with an average sprout length of 2.06. The highest values for this treatment were obtained at soaking durations of 4 hours (2.39) and 6 hours (2.29).

Based on the average for the soaking duration factor, the highest sprout length was obtained after soaking for 6 hours, with an average of 2.06 cm, followed by 2 hours of soaking at 1.90 cm and 4 hours of soaking at 1.69 cm. These results indicate that soaking for 6 hours tends to provide better conditions for seed imbibition and metabolic activation, thereby supporting more optimal sprout growth.

Based on the research results, the 100% coconut water treatment produced the highest average sprout length compared with the other treatments. These results indicate that coconut water has the potential to support the early growth of mung bean sprouts. Coconut water is known to contain various natural plant growth regulators, such as auxins, cytokinins, and gibberellins, which play roles in stimulating cell division and elongation (Yong *et al.*, 2009). In addition, coconut water contains sugars, amino acids, vitamins, and minerals that can serve as sources of energy and nutrients during the germination process. The availability of these hormones and nutrients enables more optimal metabolic activity, thereby supporting radicle growth and increasing sprout length.

These findings are consistent with those of Lakmali and Seran (2022) in okra and Talpur *et al.* (2024) in jujube, who reported that the use of coconut water can enhance germination and seedling vigor. Research by Herman *et al.* (2025) also showed that coconut water can increase the germination rate and early growth of rice seedlings. These consistent findings suggest that the bioactive compounds in coconut water can function as an effective natural priming agent in various plant species.

Among the treatment mixtures, the combination of 20% coconut water and 80% rice washing water produced the highest average sprout length compared with the other mixtures. Rice washing water contains carbohydrates, B vitamins, and various minerals that can serve as sources of nutrients for the seeds during the germination process. However, increasing the concentration of coconut water to 50%, 80%, and 90% when mixed with rice washing water did not increase sprout length. This condition is thought to be related to the high concentration of dissolved substances in the solution, which may affect water absorption by the seeds. According to Jatana *et al.* (2024), successful germination is greatly influenced by the imbibition process, that is, the absorption of water by the seeds to activate initial metabolism. A solution that is too concentrated can inhibit the imbibition process, resulting in suboptimal sprout growth.

In terms of soaking duration, the highest average sprout length was obtained after 6 hours of soaking (2.06 cm), followed by 2 hours (1.90 cm) and 4 hours (1.69 cm). These results indicate that longer soaking times tend to provide greater opportunities for seeds to absorb water and activate physiological processes that support germination. Water absorption during soaking activates hydrolytic enzymes that play a role in breaking down food reserves within the seed into energy sources for embryo growth. However, the effect of soaking duration is not always the same at every solution concentration, as evidenced by some treatments showing the highest values at the 4-hour soaking duration. This indicates that the sprout growth response is influenced by the interaction between solution composition and soaking duration.

Table 2. Results of ANOVA Analysis of the Effects of Concentration and Soaking Duration on Sprout Length

Source of Variation	df	Mean Square	F	Sig.
Concentration	5	32.216	28.503	0.000
Soaking duration	2	1.437	1.272	0.285
Concentration * Soaking duration	10	2.177	1.926	0.049
Error	108	1.130		

$R^2 = 0.603$; Adjusted $R^2 = 0.541$

The results of the analysis of variance (ANOVA) presented in **Table 2** showed that the concentration of coconut water and rice washing water had a highly significant effect on the length of mung bean sprouts ($F = 28.503$; $p < 0.001$). This indicates that differences in the concentration of the soaking solution contributed to the variation in sprout growth.

In contrast, soaking duration did not have a significant effect on sprout length ($F = 1.272$; $p > 0.05$). However, the analysis results showed a significant interaction between concentration and soaking duration ($F = 1.926$; $p > 0.05$). This indicates that the effect of solution concentration on sprout growth may vary depending on the soaking duration applied.

The coefficient of determination (R^2) value of 0.603 indicates that approximately 60.3% of the variation in sprout length can be explained by the factors of concentration, soaking duration, and their interaction, while the remainder is influenced by other factors outside the research model. These results are consistent with the study by Srimaulinda *et al.* (2021), which showed that the combination of solution concentration and soaking duration can influence the germination process of mung bean seeds. One factor that plays a crucial role in this process is seed soaking, which aims to accelerate imbibition, the absorption of water by the seed, thereby reactivating the metabolic activity necessary for germination. With sufficient water absorption, enzyme activity and various physiological processes within the seed can proceed more rapidly, thereby triggering the emergence of the radicle as a sign that germination has begun (Nadeem *et al.*, 2017). However, the soaking duration must also be considered, as it can affect the rate and percentage of germination. Excessively long soaking has the potential to cause damage to the embryo or inhibit seed growth due to excessively waterlogged conditions (Garcia *et al.*, 2014). In addition to these treatment factors, radicle length during germination can also be influenced by various other factors, such as environmental conditions, including temperature, water availability, light, pH, and seed storage conditions (Pantović *et al.*, 2024). Furthermore, the type of solution used in the soaking process can also affect radicle growth because it is related to the availability of plant growth regulators and nutrients that support early plant growth (Kumar *et al.*, 2024).

Table 3. Results of the Tukey HSD Post-Hoc Test on the Effect of Concentration on Sprout Length

Treatment	Mean Sprout Length (cm)
A6B2	4.71 ^a
A6B1	4.46 ^a
A6B3	3.60 ^a
A2B2	2.39 ^b
A2B3	2.29 ^b
A3B3	1.79 ^{bc}
A3B1	1.71 ^{bc}
A4B3	1.60 ^{bc}
A1B2	1.61 ^{bc}
A1B3	1.59 ^{bc}
A4B1	1.56 ^{bc}
A2B1	1.51 ^{bc}
A5B3	1.50 ^{bc}
A1B1	1.43 ^{bc}
A4B2	0.79 ^c
A5B1	0.71 ^c
A3B2	0.64 ^c
A5B2	0.00 ^c

Based on the results of the Tukey HSD post-hoc test in **Table 3**, the treatment combinations A6B2, A6B1, and A6B3 showed the highest average sprout lengths of 4.71 cm, 4.46 cm, and 3.60 cm, respectively. This indicates that these three treatments were not significantly different from one another but were significantly different from most of the other treatments. Treatment A6 was the control treatment with 100% coconut water; thus, this condition is thought to provide optimal water availability for seed imbibition and support metabolic activity during germination. Coconut water

naturally contains several plant growth regulators, such as auxins, cytokinins, and gibberellins (Tuyekar *et al.*, 2021). These hormones play roles in stimulating cell division, accelerating cell elongation, and increasing metabolic activity during germination. As a result, radicle growth (the primary root) becomes faster, resulting in longer radicles (Zhao, 2025). Coconut water also contains various essential nutrients, such as simple sugars (as an energy source), minerals (K, Ca, Mg), vitamins, and amino acids (G.M *et al.*, 2011). These nutrients help support respiration and metabolic processes in the sprouts, thereby increasing the energy available for radicle growth (Carganilla *et al.*, 2025). Treatment groups A2B2 and A2B3 produced sprout lengths of 2.39 cm and 2.29 cm, respectively, which were higher than those of most other treatment combinations. These results indicate that the combination of 20% coconut water and 80% rice washing water is still capable of supporting optimal sprout growth. Based on the composition of the solution, the higher proportion of rice washing water is believed to play an important role in supporting sprout growth. Rice washing water is known to contain starch, carbohydrates, protein, vitamins, and various minerals such as phosphorus, potassium, magnesium, and calcium, which can serve as sources of nutrients during the germination process (Chithambharan *et al.*, 2024). These nutrients play a role in providing the energy and nutrients needed to activate embryo metabolism, thereby supporting radicle growth during the early stages of germination (Chithambharan *et al.*, 2024).

In contrast, most of the other treatment combinations, such as A3B3, A3B1, A4B3, A1B2, A1B3, A4B1, A2B1, A5B3, and A1B1, resulted in relatively shorter sprout lengths, ranging from 1.43 to 1.79 cm. This pattern suggests that an increase in the proportion of coconut water in the mixture is not always accompanied by an increase in sprout length. In fact, in treatments with higher proportions of coconut water, such as A4 (80% coconut water) and A5 (90% coconut water), sprout growth tended to decrease. These results indicate that, among the mixture treatments, a higher proportion of rice washing water tended to result in a better sprout growth response than mixtures with a higher proportion of coconut water.

Furthermore, the effectiveness of coconut water as a priming agent is greatly influenced by the concentration used. Coconut water contains natural plant growth regulators, such as cytokinins, auxins, and gibberellins, as well as various nutrients that can support seed germination and early plant growth (Yong *et al.*, 2009). However, excessively high concentrations do not always result in a better response. Carganilla *et al.* (2025), in a study on rice seeds, showed that a lower concentration of coconut water (25%) resulted in a higher germination rate and seedling vigor compared with higher concentrations. This is thought to be because an increase in the concentration of dissolved substances can affect the seed imbibition process and reduce the effectiveness of water absorption needed to activate germination metabolism (Jatana *et al.*, 2024).

The treatment groups with the lowest mean sprout lengths were A4B2 (0.79 cm), A5B1 (0.71 cm), A3B2 (0.64 cm), and A5B2 (0.00 cm). The value of 0.00 cm for treatment A5B2 indicates that no sprout growth occurred during the observation period. These results indicate that the combination of 90% coconut water and 10% rice washing water with a 4-hour soaking duration was less supportive of the germination process.

Physiologically, successful germination begins with the imbibition process, which is the absorption of water by the seed that subsequently activates various enzymes to break down food reserves and support embryo growth (Jatana *et al.*, 2024). In treatment A5B2, the high concentration of dissolved substances derived from coconut water and rice washing water is thought to have affected the seed's water absorption process, causing the metabolic activity necessary for germination to not proceed optimally. These conditions may have inhibited radicle growth or delayed the emergence of sprouts during the observation period.

However, this study did not measure seed viability after treatment or the osmotic pressure of the solutions; therefore, it cannot be determined whether the seeds died, entered temporary dormancy, or merely experienced delayed germination. Consequently, further research is needed to investigate the physiological mechanisms that resulted in the absence of sprout growth under these treatment combinations. In the treatment combining coconut water and rice washing water, the resulting sprout length was generally shorter than that in the 100% coconut water treatment. These results indicate that the addition of rice washing water does not always enhance sprout growth. Coconut water

contains natural plant growth regulators, such as auxins, cytokinins, and gibberellins, which play a role in stimulating sprout growth (Yong *et al.*, 2009), while rice washing water contains carbohydrates, vitamins, and minerals that can serve as sources of nutrients during the germination process (Chithambharan *et al.*, 2024).

In this study, some treatments with high coconut water content actually resulted in shorter sprout lengths. This indicates that the effects of mixing coconut water and rice washing water are not always mutually supportive. There may be an unfavorable interaction between the components of these two materials, resulting in suboptimal sprout growth.

However, the treatment consisting of 20% coconut water and 80% rice washing water was still able to produce relatively longer sprouts compared with most other mixture treatments. These results indicate that a balanced solution composition can provide better conditions for the germination process. Thus, successful sprout growth is determined not only by high concentrations of coconut water or rice washing water but also by the appropriate combination of the two.

The results of this study differ from those of the study conducted by Srimaulinda *et al.* (2021), which reported that a mixture of 10 mL of coconut water and 90 mL of rice washing water, with a 6-hour soaking duration, produced the greatest radicle length in mung bean germination. The study also showed that a combination of 20 mL of coconut water and 80 mL of rice washing water with a 2-hour soaking duration produced the tallest sprouts, while the highest number of radicles was found in the combination of 50 mL of coconut water and 50 mL of rice washing water with a 6-hour soaking duration. This indicates that the addition of coconut water and rice washing water as sources of natural plant growth regulators and nutrients can enhance early plant growth.

These differing results suggest that the growth response of mung bean radicles to treatments with coconut water and rice washing water can vary even when the same treatment factors are used. These differences are likely influenced by the physiological condition of the seeds used in the study. Seed viability and vigor are critical determinants of the seeds' ability to absorb water and carry out metabolic processes during germination. Seeds with high vigor typically exhibit better enzyme activity, enabling them to optimally utilize food reserves for radicle growth (Bewley *et al.*, 2012).

In addition, differences in the nutritional composition of coconut water and rice washing water may also influence the study results. The content of natural plant growth regulators, such as auxins, cytokinins, and gibberellins, in coconut water plays a role in stimulating plant cell division and elongation (Yong *et al.*, 2009). However, the concentrations of these hormones can vary depending on the maturity level of the coconut, coconut variety, and storage conditions, so their effects on plant growth are not always the same.

On the other hand, rice washing water contains nutrients such as nitrogen, phosphorus, and other minerals that can support plant root growth (Safitri *et al.*, 2023). The nutrient content may vary depending on the rice variety, the number of washings, and the rice processing method, which can result in different growth responses in the seeds tested. Other factors that may also influence the study results include environmental conditions during the germination process, such as temperature, humidity, light intensity, and the germination medium used. These environmental conditions can affect enzyme activity and seed metabolic processes that play a role in radicle elongation (Bhatla & Lal, 2023).

This study has several limitations that should be considered when interpreting the results. First, the parameters observed in this study were limited to radicle length as an indicator of early growth; therefore, they do not comprehensively reflect other aspects of growth, such as germination percentage, germination rate, seedling weight, or root and leaf development. Second, this study only used specific variations in the concentrations of coconut water and rice washing water, as well as soaking durations; thus, it does not account for other possible treatment variations that might yield different results. Third, the study was conducted under limited environmental conditions; therefore, other environmental factors such as light intensity, temperature, and humidity were not analyzed in depth. Additionally, the number of samples used was limited, so the results obtained may not fully represent broader conditions.

Based on these limitations, future research is recommended to further investigate the effects of combining other natural ingredients as seed soaking solutions and to use a wider range of concentrations and soaking durations. Future research could also include more comprehensive

observation parameters, such as germination percentage and germination rate, root length, sprout weight, and plant growth at subsequent stages. Additionally, studies could be conducted on a larger scale and under more controlled environmental conditions or in the field to obtain more comprehensive results that can be more widely applied in mung bean cultivation.

4. CONCLUSION

Based on the research results, it can be concluded that the concentration of the coconut water and rice washing water solution had a significant effect on the length of mung bean (*Vigna radiata* L.) sprouts ($p < 0.001$), whereas the duration of seed soaking did not have a significant effect ($p > 0.05$). In addition, there was a significant interaction between solution concentration and soaking duration ($p = 0.049 < 0.05$), indicating that the sprout growth response to solution concentration was influenced by the soaking duration.

Descriptively, the 100% coconut water treatment produced the highest average sprout length, with an overall mean of 4.26 cm, whereas the 90% coconut water + 10% rice washing water treatment produced the lowest average sprout length of 0.74 cm. The results of the Tukey HSD post-hoc test showed that treatment combination A6B2 (100% coconut water with a 4-hour soaking duration) produced the longest sprout length, at 4.71 cm, followed by A6B1 (4.46 cm) and A6B3 (3.60 cm), which were not significantly different from one another but were significantly different from most of the other treatments.

Meanwhile, among the mixed treatments, the combination of 20% coconut water and 80% rice washing water showed relatively better sprout growth compared with the other mixtures, with an average sprout length of 2.06 cm. The results of the study indicate that optimal water availability through the soaking solution plays a crucial role in supporting the imbibition process and metabolic activity during germination; thus, the use of a solution with an appropriate composition can influence the success of mung bean sprout growth.

REFERENCES

- Bareke, T. (2018). Biology of seed development and germination physiology. *Advances in Plants & Agriculture Research*, 8(4), 336–346. <https://doi.org/10.15406/apar.2018.08.00336>
- Bewley, J. D., Bradford, K. J., Hilhorst, H. W. M., & Nonogaki, H. (2013). *Seeds: Physiology of development, germination and dormancy* (3rd ed.). Springer. <https://doi.org/10.1007/978-1-4614-4693-4>
- Bhatla, S. C., & Lal, M. A. (2023). *Plant physiology, development and metabolism* (2nd ed.). Springer. <https://doi.org/10.1007/978-981-99-5736-1>
- Carganilla, J. S., Aquino, J. T., Dinay-og, J. J., Cumahling, G. J. L., & Valdez, M. T. (2025). Efficacy of coconut water as a seed priming agent for enhancing germination and emergence of rice. *Journal of Interdisciplinary Perspectives*, 3(11), 199–205. <https://doi.org/10.69569/jip.2025.663>
- Chithambharan, A., Pottail, L., Sharma, S. C., Mirle, R. M., Rajalakshmi, R., & Ponnusamy, A. (2024). Conventional and scientific uses of rice-washed water: A systematic review. *Journal of Food Science and Technology*, 61(3), 414–428. <https://doi.org/10.1007/s13197-023-05722-2>
- Creswell, J. W. (2016). *Research design: Pendekatan metode kualitatif, kuantitatif, dan campuran* (A. Fawaid & R. K. Pancasari, Trans.; 4th ed.). Pustaka Pelajar.
- Fardha, R. (2024). Manufacture of plant growth regulators from organic materials using banana pith, coconut water, and sprouts to improve plant growth productivity. *Jurnal Pembelajaran Dan Pengembangan Diri*, 4(8), 1457–1468. <https://doi.org/10.47353/bj.v4i8.453>
- G.M, C. W., Muhartini, S., & Trisnowati, S. (2011). *Pengaruh air cucian beras merah dan beras putih terhadap pertumbuhan dan hasil selada (Lactuca sativa L.)*. Universitas Gadjah Mada, Yogyakarta.
- Garcia, J., Barker, D. G., & Journet, E.-P. (2006). Seed storage and germination. In U. Mathesius, E.-P. Journet, & L. W. Sumner (Eds.), *The Medicago truncatula handbook* (pp. 1–9). The Samuel Roberts Noble Foundation.
- Jatana, B. S., Grover, S., Ram, H., & Baath, G. S. (2024). Seed priming: Molecular and physiological

- mechanisms underlying biotic and abiotic stress tolerance. *Agronomy*, 14(12), 2901. <https://doi.org/10.3390/agronomy14122901>
- Kameswara Rao, N., Dulloo, M. E., & Engels, J. M. M. (2017). A review of factors that influence the production of quality seed for long-term conservation in genebanks. *Genetic Resources and Crop Evolution*, 64(5), 1061–1074. <https://doi.org/10.1007/s10722-016-0425-9>
- Kumar, M., Sarvade, S., Kumar, R., & Kumar, A. (2024). Pre-sowing treatments on seeds of forest tree species to overcome the germination problems. *Asian Journal of Environment & Ecology*, 23(5), 1–18. <https://doi.org/10.9734/AJEE/2024/v23i5543>
- Lakmali, K. N. D., & Seran, T. H. (2022). Impact of seed priming with king coconut water on growth and yield of okra (*Abelmoschus esculentus* L.). *Journal of Food and Agriculture*, 15(2), 27–46. <https://doi.org/10.4038/jfa.v15i2.5271>
- Mantena, S. K., Jagadish, Badduri, S. R., Siripurapu, K. B., & Unnikrishnan, M. K. (2003). In vitro evaluation of antioxidant properties of *Cocos nucifera* Linn. water. *Nahrung/Food*, 47(2), 126–131. <https://doi.org/10.1002/food.200390023>
- Mekkara, S., & Shekappa, D. (2021). A review on nutritional composition, antinutritional components and health benefits of green gram (*Vigna radiata* (L.) Wilczek).
- Nadeem, M. K., Qaswar, M., Ahmed, N., Rabnawaz, & Rasool, S. J. (2017). Effect of seed soaking time on germination of maize (*Zea mays* L.). *PSM Biological Research*, 2(1), 46–50.
- Pantović, J. G., Galac, M., Popović, A., & Sečanski, M. (2025). Influence of external factors on seed germination in field crops. *Selekcija i Semearstvo*, 31(1), 25–36. <https://doi.org/10.5937/SelSem2501025G>
- Safitri, D., Jaya, I. N. S., Nawangsari, N., Anggraeny, I., & Rhagat, B. (2023, November). Pemanfaatan air cucian beras sebagai pupuk organik cair untuk pertanian organik berkelanjutan. In *Prosiding Seminar Nasional Gelar Wicara* (Vol. 1, No. 2, pp. 1079–1086).
- Srimaulinda, S., Nurtjahja, K., & Riyanto, R. (2021). Pengaruh konsentrasi air kelapa dan air cucian beras dan lama perendaman terhadap perkecambahan benih kacang hijau (*Vigna radiata* L.). *Jurnal Ilmiah Biologi UMA (JIBIOMA)*, 3(2), 62–72. <https://doi.org/10.31289/jibioma.v3i2.751>
- Talpur, A., Khashkheli, A. A., Talpur, M. Y. M. K., Nizamani, N., & Khashkheli, G. H. (2024). Optimizing potential of coconut water as an organic priming agent for jujube (*Ziziphus mauritiana* L.). *Journal of Horticulture and Agricultural Sciences*, 1(1), 53–60. <https://doi.org/10.63459/jhas.2024.1.10>
- Tan, S. N., Yong, J. W. H., & Ge, L. (2014). Analyses of phytohormones in coconut (*Cocos nucifera* L.) water using capillary electrophoresis-tandem mass spectrometry. *Chromatography*, 1(4), 211–226. <https://doi.org/10.3390/chromatography1040211>
- Tuyekar, S. N., Tawade, B. S., Singh, K. S., Wagh, V. S., Vidhate, P. K., Yevale, R. P., Gaikwad, S., & Kale, M. (2021). An overview on coconut water: As a multipurpose nutrition. *International Journal of Pharmaceutical Sciences Review and Research*, 68(2), 63–70. <https://doi.org/10.47583/ijpsrr.2021.v68i02.010>
- Uebersax, M. A., Cichy, K. A., Gomez, F. E., Porch, T. G., Heitholt, J., Osorno, J. M., Kamfwa, K., Snapp, S. S., & Bales, S. (2023). Dry beans (*Phaseolus vulgaris* L.) as a vital component of sustainable agriculture and food security—A review. *Legume Science*, 5(1), e155. <https://doi.org/10.1002/leg3.155>
- Yong, J. W. H., Ge, L., Ng, Y. F., & Tan, S. N. (2009). The chemical composition and biological properties of coconut (*Cocos nucifera* L.) water. *Molecules*, 14(12), 5144–5164. <https://doi.org/10.3390/molecules14125144>
- Zhao, W., Ai, S., Yuan, H., Lv, M., & Lin, S. (2025). Comprehensive phytohormone analysis reveals the roles of auxin, cytokinin, and gibberellin in enhancing seed germination and growth of *Chimonobambusa utilis*. *Plants*, 14(24), 3780. <https://doi.org/10.3390/plants14243780>