Journal of Applied Life Sciences and Environment
https://jurnalalse.iuls.ro

USV 1842

Article
https://doi.org/10.46909/alse-574160
Vol. 57, Issue 4 (200) / 2024: 723-741

GROWTH AND SEED YIELD RESPONSES OF TWO SOYBEAN (*Glycine max* L. MERR.) VARIETIES TO COCONUT WATER PRIMING

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Received: Dec. 15, 2024. Revised: Jan. 12, 2025. Accepted: Jan. 16, 2025. Published online: Feb. 11, 2025

ABSTRACT. Soybean is an essential legume that is increasingly valued for its nutritious oil and protein contents. Despite the benefits derived from soybean, low seed viability and inconsistent germination are major production setbacks. The objective of this study was to determine the effect of seed priming agents on the growth and yield of two soybean varieties (Favour and Afayak). The research used a 2 × 5 factorial randomised complete block design with three replications. The soybean variety at 2 levels was the first factor (Favour and Afayak), and the second factor involved 5 priming treatments: 4 h of water (20°C), 6 h of water, 4 h of coconut water, 6 h of coconut water, and no priming. Coconut water priming significantly enhanced germination, with the Favour variety achieving the highest rate (75.5%) after 4 h of priming. Water priming for 4 h was most effective in enhancing plant height, stem girth and leaf development in the Afayak variety. Yield was maximised in Afayak primed with coconut water for 6 h (2520 kg/ha), while Favour primed for 4 h produced the highest number of pods (135.5). Regression analysis revealed that the growth parameters and germination percentage accounted for 95% of seed yield variation. The study concludes that coconut water is an effective priming agent, enhancing germination, growth and yield and recommends 4-h coconut water priming for Favour and 6-h priming for Afayak to optimise production.

Keywords: coconut water; germination; seed yield; soybean seed; vegetative growth.

Cite: Tandoh, P.K.; Idun, I.A.; Bemanu, B.Y.; Nyagblordzro, A.K.; Kwaah, S.; Damtuah, A. Growth and seed yield responses of two soybean (*Glycine max* L. Merr.) varieties to coconut water priming. *Journal of Applied Life Sciences and Environment* **2024**, *57* (4), 723-741. https://doi.org/10.46909/alse-574160

INTRODUCTION

Soybean (*Glycine max*), a vital legume species of the Fabaceae family (bean), is gaining increasing popularity in Sub-Saharan Africa and other parts of the world due to its potential to alleviate poverty and enhance nutrition (Mahoussi *et al.*, 2020). Soybean oil is the primary source of edible oils globally, with soybeans accounting for 30% of the world's output (Assefa, 2008).

According to Lokuruka *et al.* (2011), soybean seeds are rich in calcium, phosphorus and vitamins, containing 40–45% protein, 20–22% oil and 20–26% carbohydrates. The high protein and oil contents contribute to the crop's significant utility (Bellaloui *et al.*, 2010; Hussain *et al.,* 2020; Orf, 2010). The primary product derived from soybean is soybean meal, which is widely used in the production of fish, poultry, pig and dairy products (Ibáñez *et al.*, 2020).

In 2023, global soybean production reached approximately 394.87 million metric tonnes, cultivated over an estimated 120 million hectares. The leading producers were Brazil (accounting for 38.7% of global production), the United States (28.7%), Argentina (12.2%), China (5.3%) and India (3%). Africa's contribution remained minimal, producing about 0.9% of the global soybean output, which is insufficient to meet the continent's growing demand for soybean products (FAOSTAT, 2023).

The lack of coordinated crop establishment as a result of unfavourable weather and soil conditions is a major obstacle to attaining high yields and production in agricultural plants (Engelbrecht *et al*., 2020). Soybean plant density per unit area often falls below the desired levels due to low seed viability (Puozaa *et al*., 2023). Poor or uneven seed germination is a prevalent issue in soybean production, largely due to the delicate nature of the seed coat (Rao *et al.*, 2023). Soybean plants frequently fall short of the target density per unit area, even when they are grown from premium seeds; this could be because of low seed viability. However, appropriate pre-sowing physiological seed enhancement treatments, such as seed priming, can help overcome this challenge (Corbineau *et al*., 2023).

According to Corbineau *et al.* (2023), seed priming is a technique that improves the viability of degraded seeds and increases their capacity to grow in a variety of environments. Seed priming results in high rates of germination and field emergence, effective field establishment, and robust seedlings. Seed priming involves controlled seed imbibition through soaking or moisturising, allowing metabolic activities to commence before planting, while preventing radicle or plumule emergence (Nawaz, 2025).

Over time, seed priming techniques have been modified to incorporate various methodologies. Ashraf and Foolad (2005) noted that the benefits and drawbacks of priming vary depending on the plant species, growth stage, priming agent concentration, and priming duration. This technique improves germination, seedling growth, seedling uniformity and yield, particularly under stressful growth conditions, compared to unprimed seeds (Fattahi *et al*., 2019; Souri and Hatamian, 2019).

According to Moradi and Younesi (2009), priming seeds using osmo- or

hydro-priming speeds up germination and decreases the emergence time; however, compared to unprimed seeds, primed seeds performed poorly in accelerated ageing experiments.

Although there is limited research on the use of coconut water (CW) for priming seeds, it contains enzymes that may promote seed germination. CW contains minerals, such as potassium, calcium, magnesium, iron, sodium, phosphorus, zinc, manganese, copper, sulphur, aluminium, boron, selenium and chlorine.

Potassium is the major mineral in CW, followed by sodium (Jean *et al*., 2009). CW exhibits characteristics similar to root hormones due to the presence of plant growth regulators. It is natural supplement rich in compounds, such as indole-3-acetic acid (IAA), cytokinins, abscisic acid (ABA) and salicylic acid, which play critical roles in promoting plant growth and development (Kende and Zeevaart, 1997; Yong *et al.*, 2009).

In plant tissue culture and micropropagation, CW is a crucial growth supplement (Yong *et al.,* 2009). Reducing the amount of time between seeding and seedling emergence, which is critical in crop production, has been the focus of recent research studies.

Thus, the purpose of this study was to determine how different seed priming agents and the priming duration affect the development and seed yield of two soybean varieties (Favour and Afayak).

MATERIALS AND METHODS

Experimental site

This study was carried out at Kwame Nkrumah University of Science and Technology's Horticultural Department, Faculty of Agriculture, in Kumasi, Ghana. With an average annual rainfall of 1500 mm, the experimental site experiences bimodal rainfall patterns. The main rainy season runs from mid-March to July, with a brief dry spell in August. The minor rainy season occurs from September to November. According to the Metrological Department of KNUST (2012), the primary dry season lasts from late November to early March.

The planting period occurs in the short dry season from December to the minor rainy season in April. The field, which has sandy loam soil, is situated at latitude 5°361 N and longitude 0°101 E. During the study period, the average rainfall was 645 mm. The mean relative humidity ranged from 27% at noon to 66% in the morning, and the mean lowest and highest temperatures were 22 and 31°, respectively.

Sources of seeds and materials for the experiment

Seeds of two soybean varieties (Favour and Afayak) were obtained from the Savannah Agricultural Research Institute (SARI), Tamale, Ghana. CW and distilled water were obtained from the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Experimental design and procedure

A 2 × 5 factorial with 3 replications was used to set up the experiment in a randomised complete block design (RCBD). The first factor was the variety at two levels (Favour and Afayak). The second factor was the priming agent at 5 levels: primed with water for 4 h, primed with tap water (20°C) for 6 h, primed with

CW for 4 h, primed with CW for 6 h and no priming. A pot experiment (12 kg soil/pot) was carried out on a concrete floor. Air-dried soil (12 kg) was placed in a plastic pot with a 60-cm diameter, 60-cm depth and weight of 1.0 kg. A drainage hole was created at the bottom. The soybean seeds (100 seeds each for both Favour and Afayak) were immersed in 60 mL of CW for 4 and 6 h. Following this, the seeds were immediately. The soybean seeds (100 seeds each for both Favour and Afayak) were soaked with distilled water (60 mL, obtained from a laboratory distiller) for 4 and 6 h, after which the seeds were removed and sown. No treatment was applied when planting the soybean seeds as a control.

Sowing was performed in buckets with three seeds per hole and two holes in each bucket in a row at a distance of 10 cm. There were 10 pots for each treatment with 2 seedlings per pot, for a total of 20 plants. There were 300 pots total in the the experiment, with each block containing 100 pots. Of the 20 plants in each treatment, 15 seedlings were randomly sampled and tagged for data collection. Weeding, insect pest control, disease management, and other standard agronomic procedures were completed on a schedule.

Collected data

The following parameters were measured: germination count, seedling emergence, plant height, number of leaves and number of days needed for all plants in the container to reach 50% flowering.

Germination percentage

The following formula was used to calculate the germination percentage (*Equation 1*).

$$\frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ planted} \times 100 \quad (1)$$

Plant height (cm)

The plant height was measured every 2 weeks on randomly selected and tagged plants using a measuring tape. The average was calculated per plant.

Number of leaves

The number of leaves was counted every 2 weeks on randomly chosen and marked plants, and an average was determined for each plant.

Stem girth

The stem girth was measured every 2 weeks on randomly chosen and marked plants using a vernier calliper. The average was determined for each plant.

Number of branches

The number of branches was counted during the reproductive stage, around R1 (begin podding) or R2 (full bloom) on the soybean growth stage scale.

Seed yield parameters

Pod number

The number of pods was determined by counting the total number of pods generated per plant.

Yield

The average weight of each seed was measured using a digital balance and converted to kg/ha to determine the yield.

Data analysis

Statistix Software version 10.0 was used to perform an analysis of variance (ANOVA) on the acquired data. At a 5% probability level, the mean was separated using Tukey's honestly significant difference test.

RESULTS

Germination percentage of soybean cultivars

Significant differences were recorded in the interaction between priming agents and varieties (*Table 1*). The highest germination percentage (75.50%) was recorded in the Favour variety primed with CW for 4 h, while the lowest was observed in both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, the highest germination percentage (67.15%) was recorded by seeds primed with CW for 4 h, and the least was recorded in seeds soaked in water for 6 h. For the variety factor, Favour recorded the highest germination percentage (37.06%), and Afayak did not germinate (0).

Plant height of soybean varieties at 4 weeks after planting

At 4 weeks after planting, significant ($p<0.01$) variations in plant height were observed based on priming agent, variety or their interaction (*Table 2*). Seeds primed with water for 6 h gave the least plant height for both varieties.

Plant height of soybean varieties at 6 weeks after planting

At 6 weeks after planting, significant ($p<0.01$) differences were observed due to the interaction of the priming agent and variety (*Table 3*). The highest plant height (61.5 cm) was recorded for the Afayak variety primed with water for 4 h, while the least was observed both varieties (Afayak and Favour) soaked in water for 6 h. Among the priming agents, the tallest plants (58.375 cm) were observed after seeds were soaked in water for 4 h, and the lowest height was observed when seeds were soaked in water for 6 h. There was no significant difference between Favour and Afayak.

Plant height of two soybean varieties at 8 weeks after planting

At 8 weeks after planting, significant ($p<0.01$) differences were observed in plant height due to the interaction of the priming agent and variety (*Table 4*). The highest plant height (93.5 and 93.0 cm) was recorded in both varieties primed by soaking in water for 4 h, while the shortest plants were observed in both varieties (Afayak and Favour) primed by soaking in water for 6 h. Among the priming agents, seeds primed with water for 4 h produced the tallest plants (93.25 cm), whereas seeds primed with water for 6 h produced the shortest plants. Among the varieties, the highest plant height (68.01 cm) was recorded by Favour and the lowest was recorded by Afayak.

Plant height of soybean varieties at 12 weeks after planting

At 12 weeks after planting, significant ($p<0.01$) differences in plant height were recorded due to the interaction between the soybean variety and priming agent (*Table 5*). The highest plant height (135.5 cm) was recorded for the Afayak variety primed with water for 4 h, and the shortest plants were observed in both varieties (Afayak and Favour) soaked in water for 6 h. Among the priming agents, seeds primed with water for 4 h produced the tallest plants (128.0 cm), whereas seeds primed with water for 6 h produced the shortest plants. No significant differences were recorded between the varieties.

Plant height of the soybean varieties at 16 weeks after planting

At 16 weeks after planting, significant ($p<0.01$) differences in plant height were recorded for the interaction between the priming agent and variety (*Table 6*). The highest plant height (136.0 cm) was recorded by the Afayak variety primed with water for 4 h, while the lowest was observed for both varieties (Afayak and Favour) when primed with water for 6 h. Among the priming agents, seeds primed with water for 4 h produced the tallest plants (129.5 cm), whereas seeds primed with water for 6 h produced the shortest plants. Among the varieties, the highest plant height (129.5 cm) was recorded by Favour, and the lowest was recorded by Afayak.

Number of leaves of the soybean varieties at 4 weeks after planting

Significant ($p<0.01$) differences in the number of leaves were recorded due to the interaction between the priming agent and variety at 4 weeks after planting (*Table 7*). The Afayak variety primed with water for 4 h had the greatest number of leaves (22.5), while the least was recorded in both the Afayak and Favour varieties primed with water for 6 h. Of the priming agents, seeds primed with water for 4 h had the most leaves (20.5), and seeds primed with water for 6 h had the fewest leaves. No significant differences were observed between the varieties

Number of leaves in soybean varieties at 6 weeks after planting

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in the number of leaves at 6 weeks after planting (*Table 8*). The Afayak variety primed with water for 4 h had the most leaves (36.5), while both varieties (Afayak and Favour) primed with water for 6 h had the least. Among the priming agents, seeds primed with water for 4 h had the most leaves (34.0), whereas seeds primed with water for 6 h had the fewest leaves. There were no significant differences in the number of leaves between varieties.

Number of leaves in soybean varieties at 8 weeks after planting

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in the number of leaves at 8 weeks after planting (*Table 9*). The Afayak variety primed with water for 4 h had the most leaves (82.0), while both varieties (Afayak and Favour) soaked for 6 h in water had the least. Among the priming agents, seeds primed with water for 4 h had the most leaves (77.5), whereas seeds primed with water for 6 h had the fewest leaves. The most leaves (54.4) was recorded for Favour, and the least was recorded for Afayak.

Number of leaves in soybean varieties at 12 weeks after planting

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in the number of leaves at 12 weeks after planting (*Table 10*). The Afayak variety primed with water for 4 h had the most leaves (380.0), while both varieties (Afayak and Favour) primed with water for 6 h had the least. Among the priming agents, seeds primed with water for 4 h had the most leaves (299.5), whereas seeds primed with water for 6 h had the fewest leaves. For the varieties, the maximum number of leaves (169.6) was recorded for Afayak, and the least was observed for Favour.

Table 1 – Effect of priming agents on the germination percentage (%) in two soybean varieties

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	42.1^{d}	33.8^{e}	37.95^{c}
Coconut water + 4 h	58.5^{b}	75.5^{a}	67.15^{a}
Coconut water + 6 h	58.8^{b}	50.5^{c}	54.65^{b}
Water + 4 h	8.8^{g}	25.5^{f}	17.15^{d}
Water + 6 h	0^{h}	0^{h}	0^{e}
Mean	33.7^{b}	37.06^{a}	
CV = 0.84			
HSD (0.01): Priming Agent = 0.708, Variety = 0.302, Priming Agent × Variety = 1.210			

Means followed by different letter(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 2 – Effect of priming agents on the plant height (cm) of 2 soybean varieties at 4 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	30.35^{a}	34.5^{a}	32.43^{a}
Coconut water + 4 h	35.85^{a}	33.1^{a}	34.475^{a}
Coconut water + 6 h	32.9^{a}	30.85^{a}	31.875^{a}
Water + 4 h	36.5^{a}	33.95^{a}	35.225^{a}
Water + 6 h	0^{b}	0^{b}	0^{b}
Mean	27.12^{a}	26.48^{a}	
CV = 10.69			
HSD (0.01): Priming Agent = 6.809, Variety = 0.201, Priming Agent × Variety = 11.627			

Means followed by different letters(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 3 – Effect of priming agents on plant height (cm) of 2 soybean varieties at 6 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	51.0b^{c}	52.75^{bc}	51.875^{b}
Coconut water + 4 h	56.5a^{b}	51.65^{bc}	54.075^{b}
Coconut water + 6 h	49.4^{c}	52.85^{bc}	51.125^{b}
Water + 4 h	61.5^{a}	55.25^{bc}	58.375^{a}
Water + 6 h	0^{d}	0^{d}	0^{c}
Mean	43.68^{a}	42.5^{a}	
CV = 3.45			
HSD (0.01): Priming Agent=3.529, Variety = 1.504, Priming Agent × Variety = 6.027			

Means followed by different letter(s) differ from each other at a 5% probability levelaccording to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 4 – Effect of priming agents on the plant height (cm) of 2 soybean varieties at 8 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	74.0^{d}	91.25^{a}	82.625^{b}
Coconut water + 4 h	77.0^{cd}	86.15^{b}	81.575^{b}
Coconut water + 6 h	78.75^{c}	69.65^{e}	74.200^{c}
Water + 4 h	93.5^{a}	93.0^{a}	93.25^{a}
Water + 6 h	0^{f}	0^{f}	0^{d}
Mean	64.65^{b}	68.01^{a}	
CV = 1.57			
HSD (0.01): Priming Agent = 2.468, Variety = 1.051, Priming Agent × Variety = 4.215			

Means followed by different letter(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 5 – Effect of priming agents on the plant height (cm) of 2 soybean varieties at 12 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	100.5^{d}	106.5^{cd}	103.5^{c}
Coconut Water + 4 h	111.4^{bcd}	113.4^{bc}	112.4^{b}
Coconut water + 6 h	102.5^{cd}	110.65^{bcd}	106.57^{bc}
Water + 4 h	135.5^{a}	120.50^{b}	128.0^{a}
Water + 6 h	0^{e}	0^{e}	0^{d}
Mean	89.98^{a}	90.21^{a}	
CV = 3.48			
HSD (0.01): Priming Agent = 7.452, Variety = 3.175, Priming Agent × Variety = 12.73			

Means followed by different letter(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 6 – Effect of priming agents on the plant height (cm) of 2 soybean varieties at 16 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	101.5^{d}	112.0^{c}	106.75^{c}
Coconut water + 4 h	112.75^{c}	114.5^{c}	113.63^{b}
Coconut water + 6 h	103.0^{d}	111.65^{c}	107.33^{c}
Water + 4 h	136.0^{a}	123.0^{b}	129.5^{a}
Water + 6 h	0^{e}	0^{e}	0^{d}
Mean	90.65^{b}	129.5^{a}	
CV = 1.54			
HSD (0.01): Priming Agent = 3.353, Variety = 1.429, Priming Agent × Variety = 5.723			

Means followed by different letter(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 7 – Effect of priming agents on the number of leaves of 2 soybean varieties at 4 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	15.5^{b}	17.5^{b}	16.5^{b}
Coconut water + 4 h	17.5^{b}	15.5^{b}	16.5^{b}
Coconut water + 6 h	17.0^{b}	18.5^{b}	17.75^{b}
Water + 4 h	22.5^{a}	18.5^{b}	20.5^{a}
Water + 6 h	0^{c}	0^{c}	0c
Mean	14.5^{a}	14.0^{a}	
CV = 6.38			
HSD (0.01): Priming Agent = 2.162, Variety = 0.921, Priming Agent × Variety = 3.691			

Means followed by different letter(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 8 – Effect of priming agents on the number of leaves of 2 soybean varieties at 6 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	27.5^{ab}	26.5^{ab}	27.0^{ab}
Coconut water + 4 h	21.5^{b}	28.0^{ab}	24.75^{b}
Coconut water + 6 h	26.5^{ab}	21.5^{b}	24.0^{b}
Water + 4 h	36.5^{a}	31.5^{ab}	34.0^{a}
Water + 6 h	0^{c}	0^{c}	0^{c}
Mean	22.4^{a}	21.5^{a}	
CV = 16.23			
HSD (0.01): Priming Agent = 8.465, Variety = 3.606, Priming Agent × Variety = 14.455			

Means followed by different letter(s) differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 9 – Effect of priming agents on the number of leaves of 2 soybean varieties at 8 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	67.0^{bc}	71.0^{b}	69.0^{b}
Coconut water + 4 h	39.5^{e}	56.0^{d}	47.75^{c}
Coconut water + 6 h	59.5^{cd}	72.0^{ab}	65.75^{b}
Water + 4 h	82.0^{a}	73.0^{ab}	77.5^{a}
Water + 6 h	0^{f}	0^{f}	0^{d}
Mean	49.6^{b}	54.4^{a}	
CV = 5.21			
HSD (0.01): Priming Agent = 2.468, Variety = 1.051, Priming Agent × Variety = 4.215			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 10 – Effect of priming agents on the number of leaves of 2 soybean varieties at 12 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	153.0^{d}	192.5^{c}	172.75^{b}
Coconut water + 4 h	113.5^{e}	149.5^{d}	131.5^{d}
Coconut water + 6 h	201.5^{c}	112.0^{e}	156.75^{c}
Water + 4 h	380.0^{a}	219.0^{b}	299.5^{a}
Water + 6 h	0^{f}	0^{f}	0^{e}
Mean	169.6^{a}	134.6^{b}	
CV = 2.41			
HSD (0.01): Priming Agent = 8.718, Variety = 3.714, Priming Agent × Variety = 14.889			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Number of leaves in soybean varieties at 16 weeks after planting

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in the number of leaves at 16 weeks after planting (*Table 11*). The maximum number of leaves (374.0) was recorded for the Afayak variety primed with water for 4 h, while the least was observed for both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, seeds primed with water for 4 h had the most leaves (293.0), whereas seeds primed with water for 6 h had the fewest leaves. For the varieties, Afayak had the most leaves (165.1), and Favour had the least.

Stem girth of soybean varieties at 4 weeks after planting

Significant ($p<0.01$) differences in stem girth were observed due to the interaction between the priming agent and variety at 4 weeks after planting (*Table 12*). The highest stem girth (4.9) was recorded for the Afayak variety primed with CW for 4 h, while the lowest was observed for both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, the highest stem girth (4.9) was recorded for seeds primed with CW for 4 h, and the lowest was observed for seeds primed with water for 6 h. Favour had the highest stem girth (3.3), and Afayak had the lowest.

Stem girth of soybean varieties at 6 weeks after planting

Significant ($p<0.01$) differences in stem girth were observed due to the interaction between the priming agent and variety at 6 weeks after planting (*Table 13*). The highest stem girth (7.5) was recorded for the Afayak variety primed with water for 4 h, while the lowest was observed in both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, seeds primed with water for 4 h had the maximum stem girth (7.0), whereas seeds primed with water for 6 h had the lowest. No significant differences were observed between varieties.

Stem girth of soybean varieties at 8 weeks after planting

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in stem girth at 8 weeks after planting (*Table 14*). The highest stem girth (12.0) was recorded by

the Favour variety primed with water for 4 h, while the lowest was observed in both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, seeds primed with water for 4 h had the highest stem girth (10.75), whereas seeds primed with water for 6 h had the smallest. No significant differences in stem girth were observed between varieties.

Stem girth of soybean varieties at 12 weeks after planting

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in stem girth at 12 weeks after planting (*Table 15*). The highest stem girth (14.75) was recorded for the Favour variety primed with water for 6 h, while the lowest was observed in both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, seeds primed with water for 4 h had the highest stem girth (14.13), whereas seeds primed with water for 6 h had the smallest stem girth. No significant differences were recorded between varieties.

Stem girth of soybean varieties at 16 weeks after planting

There was no significant ($p<0.01$) interaction effect between the variety and priming agent on stem girth (*Table 16*). Among the priming agents, seeds primed with water for 4 h had the highest stem girth (16.5), whereas seeds primed with water for 6 h had the lowest stem girth. There were no notable differences between varieties.

Number of branches in soybean varieties

The interaction between the variety and priming agent showed significant ($p<0.01$) differences in the number of branches (*Table 17*). The highest number of branches (8.0) was recorded for the Afayak variety primed with water for 4 h, while the least was observed in both varieties (Afayak and Favour) primed with water for 6 h. Seeds primed with water for 4 h had the most branches (7.25), while seeds treated with water for 6 h had the fewest. Afayak had the most branches (4.9) among the varieties, whereas Favour had the fewest.

Number of pods in the soybean varieties

The interaction between the variety and priming agent showed significant ($p<0.01$) differences for the number of pods (*Table 18*). Favour variety primed with CW for 4 h had the most pods (135.5), while both varieties (Afayak and Favour) primed with water for 6 h had the least. Among the priming agents, the highest number of pods (95.0) was recorded for seeds primed with CW for 4 h, and the least was observed in seeds primed with water for 6 h. Afayak recorded the most pods (54.2), while Favour recorded the fewest.

Yield of the soybean varieties

The interaction between the variety and priming agent showed significant ($p<0.01$) differences for yield (*Table 19*). The highest yield was recorded for the Afayak variety primed with CW for 6 (2520 kg/ha) and 4 h (2508 kg/ha), while the least was observed in both varieties (Afayak and Favour) primed with water for 6 h. Among the priming agents, the highest seed yield was recorded for seeds primed with CW for 6 (1402 kg/ha) and 4 h ((1380 kg/ha). The lowest yield was observed in seeds primed with water for

6 h. For the varieties, the highest seed yield (921 kg/ha) was recorded for Afayak, and the lowest (427.7 kg/ha) was recorded for Favour.

Correlation among parameters

There was a strong, positive, significant correlation between stem girth and plant height (r=0.97), branches and stem girth (r=0.9174), plant height and branches (r=0.89), number of leaves and branches (r=0.84), plant height and number of leaves (r=0.79), and germination percentage and seed yield (r=0.77), as shown in *Table 20*.

Regression analysis among the parameters

Multiple regression analysis showed that all growth parameters (number of branches, germination percentage, plant height, number of leaves and stem girth) significantly affected seed yield, such that 95% of the variation in seed yield was accounted for by the growth parameters (*Equation 2*):

$$Y_{(\text{Seed yield})} = 0.11092 + 0.24579_{(\text{Branches})} + 0.28865_{(\text{Germination percentage})} - 0.22051_{(\text{Plant height})} + 0.4673_{(\text{leaves})} + 0.53779_{(\text{Stem girth})} \quad (2)$$

Table 11 – Effect of priming agents on the number of leaves of 2 soybean varieties at 16 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	140.0^{c}	145.0^{c}	142.5^{b}
Coconut water + 4 h	116.5d^{e}	139.5^{cd}	128.0^{c}
Coconut water + 6 h	195.0^{b}	104.5^{e}	149.75^{b}
Water + 4 h	374.0^{a}	212.0^{b}	293.0^{a}
Water + 6 h	0^{f}	0^{f}	0^{d}
Mean	165.1^{a}	120.2^{b}	
CV = 4.04			
HSD (0.01): Priming Agent = 13.676, Variety = 5.827, Priming Agent × Variety = 23.355			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 12 – Effect of priming agents on the stem girth (mm) of 2 soybean varieties at 4 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	2.85^{c}	4.5^{ab}	3.675^{B}
Coconut water + 4 h	4.9^{a}	4.5^{ab}	4.9^{A}
Coconut water + 6 h	3.0^{bc}	3.5a^{bc}	3.25^{B}
Water + 4 h	2.5^{c}	4.0^{abc}	3.25^{B}
Water + 6 h	0^{d}	0^{d}	0^{C}
Mean	2.65^{b}	3.3^{a}	
CV =13.09			
HSD (0.01): Priming Agent = 0.925, Variety = 0.394, Priming Agent × Variety = 1.580			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 13 – Effect of priming agents on the stem girth (mm) of 2 soybean varieties at 6 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	4.35^{b}	5.5^{ab}	4.925^{b}
Coconut water + 4 h	6.25^{ab}	5.15^{b}	5.7^{ab}
Coconut water + 6 h	6.25^{ab}	4.65^{b}	5.45^{b}
Water + 4 h	7.5^{a}	6.5^{ab}	7.0^{a}
Water + 6 h	0^{c}	0^{c}	0^{c}
Mean	4.87^{a}	4.36^{a}	
CV = 12.26			
HSD (0.01): Priming Agent = 1.344, Variety = 0.573, Priming Agent × Variety = 2.295			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 14 – Effect of priming agents on the stem girth (mm) of 2 soybean varieties at 8 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	9.5^{ab}	7.75^{b}	8.63^{b}
Coconut water + 4 h	8.2^{b}	8.1^{b}	8.15^{b}
Coconut water + 6 h	8.25^{b}	7.5^{b}	7.88^{b}
Water + 4 h	9.5^{ab}	12.0^{a}	10.75^{a}
Water + 6 h	0^{c}	0^{c}	0^{c}
Mean	7.09^{a}	7.07^{a}	
CV = 9.19			
HSD (0.01): Priming Agent = 1.546, Variety = 0.659, Priming Agent × Variety = 2.640			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 15 – Effect of priming agents on the stem girth (mm) of 2 soybean varieties at 12 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	12.5^{bc}	11.25^{cd}	11.88^{b}
Coconut water + 4 h	8.9^{e}	10.9^{cde}	9.9^{c}
Coconut water + 6 h	10.75^{cde}	9.65^{de}	10.2^{c}
Water + 4 h	13.5^{ab}	14.75^{a}	14.13^{a}
Water + 6 h	0^{f}	0^{f}	O^{d}
Mean	9.13^{a}	9.31^{a}	
CV = 5.46			
HSD (0.01): Priming Agent = 1.196, Variety = 0.510, Priming Agent × Variety = 2.043			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 16 – Effect of priming agents on the stem girth (mm) of 2 soybean varieties at 16 weeks after planting

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	13.5^{b}	12.5^{bc}	13.0^{b}
Coconut water + 4 h	10.75^{c}	11.8^{bc}	11.28^{c}
Coconut water + 6 h	12.15^{bc}	10.9^{c}	11.53^{c}
Water + 4 h	16.75^{a}	16.25^{a}	16.5^{a}
Water + 6 h	0^{d}	0^{d}	0^{d}
Mean	10.63^{a}	10.29^{a}	
CV = 5.26			
HSD (0.01): Priming Agent = 1.307, Variety = 0.557, Priming Agent × Variety = 2.231			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 17 – Effect of priming agents on the number of branches in two soybean varieties

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	6.5^{ab}	3.5^{d}	5.0^{b}
Coconut water + 4 h	5.0^{bcd}	4.0^{cd}	4.50^{b}
Coconut water + 6 h	5.0^{bcd}	5.5^{bc}	5.25^{b}
Water + 4 h	8.0^{a}	6.5^{ab}	7.25^{a}
Water + 6 h	0^{e}	0^{e}	0^{c}
Mean	4.9^{a}	3.9^{b}	
CV = 10.16			
HSD (0.01): Priming Agent = 1.063, Variety = 0.453, Priming Agent × Variety = 1.814			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 18 – Effect of priming agents on the number of pods in two soybean varieties

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	78.5^{c}	6.5^{f}	42.5c
Coconut water + 4 h	54.5^{d}	135.5a	95.0a
Coconut water + 6 h	132.5^{b}	18.5e	75.5b
Water + 4 h	5.5f^{g}	4.5g	5.0d
Water + 6 h	0^{h}	0^{h}	0.e
Mean	54.2^{a}	33.0^{b}	
CV =			
HSD (0.01): Priming Agent = 0.708, Variety = 0.302, Priming Agent × Variety = 1.210			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 19 – Effect of priming agents on the yield (kg/ha) of soybean varieties

Priming Agent	Variety		
	Afayak	Favour	Mean
Control	998[d]	138[f]	568.00[b]
Coconut water + 4 h	1102[c]	1658[b]	1380[a]
Coconut water + 6 h	2520[a]	284[e]	1402[a]
Water + 4 h	2508[a]	58[g]	128.3[c]
Water + 6 h	0[h]	0[h]	0[d]
Mean	921.6[a]	427.6[b]	
CV = 1.75			
HSD (0.01): Priming Agent = 28.4, Variety = 12.08, Priming Agent × Variety = 48.40			

Means followed by different letters differ from each other at a 5% probability level according to Tukey's HSD. HSD: Honestly significant difference. CV: Coefficient of variation

Table 20 – Correlation relationship between germination, growth and seed yield parameters

Variables	Correlation coefficient	Probability value (5%)
Stem girth and plant height	0.9669	0.0000
Branches and stem girth	0.9174	0.0002
Plant height and branches	0.88824	0.0007
Number of leaves and branches	0.8429	0.0022
Plant height and number of leaves	0.7876	0.0068
Germination percentage and seed yield	0.7717	0.0089

DISCUSSION

In this study, the highest germination percentage (75.50%) was recorded for the Favour variety primed with CW for 4 h, while the lowest was observed in both varieties (Afayak and Favour) primed with water for 6 h.

This observation could be due to the nutrient-rich nature of CW, which provides essential elements for seed germination, as reported by Yong *et al.* (2009). This finding is in line with those of Sharma *et al*. (2014), who stated that CW priming resulted in an increased germination rate.

Lower seed germination was recorded in seeds soaked in water for a prolonged duration (6 h), which may be due to excessive nutrient leaching and oxygen depletion, leading to hormonal imbalance and seed damage, as reported by Devika *et al*. (2021).

In this study, the effectiveness of seed priming on the vegetative growth of soybean plants was consistently demonstrated to be influenced by both the soybean variety and the priming agent, coupled with the priming duration. Priming with water for 4 h generally led to better vegetative growth and development, producing plants with the highest height, number of leaves, stem girth and number of branches.

This was particularly evident for the Afayak variety and highlights the importance of carefully selecting the appropriate priming agent and duration for different soybean varieties to optimise plant growth and development (Fiodor *et al.,* 2023). The Favour variety also showed maximum stem growth when

soaked in water for 4 h. The results agree with those of Ashraf and Foolad (2005) and Moradi and Younesi (2009), who showed that optimising the priming duration to balance water absorption and avoid stress factors that hinder plant growth, producing vigorous plants.

In this study, Favour primed with CW for 4 h produced the most pods (135.5), while both varieties (Afayak and Favour) primed with water for 6 h produced the least. CW priming for 4 h significantly increased the number of pods, particularly in the Favour variety. This may be due to the composition of CW, which promotes growth and enhances pod development by providing essential elements during the critical stages of flowering and pod formation (Yong *et al*., 2009). These observations are in line with those of Sankar *et al.* (2020), who observed a higher pod number in mung bean after CW priming.

The differences observed in the varieties may be due to genetic variations, thus resulting in the variations exhibited in their response to the priming agents and priming duration. The increase in the number of pods in Favour compared to Afayak suggests that Favour is more responsive to the benefits of CW priming.

Although Afayak showed a relatively higher number of pods when primed with water for 4 h (54.5), this value was significantly lower than when primed with CW for the same duration. This suggests that although water priming can support pod development to some extent, it may not provide the additional benefits that CW provides, such as enhanced nutrient supply and hormonal balance.

In the current study, Afayak primed with CW for 6 (2550 kg/ha) and 4 h (2508 kg/ha) had highest yield. The lowest yield was observed in both varieties (Afayak and Favour) primed with water for 6 h. The data suggest that CW priming, especially for 4 and 6 h, significantly enhanced soybean yield.

The Afayak variety particularly benefited from this treatment, achieving the highest recorded yield (2520 kg/ha). CW, which is rich in nutrients and growth-promoting hormones, likely contributes to optimal seed filling and development, resulting in heavier seeds (Yong *et al*., 2009; Zare and Vazin, 2013).

The available phytohormones in CW, such as ABA, gibberellic acid (GA), cytokinins, IAA and ethylene, regulated the seed-filling processes (Ahmad *et al*., 2018). Among the hormones, ABA plays a central role, as it accumulates at high levels from fertilisation to seed maturation.

Therefore, ABA functions as a signalling molecule and is important for seed filling, seed growth, dormancy and plant stress responses (Nambara and Marion-Poll, 2005).

The higher average yield recorded by Afayak compared to Favour suggests that Afayak may have a more robust response to priming or that its seed development process may be less sensitive to variations in priming conditions. The significant increase in yield for seeds primed with CW compared to other treatments highlights the effectiveness of CW as a priming agent. This suggests that bioactive compounds in CW, such as cytokinins, play a critical role in promoting seed filling and enhancing the overall seed quality (Yong *et al.*, 2009).

Our results showed a strong, positive, significant correlation between stem girth and plant height (r=0.97), number of branches and stem girth (r=0.92), plant height and number of branches (r=0.89), number of leaves and branches (r=0.84), plant height and number of leaves (r=0.79), and germination percentage and seed yield (r=0.77).

Multiple regression analysis showed that all growth parameters significantly affected seed yield, such that 95% of variation in the seed yield was accounted for by the growth parameters (*Equation 2*).

These relationships suggest that the soybean yield significantly depends on the growth variables. This agrees with the findings of Lamptey *et al.* (2015), who also reported a significant effect of growth parameters on soybean yield.

Kasu-Bandi *et al.* (2019) also reported a similar correlation between growth parameters and soybean yield under the influence of *Bradyrhizobium japonicum*.

CONCLUSIONS

The Favour variety primed with CW for 4 h showed improved germination. The Afayak soybean variety primed with water for 4 h consistently demonstrated the best performance in vegetative growth parameters (viz., plant height, number of leaves, number of branches and stem girth).

Therefore, to boost the vegetative growth of this variety, seeds should be primed with water for 4 h. Additionally, the Afayak soybean variety primed with CW for 6 h, produced the highest yield (2520 kg/ha) even though Favour primed with CW for 4 h produced the highest number of pods per plant (135.5). Therefore, for Afayak seed production, priming should be conducted with CW for 6h.

This study revealed strong, positive, significant relationships among the vegetative and yield parameters. This indicates that the Favour and Afayak varieties should be primed with CW for 4 and 6 h to improve germination, vegetative growth and seed yield.

Author contributions: Conceptualization of the manuscript and development of the methodology: PKT and IAI; Data collection and curation: AKN, SK and AD; Data analysis and interpretation: PKT, AKN, SK and AD; Writing of the orginal manuscript: PKT, IAI and BYB; Writing, review and editing: PKT, IAI and BYB. All authors declare that they have read and approved the publication of the manuscript in this present form.

Data availability: The data supporting the findings of the research are available upon request from the lead authors.

Conflicts of interest: The authors declare no conflict of interest.

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Academic Editor: Dr. Iuliana MOTRESCU