

Original Article

Effects of Coconut Water Seed Priming on Germination and Seedling Growth of *Capsicum annuum*

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Abstract. Uneven and low germination in pepper (*Capsicum annuum* L.) is commonly associated with seed dormancy and variability in seed quality. Coconut water contains growth-promoting substances, including cytokinins and gibberellins; however, the optimal concentration and soaking duration for seed priming remain undefined. This study evaluated the use of coconut water as a pre-sowing treatment to enhance pepper germination and early seedling growth. The experiment was conducted in a greenhouse using a Completely Randomized Design (CRD) with 11 treatments and three replications. Four coconut water concentrations (25%, 50%, 75%, and 100%) and two soaking durations (12 and 24 hours) were evaluated. Distilled water and untreated seeds served as controls. A total of 825 seeds were used. Data were analyzed using analysis of variance (ANOVA), and treatment means were compared using the Duncan Multiple Range Test (DMRT) at a 5% significance level. Seeds primed with 50% coconut water for 24 hours exhibited the highest germination percentage, improved uniformity, and enhanced seedling growth (shoot length, stem diameter, leaf number, and fresh biomass). Seeds treated with distilled water and 25% coconut water showed comparable performance, and both outperformed the untreated control. Higher concentrations ($\geq 75\%$) did not improve performance and were associated with reduced growth. Priming pepper seeds with 50% coconut water for 24 hours is an effective, low-cost, and eco-friendly approach to enhance germination and early seedling vigor.

Keywords: Coconut water; Germination; Pepper; Seedling emergence; Seed priming.

Pepper (*Capsicum annuum*) can be cultivated under both open-field conditions and protected environments, allowing improved environmental control and more stable year-round production. However, successful crop establishment largely depends on rapid and uniform seed germination, which is essential for achieving uniform seedling growth and optimal yield performance. In *Capsicum annuum*, germination is often delayed and uneven due to physiological constraints and seed coat characteristics that can restrict water uptake and slow down metabolic activation, resulting in non-uniform emergence and reduced field performance (Finch-Savage & Bassel, 2016; Thakur et al., 2024). This constraint highlights the need for effective seed enhancement techniques.

Seed priming is a widely used pre-sowing technique that involves controlled hydration, meaning soaking seeds in water or a solution to partially hydrate them so that metabolic activities necessary for germination start, but

without allowing the root (radicle) to emerge. After priming, seeds are re-dried to their original moisture content, resulting in improved germination rate, uniformity, and seedling vigor, particularly under suboptimal environmental conditions (Zhang et al., 2022; Eraña & Valdez, 2025). Because of its simplicity and cost-effectiveness, seed priming has emerged as a key strategy in modern crop production.

Coconut water, derived from *Cocos nucifera* L., is abundant in the Philippines and contains various bioactive compounds, including sugars, amino acids, vitamins, and minerals (Liu et al., 2022). More importantly, it contains natural phytohormones including auxins, gibberellins, and cytokinins, which play key roles in cell division, elongation, and mobilization of seed reserves (Liu et al., 2022). Several studies have reported that coconut water can enhance germination and early growth in different crops (Kumar et al., 2020; Talpur et al., 2024).

Despite these findings, there is limited and inconsistent information on the optimal concentration and soaking duration of coconut water specifically for *Capsicum annuum*. This lack of clarity makes it difficult to recommend standardized priming protocols for pepper production. Therefore, this study aimed to evaluate the effects of different concentrations and soaking durations of coconut water on the germination, emergence, and early seedling growth of *Capsicum annuum*. Specifically, it sought to determine the most effective treatment that can improve seed performance and seedling vigor under controlled conditions.

Methodology

Research Design

The study used a Completely Randomized Design (CRD) with 11 treatments and three replications. A CRD was selected for this experiment because it is ideal for situations where the experimental units are homogeneous and the environmental conditions can be considered uniform, such as in controlled laboratory or greenhouse settings. This design allows each treatment to be assigned randomly to the experimental units, minimizing bias and ensuring that any observed differences in germination and seedling growth can be attributed to the treatments rather than to environmental variability. The CRD is simple, efficient, and appropriate for comparing multiple treatments, as in this study, where 11 different priming conditions are being evaluated.

Sampling, Experimental Materials, and Equipment

The experimental units consisted of *Capsicum annuum* seeds sourced from a single batch to ensure uniformity. A total of 825 seeds were used, with 25 seeds per replication for each of the 11 treatments. Seeds were selected based on uniform size, shape, and apparent health to minimize variability. The seeds were randomly assigned to treatments following a Completely Randomized Design (CRD) to ensure experimental consistency. Pepper seeds with a recorded germination rate of 85% were utilized in the study. The materials used included filter papers, germination boxes, and seedling trays for seed priming and germination. Measuring tools such as a ruler, caliper, and weighing scale were used to record seedling growth parameters. Distilled water was used for hydropriming and solution preparation, while coconut water solutions at 25%, 50%, 75%, and 100% concentrations were prepared for priming treatments. A timer was used to monitor soaking durations of 12 and 24 hours.

Treatments

The treatments consisted of four concentrations of coconut water (25%, 50%, 75% and 100%) and two soaking durations (12 and 24 hours), with distilled water and untreated seeds serving as controls. Specifically, the treatments were as follows: T0, untreated control; T1, distilled water for 12 hours; T2, 25% coconut water for 12 hours; T3, 50% coconut water for 12 hours; T4, 75% coconut water for 12 hours; T5, 100% coconut water for 12 hours; T6, distilled water for 24 hours; T7, 25% coconut water for 24 hours; T8, 50% coconut water for 24 hours; T9, 75% coconut water for 24 hours; and T10, 100% coconut water for 24 hours.

Data Gathering Procedure

The study used “Hiwaga F1” pepper seeds for both germination and emergence experiments. Seeds were disinfected in a 1% sodium hypochlorite solution for 3 minutes, rinsed twice with distilled water, and air-dried before soaking in their respective priming solutions for 12 or 24 hours. Seeds were then rinsed twice and placed in sterilized containers fully submerged in the solution. Coconut water priming solutions were prepared from immature coconuts and diluted with distilled water to obtain concentrations of 25%, 50%, 75%, and 100%. The pH of each solution was measured and recorded. For germination experiments, 25 seeds per treatment were placed on two layers of dampened filter paper in germination boxes under controlled conditions. Five milliliters of distilled water were sprayed daily during the first week to maintain moisture. Observations included percent

germination, mean germination time (T50), germination variability (T90–T10), and germination homogeneity. For seedling emergence and growth, seeds were sown in trays containing a 1:1 mixture of vermicompost and garden soil. Trays were placed in a greenhouse constructed with bamboo frames, polyethylene cover, and ventilation netting. Environmental conditions were monitored, and seedlings were watered regularly. Data collected included final emergence percentage at 7 days, total number of leaves at 14 days, shoot length and stem diameter at 28 days, leaf color at 28 days, and growth parameters at 28 days, including shoot and root fresh and dry weights (oven-dried at 70°C for 24 hours).

Data Analysis Procedure

All statistical analyses were performed using the Statistical Tool for Agricultural Research (STAR) version 2.0.1 (IRRI, 2014). Prior to statistical analysis, the assumptions of one-way ANOVA were verified. Normality of data distribution was assessed using the Shapiro–Wilk test, while homogeneity of variances was evaluated using Levene’s test. Residual plots were also visually inspected to confirm homoscedasticity. Data were then subjected to a one-way analysis of variance (ANOVA) at the 5% significance level. Where significant differences were detected, treatment means were compared using Duncan’s Multiple Range Test (DMRT). To provide a more robust interpretation of treatment effects, effect sizes were estimated using omega squared (ω^2), and 95% confidence intervals (CI) for treatment means were computed using the pooled error variance (MS_error) to assess precision.

Ethical Considerations

This study used only plant materials, and although formal ethical approval was not required, all research adhered to standard ethical and environmental practices, including responsible seed sourcing, safe waste disposal, proper use of pesticides, and avoidance of GMOs and endangered species.

Results and Discussion

Germination Parameters of Pepper

Table 1. Summary of Germination Parameters of Pepper (*Capsicum annuum*) as Influenced by Water and Coconut Water Priming for 12 and 24 Hours of Soaking Duration

Treatments	Percent Germination (%)	Mean Germination Time (T50, h)	Mean Spread of Germination (T90-T10, h)
T1	100.00	66.70 ^b	34.22 ^{cd}
T2	100.00	66.80 ^b	39.52 ^{bcd}
T3	100.00	66.37 ^b	39.46 ^{bcd}
T4	98.33	66.68 ^b	39.91 ^{bc}
T5	97.33	69.74 ^b	39.98 ^{bc}
T6	100.00	37.20 ^d	21.10 ^d
T7	100.00	37.44 ^d	21.54 ^{cd}
T8	100.00	37.19 ^d	21.14 ^d
T9	97.00	42.26 ^c	39.75 ^{bc}
T10	96.67	44.06 ^c	53.33 ^b
T0(Control)	96.00	99.39 ^a	72.41 ^a
CV (%)	1.77	2.33	16.29

Note: Means within a column followed by the same letter are not significantly different at the 5% level using DMRT.

Percent Germination

Treatment significantly influenced germination percentage ($p = .039$), showing a moderate effect size ($\eta^2 = .55$; $\omega^2 = .45$) and a 95% confidence interval of (± 2.10). Mean comparisons revealed that lower concentrations of coconut water (25% and 50%) and distilled water (T1, T2, T3, T6, T7, and T8) consistently achieved 100% germination. This parity suggests that higher concentrations offer no additional physiological advantage for initial emergence. Conversely, higher concentrations (T4, T5, T9, and T10) failed to enhance germination, indicating a threshold effect. This plateau may stem from osmotic stress or a supra-optimal hormonal imbalance—where excessive phytohormones inhibit rather than promote activity. These results align with Thakur et al. (2024), who characterized coconut water as a natural biostimulant that optimizes early development and seedling establishment when applied at balanced concentrations, particularly through seed priming strategies.

Mean Germination Time (T50, h)

Mean germination time was highly significantly influenced by treatments ($p < .001$), with a very large effect size ($\eta^2 = .997$; $\omega^2 = .995$), suggesting that treatment differences strongly affected germination speed. A very narrow

confidence interval (± 0.27 h) further indicates high consistency among replicates. Faster germination was observed in treatments soaked for 24 hours, particularly T8 (37.19 h), T6 (37.20 h), and T7 (37.44 h). This indicates that both soaking duration and appropriate coconut water concentration contribute to faster germination. In contrast, seeds primed for 12 hours showed moderate germination times (66.37–69.74 h), while the untreated control exhibited the slowest germination (99.39 h). Overall, coconut water priming improved germination speed compared with the control. These findings are consistent with those of Carganilla et al. (2025) in rice, where coconut water priming enhanced enzymatic activity and energy mobilization, thereby promoting faster germination.

Mean Spread of Germination (T90- T10, h)

Germination synchrony (spread) was significantly affected by treatments ($p < .001$, $\eta^2 = .90$; $\omega^2 = .87$), with an approximate confidence interval of (± 6.28 h). The most uniform germination occurred in seeds soaked for 24 hours in distilled water or low coconut water concentrations (T6, T7, and T8), reducing the spread to ~21 h (21.10–21.54 h) compared to 72.41 h in the control. In contrast, shorter soaking durations and higher concentrations resulted in wider germination spread, suggesting delayed metabolic activation across seeds. As reported by Farooq et al. (2019) and Carganilla et al. (2025), optimized priming conditions enhance uniform water uptake and synchronize physiological processes, leading to more consistent radicle emergence across the seed population.

Growth and Morphological Parameters

Table 2. Growth and Morphological Parameters of Pepper (*Capsicum annuum*) as Influenced by Water and Coconut Water Priming for 12 and 24 Hours of Soaking Duration

Treatments	Percent Emergence	Number of Leaves	Mean Shoot Length (cm)	Stem Diameter (mm)	Leaf Color (CCI)
T1	82.67 ^{ab}	5.60 ^{ab}	8.68 ^a	1.75 ^{ab}	13.10 ^{abc}
T2	82.66 ^{ab}	5.70 ^{ab}	8.63 ^{ab}	1.69 ^b	13.08 ^{abc}
T3	84.00 ^{ab}	5.45 ^{bc}	8.81 ^a	1.76 ^{ab}	13.13 ^{abc}
T4	78.67 ^{ab}	4.83 ^{cd}	8.29 ^{bc}	1.54 ^c	12.83 ^c
T5	70.67 ^{bc}	4.50 ^d	8.01 ^{cd}	1.45 ^{cd}	12.78 ^c
T6	84.00 ^{ab}	6.07 ^{ab}	8.96 ^a	1.76 ^{ab}	13.64 ^a
T7	84.00 ^{ab}	6.20 ^a	8.83 ^a	1.70 ^{ab}	13.53 ^{ab}
T8	90.67 ^a	6.30 ^a	8.98 ^a	1.83 ^a	13.72 ^a
T9	74.67 ^{bc}	4.82 ^{cd}	8.13 ^{cd}	1.47 ^{cd}	13.13 ^{abc}
T10	73.33 ^{bc}	4.37 ^d	7.88 ^d	1.37 ^d	12.87 ^{bc}
T0(Control)	64.00 ^d	4.77 ^{cd}	7.80 ^d	1.37 ^d	12.85 ^{bc}
CV (%)	5.96	4.63	1.49	2.83	1.78

Note: Means within a column followed by the same letter are not significantly different at the 5% level using DMRT.

Percent Emergence

Percent emergence was significantly affected by treatments ($p < .001$), with a large effect size ($\eta^2 = .78$; $\omega^2 = .68$) and an approximate 95% CI of ± 2.10 , indicating that a substantial proportion of variation was explained by the treatments. T8 (50% coconut water for 24 hours) achieved the highest emergence (90.67%), significantly higher than the untreated control (64.00%). The data suggest a bell-shaped response curve, where moderate concentration (50%) optimized emergence, while higher concentrations (75–100%) caused a decline. This decline indicates a potential inhibitory osmotic effect or hormonal toxicity at excessive levels, which disrupts the physiological balance required for early establishment. These findings align with those of Lakmali and Seran (2022), who found that moderate concentrations of king coconut water in okra improved germination and seedling establishment, whereas higher concentrations reduced performance.

Number of Leaves

The number of leaves was significantly influenced by treatments ($p < .001$), with a very large effect size ($\eta^2 = .92$; $\omega^2 = .88$) and a confidence interval of (± 0.52 leaves), indicating strong treatment responsiveness. Higher leaf numbers were observed in T8 (6.30) and T7 (6.20), along with relatively high values in T1 (6.60), T6 (6.07), T2 (5.70), and T3 (5.45). In contrast, T4 (4.83), T9 (4.82), and T10 (4.37) produced fewer leaves, comparable to the control (4.77). Similar findings were reported by Nwonuala (2021), who observed increased leaf production following coconut water priming. Likewise, Zhang et al. (2022) reported that natural priming agents improve leaf development and overall seedling vigor. This response may be linked to growth regulators in coconut water that promote cell division and expansion.

Mean Shoot Length

Shoot length was significantly influenced by treatments ($p < .001$), with a very large effect size ($\eta^2 = .92$; $\omega^2 = .90$) and a narrow confidence interval (± 0.26 cm), indicating strong treatment effects and high precision. Seedlings treated with moderate concentrations (25–50%) exhibited the longest shoots (8.83–8.98 cm), significantly longer than those in the control (7.80 cm). Lower concentrations with shorter soaking durations yielded moderate shoot lengths (8.29–8.68 cm), whereas the highest concentration (100%) produced shorter shoots (7.88–8.01 cm). Similar trends were reported by Oladzad et al. (2020) in soybean, where bio-based priming improved shoot development.

Stem Diameter

Stem diameter was significantly affected by treatments ($p < .001$), with a very large effect size ($\eta^2 = .95$; $\omega^2 = .94$) and a very small confidence interval (± 0.06 mm), indicating strong and consistent treatment effects. The thickest stems were observed in T8 (1.83 mm), followed by moderate treatments such as T1 (1.75 mm), T3 and T6 (1.76 mm), and T7 (1.70 mm). In contrast, thinner stems were recorded in T10 (1.37 mm), T5 (1.45 mm), and the control (1.37 mm). These results suggest that optimal coconut water concentrations enhance seedling vigor, whereas excessive levels may limit structural development. This is consistent with Reddy et al. (2021), who reported that organic and botanical priming treatment improved seedling vigor in pigeon pea. This is also supported by Zainudin and Adini (2019), who found that coconut water concentration and soaking duration significantly influence seedling growth in papaya.

Leaf Color Measurement

Chlorophyll content was significantly influenced by treatments ($p < .001$), with a large effect size ($\eta^2 = .74$; $\omega^2 = .68$) and a confidence interval of (± 0.43), indicating moderate variability in response. Higher chlorophyll content was observed in T8 (13.72) and T6 (13.64) than in the control (12.85). Moderate values were recorded in T1 (13.10), T2 (13.08), T3, and T9 (13.13), while the highest concentrations (75–100%) resulted in lower chlorophyll content (12.78–12.87). This pattern suggests that moderate priming enhances photosynthetic capacity, while excessive concentrations may reduce pigment accumulation. These findings are consistent with Ogunyemi et al. (2020), who reported improved chlorophyll content following natural seed priming.

Biomass Accumulation of Pepper

Table 3. Biomass Accumulation of Pepper (*Capsicum annum*) as Influenced by Water and Coconut Water Priming for 12 and 24 Hours of Soaking Duration

Treatments	Shoot Fresh Weight (g)	Shoot Dry Weight (g)	Root Fresh Weight (g)	Root Dry Weight (g)
T1	0.61 ^{ab}	0.12	0.32 ^{bc}	0.04 ^{abcd}
T2	0.56 ^{bc}	0.12	0.32 ^{bc}	0.03 ^{bcd}
T3	0.58 ^{ab}	0.13	0.37 ^{ab}	0.04 ^{abcd}
T4	0.51 ^{bcd}	0.12	0.28 ^{cd}	0.02 ^{def}
T5	0.46 ^{cd}	0.11	0.29 ^{cd}	0.02 ^{ef}
T6	0.62 ^{ab}	0.11	0.39 ^{ab}	0.04 ^{ab}
T7	0.61 ^{ab}	0.12	0.38 ^{ab}	0.04 ^{abc}
T8	0.69 ^a	0.13	0.41 ^a	0.04 ^a
T9	0.59 ^{ab}	0.11	0.27 ^{cd}	0.03 ^{cde}
T10	0.47 ^{cd}	0.11	0.23 ^d	0.02 ^f
T0(Control)	0.44 ^d	0.11	0.22 ^d	0.02 ^f
CV (%)	6.69	9.92	9.05	13.17

Note: Means within a column followed by the same letter are not significantly different at the 5% level using DMRT.

Shoot Fresh Weight

Shoot fresh weight was significantly affected by treatments ($p < .001$), with a very large effect size ($\eta^2 = .85$; $\omega^2 = .81$) and a very small confidence interval (± 0.03 g), indicating high precision of treatment effects. The highest shoot fresh weight was observed in T8 (0.69 g), significantly higher than the control (0.44 g). Moderate increases were also recorded in T1 (0.61 g), T3 (0.58 g), T6 (0.62 g), T7 (0.61 g), and T9 (0.59 g), indicating enhanced biomass accumulation. In contrast, the highest concentration treatments (100% coconut water) resulted in lower shoot fresh weights (0.46–0.47 g). These results suggest that moderate concentrations of coconut water enhance biomass production, whereas excessive concentrations may limit growth. This finding is consistent with Oliveira et al. (2021), who reported increased seedling biomass in papaya following coconut water priming.

Shoot Dry Weight

Shoot dry weight was not significantly affected by treatments ($p = .201$), with a small effect size ($\eta^2 = .37$; $\omega^2 = .01$) and a narrow confidence interval (± 0.01 g), indicating limited treatment influence on this trait. Although slight numerical differences were observed, with the highest value in T8 (0.13 g) and the lowest in T10 (0.11 g), these were statistically comparable to the control (0.11 g). This suggests that coconut water priming had minimal impact on dry matter accumulation under the conditions of this study.

Root Fresh Weight

Root fresh weight was significantly affected by treatments ($p < .001$), with a very large effect size ($\eta^2 = .86$; $\omega^2 = .82$) and a small confidence interval (± 0.03 g), indicating consistent treatment effects. The highest root fresh weight was observed in T8 (0.41 g), markedly higher than the control (0.22 g). Moderate increases were also recorded in T3 (0.37 g), T6 (0.39 g), and T7 (0.38 g), whereas lower values were observed in the higher-concentration treatments (0.23–0.29 g). These results indicate that moderate concentrations of coconut water promote root biomass accumulation, consistent with Lakmali and Seran (2022), who reported that seed priming with king coconut water improved root length in okra.

Root Dry Weight

Root dry weight was significantly affected by treatments ($p < .001$), with a very large effect size ($\eta^2 = .88$; $\omega^2 = .86$), indicating strong treatment influence on root biomass accumulation. The highest root dry weights were recorded in T8, T6, and T7 (0.04 g), statistically comparable to T1 and T3 (0.04 g). In contrast, T5 and T10 (0.02 g) did not differ significantly from the control (0.02 g), which recorded the lowest biomass. This pattern suggests that moderate coconut water priming enhances root development, whereas excessive concentrations may reduce effectiveness.

Conclusion

This study demonstrated that priming “Hiwaga F1” pepper seeds in 50% coconut water for 24 hours significantly enhanced seed germination, emergence, and early seedling growth. Moderate concentrations (25–50%) also improved performance, whereas higher concentrations (>75%) reduced growth, highlighting the importance of optimal priming conditions. These findings indicate that coconut water is a simple, sustainable, and cost-effective priming agent that can improve uniform crop establishment, reduce planting costs, and support early-stage seedling vigor. Adoption of this technology could benefit smallholder farmers, particularly in coconut-producing regions, and contribute to more resilient and productive pepper cultivation. Future research should evaluate its effectiveness across different pepper varieties and field conditions, and explore integration with broader agronomic practices to further optimize crop performance.

Contributions of Authors

Author 1: Jenny T. Aquino is the author of the study, the researcher of the experimental framework, experimenter, data collection and analysis, and the preparation of the manuscript. Aquino conducted a major study and interpreted the study.

Author 2: Jonabelle S. Carganilla participated in the experiment, contributed to data collection, and assisted in the organization and preparation of materials for analysis.

Author 3: Jessica J. Dinay-og assisted in conducting the experiment and gathering data, as well as in preparing the supporting documentation.

Author 4: Glen Joy L. Cumahling contributed to the experiment, participated in data collection, and assisted in the preparation of documentation.

Author 5: Manolo T. Valdez supervised the study, contributed to the study design, assisted with statistical analysis and interpretation of results, and revised and refined the manuscript. The final version of the manuscript was reviewed and approved by all authors.

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Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of the paper.

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