International Journal of Plant & Soil Science

Volume 36, Issue 12, Page 225-237, 2024; Article no.IJPSS.127862
ISSN: 2320-7035

Comparative Efficacy of Botanical Priming Agents on Germination Kinetics and Post-transplant Performance of *Brassica rapa*: A Correlation Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. Author IC conceptualized the study, developed the methodology, conducted the experiments, analyzed the data, and drafted the manuscript. Author SC supervised the study, validated the methodology, and reviewed the manuscript. Author RVJr. provided resources and aided in data validation. Author JF contributed to statistical analysis and data interpretation. Author BB assisted with experimental design and manuscript editing. All authors approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i125196

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/127862

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Cite as: *Cuares, Irish, Siony Cordova, Ratunil Virgilio Jr., Joanna Feril, and Bernadette Bagaipo. 2024. "Comparative Efficacy of Botanical Priming Agents on Germination Kinetics and Post-Transplant Performance of Brassica Rapa: A Correlation Analysis". International Journal of Plant & Soil Science 36 (12):225-37. https://doi.org/10.9734/ijpss/2024/v36i125196.*

Original Research Article

Received: 15/11/2024
Accepted: 09/12/2024
Published: 13/12/2024

ABSTRACT

Aims: Short-duration crops like pechay (*Brassica rapa*) require rapid establishment and enhanced early vigor for optimal productivity, making seed quality improvement crucial. Seed priming with plant extracts offers a sustainable alternative to conventional priming methods, but their effectiveness and optimal application parameters still need to be explored. This study evaluated the efficacy of single-application seed priming using *Ficus nota* water extract, banana water extract, and coconut water on pechay seed performance and subsequent crop development.

Place and Duration of Study: Surigao del Norte Horticultural Garden (SNSU) on August to October, 2024.

Methodology: The experiment utilized a Completely Randomized Design with four treatments (distilled water, *Ficus nota* extract, banana water extract, and coconut water) replicated three times, examining germination parameters, vegetative growth characteristics, and final yield metrics under Type II climate conditions.

Results: Results revealed that distilled water and *Ficus nota* water extract emerged as the most effective priming agents. Distilled water achieved optimal germination timing (28.86 days) and emergence percentage (78.67%), while *Ficus nota* extract demonstrated comparable effectiveness with the highest survival rate (93.33%). Both treatments produced superior fresh weight yields, being 97.63 g and 86.40 g, respectively and dry matter content, being 37.96% and 35.31%, respectively. Correlation analyses established critical relationships between early development and final crop performance, with perfect positive correlation between germination timing and mortality (r = 1.000) and strong correlations between environmental factors and yield parameters.

Conclusion: The study concludes that while distilled water provides a cost-effective priming solution, *Ficus nota* extract offers promise as a locally-sourced alternative. Environmental factors significantly modulated plant responses to priming treatments, with temperature showing consistent negative correlations with survival (r = -0.488) and yield parameters (r = -0.531). These findings establish a framework for optimizing seed priming protocols in short-duration crop production, particularly emphasizing the need for concentration optimization in plant extract applications and considering environmental interactions for maximizing treatment effectiveness.

Keywords: Seed priming; plant extracts; Brassica rapa; germination enhancement; crop establishment; environmental correlation.

1. INTRODUCTION

Seed quality plays a crucial role in crop success, particularly for short-duration crops like pechay (*Brassica rapa*), where the growing period spans only 30-45 days (Nacua et al. 2019). This limited cultivation window presents significant challenges in achieving optimal yield potential, as conventional crop management practices, such as fertilizer applications, may need to be more effective in supporting early plant development. Suriyagoda et al. (2020) demonstrated that reduced crop duration significantly impacts biomass accumulation rates and overall productivity, highlighting the need for enhanced seed performance to establish vigorous seedlings and maintain sustained growth until harvest.

Seed priming has become a practical solution for improving seed performance and early crop establishment. This pre-sowing treatment involves controlled seed hydration to initiate metabolic processes before germination, potentially reducing the time between sowing and emergence (Raj & Raj 2019). While various priming methods exist, many conventional techniques involve synthetic chemicals or complex protocols that may need to be more practical for small-scale farmers. Indurugalla et al. (2023) emphasize that seed priming is considered a low-cost, eco-friendly, and sustainable technique to promote seed germination and initial plant growth, creating a need for accessible, safe, and effective priming alternatives.

Plant extracts represent a promising category of priming agents due to their safety, local availability, and potential growth-promoting properties. Recent studies by Wazeer et al. (2024) indicate that plant-based biostimulants applied to seeds improve germination, seedling growth, and stress tolerance. Natural extracts contain bioactive compounds that influence seed metabolism through multiple pathways. According to Oliveira and Gomes-Filho (2016) these effects are related to the repair and build-up of nucleic acids, enhanced protein synthesis, improved membrane repair, and reduced lipid peroxidation through enhanced antioxidative activities. Sen and Puthur (2020) further explain that priming activates various enzymes and enhances levels of proteins, carbohydrates, phytohormones, and other metabolites essential for early plant development.

This study investigates the comparative effectiveness of *F. nota* water extract, banana water, and coconut water extracts as seed priming agents for pechay production. The selection of these extracts is supported by previous research: Knothe et al. (2019) identified beneficial compounds in *F. nota*, including polyunsaturated fatty acids and bioactive triterpenes; Islam et al. (2022) documented 44 beneficial plant compounds in banana extracts; and Agampodi and Jayawardena (2007) quantified natural growth regulators in coconut water (IAA: 0.088 mg L^{-1}, GA: 0.076 mg L^{-1}, kinetin: 0.044 mg L^{-1}). By examining seed performance parameters alongside environmental correlations, this study aims to establish evidence-based recommendations for utilizing plant extracts in seed priming applications, contributing to developing practical, sustainable seed enhancement techniques for short-duration crop production.

2. MATERIALS AND METHODS

2.1 Experimental Design and Location

The study was conducted from August to October 2024 in Surigao del Norte State University (SNSU) Mainit Campus Horticultural Gardens, Mainit, Surigao del Norte, Philippines (9°31’33.7 “N, 125°34’01.8 “E) under Type II climate. The experiment utilized a Completely Randomized Design (CRD) with four treatments replicated three times: T1 (distilled water), T2 (*F. nota* water extract), T3 (banana water extract), and T4 (coconut water). Each replication contained 30 seeds, totaling 360 Pechay seeds.

2.2 Plant Extract Preparation and Seed Priming

F. nota extract was collected from leaf transpiration moisture after six hours of daylight exposure, as outlined by Taer (2024). Banana water was extracted from pressed pseudostem, while coconut water was obtained from fresh green coconuts. Pechay seeds (var. Pavito) were primed by soaking in respective solutions for 30 minutes.

2.3 Pre-transplant Management

Seeds were sown in plastic boxes (20 × 15 × 10 cm) lined with Whatman filter paper #42 as germination media, each containing 30 seeds. After 50% germination, a 2:1 sand-vermicompost mixture was added to each seed box to support the growing seedlings. Seedlings were maintained under nursery conditions for 20 days.

2.4 Post-transplant Management

To ensure continuity of the carry-over effect of seed priming, the ten viable seedlings per replicate box measured for pre-transplanting data were subsequently transplanted into polyethylene bags (3” × 3” × 10” size) containing a mixture of topsoil, garden soil, and charcoaled rice hull (3:4:3). Plants were maintained under field conditions for a 40-day growing period with regular watering and pest monitoring.

2.5 Data Collection

Pre-transplant parameters included days to 50% germination and seedling emergence percentage (calculated as [Number of germinated plants/Total seeds sown] × 100). Root and shoot lengths were measured from thirty randomly selected seedlings per treatment (approximately 10 per replicate) at 20 days after sowing using a 12-inch ruler. Post-transplant measurements comprised plant height at 10-day intervals and leaf area index using the Easy Leaf Area mobile app. Fresh weight was recorded immediately after harvest, and dry matter content was determined after drying at 60°C for 24 hours using the formula: (Calculated as [Dry weight/Fresh weight] × 100). The AccuWeather online application monitored environmental data (temperature, humidity, precipitation).

2.6 Statistical Analysis

Data were analyzed using SPSS software. Analysis of variance (ANOVA) for CRD and Friedman's non-parametric chi-square tests were performed on non-normally distributed data at p≤0.05. Treatment means were compared using Tukey's HSD test for ANOVA and Stepwise Step-down for Friedman. Correlation analysis was conducted between growth parameters and environmental factors.

3. RESULTS AND DISCUSSION

3.1 Pre Transplant Performance

3.1.1 Early seedling development response to plant extract priming

Distilled water (control) emerged as the most effective priming agent for early seedling development (Table 1). The data shows it achieved the fastest germination (28.86 days), highest emergence (78.67%), and lowest mortality (11.10%). This performance is supported by the perfect positive correlation (*r* = 1.000) among days to 50% germination and mortality rate and the strong negative correlation (*r* = -0.661) among seedling emergence and mortality, indicating that initial germination timing significantly influences seedling survival (Table 3). *F. nota* extract showed moderate germination timing (35.50 days) with stable emergence (67.67%) and mortality (13.30%) rates among plant extract treatments. According to Knothe et al. (2019), this response may be attributed to *Ficus nota*'s composition of polyunsaturated fatty acids, squalene, pentacyclic triterpenes (α-amyrin, β-amyrin, lupeol), and sterols. These compounds influence seed metabolism through multiple pathways, including cell membrane permeability, cell division, protein synthesis, enzyme activity, and hormone regulation (2015).

Banana water extract exhibited the most delayed germination (66.63 days), while maintaining relatively high emergence (70.00%), but increased mortality (21.07%). Islam et al. (2022) identified 44 beneficial plant compounds in banana extracts that influence seedling growth, with optimal effects at specific concentrations (5-15%). Coconut water produced intermediate germination delay (57.73 days) with the poorest emergence (57.67%) and highest mortality (22.20%). Agampodi and Jayawardena (2007) attributed such effects to coconut water's plant growth regulator content, specifically IAA (0.088 mg L^{-1}), GA (0.076 mg L^{-1}), and kinetin (0.044 mg L^{-1}). The varying response patterns suggest concentration-dependent effects of plant extracts on seed development. Ignat et al. (2009) noted that polyphenols can act as biostimulators or growth inhibitors depending on concentration. Seed priming influences various processes, including repair and build-up of nucleic acids, protein synthesis enhancement, membrane repair, and antioxidative activities (2016). Furthermore, Bryksová et al. (2020) demonstrated that hormone-based priming affects endogenous cytokinins, auxins, and abscisic acid levels, influencing germination and early development. Moving forward, research should focus on molecular analysis of gene expression patterns during priming with different plant extracts, investigation of hormone signaling pathways (Nakaune et al. 2012) optimization studies for extract concentrations, and examination of interaction effects between bioactive compounds. This comprehensive approach would help elucidate the complex interactions between bioactive compounds and seed physiology that determine priming outcomes.

Table 1. Days to 50% germination, seedling emergence percentage, and mortality rate of pechay (*B. rapa*) as influenced by different seed priming treatments

Treatment	Days to 50% germination (days)	Seedling emergence (%)	Mortality rate (%)
Distilled water	28.86^{a}	78.67^{d}	11.10^{a}
F. nota water extract	35.50^{b}	67.67^{b}	13.30^{b}
Banana water extract	66.63^{d}	70.00^{c}	21.07^{c}
Coconut water	57.73^{c}	57.67^{a}	22.20^{d}
Chi-square	145.862	83.571	106.071
Asymp. Sig.	<0.001**	<0.001**	<0.001**

*^{abcd}Column means of different letters are statistically different at 0.05 levels; **Highly significant at 0.05 level*

3.1.2 Early vegetative development parameters

Root length analysis revealed significant differences (p = 0.007), with banana water extract producing the longest roots (2.89 cm) compared to the distilled water control (2.17 cm) as reflected in Table (2). In contrast, shoot length showed no significant differences (p = 0.453) across treatments, ranging from 7.52 cm in distilled water to 7.13 cm in *F. nota* extract-primed seeds. The enhanced root development in banana water extract treatment aligns with Islam et al. (2022) findings. Their research identified beneficial compounds, including 1-amino-1-carboxycyclopropane, 4-aminobenzoic acid, and glutamic acid in banana extracts that promote seedling development. The optimal response in root growth occurred at lower concentrations (5-15%), suggesting concentration-dependent effects of these bioactive compounds. Coconut water (2.60 cm) and *Ficus nota* water extract (2.55 cm) treatments showed intermediate root length responses. Agampodi and Jayawardena (2007) attributed coconut water's effects to its natural plant growth regulators, specifically IAA (0.088 mg L^{-1}), GA (0.076 mg L^{-1}), and kinetin (0.044 mg L^{-1}). The moderate effect of *F. nota* extract relates to its phytochemical composition, including polyunsaturated fatty acids, squalene, and pentacyclic triterpenes, as Knothe et al. (2019) reported.

The uniform shoot development across treatments suggests reduced sensitivity to priming solutions during early growth stages. This response pattern supports Oliveira and Gomes-Filho (2016) findings that seed priming effects involve complex physiological changes, including nucleic acid repair, enhanced protein synthesis, and improved antioxidative activities. Sen and Puthur (2020) explain that priming activates various enzymes and enhances levels of proteins, carbohydrates, and phytohormones, which may contribute to maintaining consistent shoot development patterns. The differential response between root and shoot development can be explained by varying growth-regulating mechanisms. Nakaune et al. (2012) demonstrated that priming treatments affect the expression of growth-related genes differently, supporting the concept that root and shoot development respond independently to different signaling pathways. This aligns with Wazeer et al. (2024) observation that plant-based biostimulants can improve seed quality through complex mechanisms affecting plant organs differently. Future research should focus on understanding the molecular basis of these differential responses, particularly examining the role of specific bioactive compounds in regulating root versus shoot development during early seedling growth.

3.2 Post-transplant Performance

3.2.1 Meteorological data after transplanting pechay seedling

Temperature patterns during the 40-day growing period are detailed in Fig. (1). Daily average temperatures are confined within 83.63-84.71°F, while the peak average was 40 DAT (84.71°F). The highest average humidity was documented at 30 DAT (80.33%), contrasting with the lowest reading at 40 DAT (78.49%). Precipitation remained minimal across the growing period, with the highest precipitation occurring at 20 DAT (0.13 mm), while 10 DAT and 40 DAT registered the lowest values (0.03 mm). The meteorological data suggests relatively stable growing conditions with moderate temperature fluctuations, regular humidity patterns, and minimal rainfall. These environmental parameters created a baseline context for

Table 2. Pre-transplant root and shoot length of pechay (*B. rapa*) seedlings as influenced by different seed priming treatments

Treatment	Root length	Shoot length
Distilled water	2.17^{a}	7.52
F. nota water extract	2.55^{ab}	7.13
Banana water extract	2.89^{b}	7.23
Coconut water	2.60^{ab}	7.14
F-value	4.191	0.882
P-value.	0.007**	0.453^{ns}

*^{ab}Column means of different letters are statistically different at 0.05 levels; **Highly significant at 0.05 level; ^{ns}Not Significant*

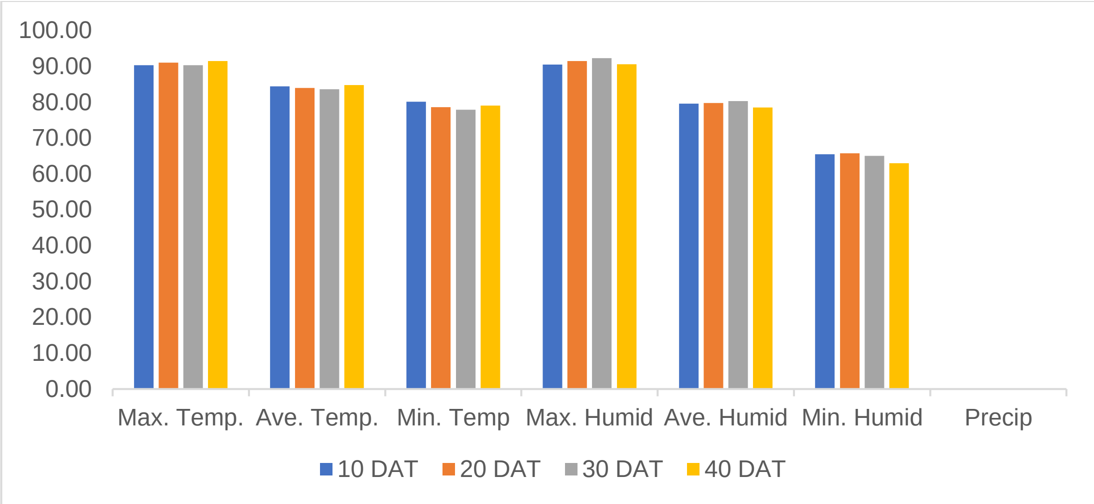

Fig. 1. Daily temperature (°F), relative humidity (%), and precipitation (mm) during the 40-day growing period of transplanted pechay (*B. rapa*)

evaluating the effects of seed priming treatments on pechay development under typical Type II climate conditions.

3.2.2 Pearson correlation between post-transplant agronomic traits and growing-period weather in pechay (*B. rapa*)

Temperature exhibited strong negative correlations with key plant performance indicators, specifically survival rate (r = -0.488), fresh weight (r = -0.531), and dry matter content (r = -0.525). This inverse relationship indicates that elevated temperatures adversely affected plant development and biomass accumulation during the growing period. Relative humidity demonstrated an opposite effect pattern, showing positive correlations of comparable magnitude with survival rate (r = 0.484), fresh weight (r = 0.511), and dry matter content (r = 0.501). These relationships suggest that higher humidity levels created favorable plant growth and development conditions, particularly for biomass accumulation and survival. Precipitation showed limited influence on plant growth parameters, with only plant height at 10 DAT exhibiting a significant negative correlation (r = -0.391). The absence of significant correlations between precipitation and other growth metrics indicates that rainfall had minimal impact on overall plant development during the growing period. Notably, vegetative growth parameters, including plant height measurements and leaf index values at various stages, showed no significant correlations with temperature or humidity. This finding suggests that these growth characteristics maintained relative independence from weather conditions throughout the growing period. The correlation patterns demonstrate that

Table 3. Pearson correlation coefficients between post-transplant agronomic characteristics and meteorological parameters during the growing period of pechay (*Brassica rapa*)

Parameter	Ave. temperature	Ave. humidity	Precipitation
Plant height @ 10 DAT	0.182	-0.229	-0.391*
Plant height @ 20 DAT	-0.097	0.029	-0.258
Plant height @ 30 DAT	-0.101	0.081	-0.238
Plant height @ 40 DAT	-0.231	0.167	-0.148
Leaf index @ 20 - DAT	-0.286	0.185	-0.181
Leaf index @ 30 - DAT	0.026	-0.074	-0.208
Leaf index @ 40 - DAT	-0.021	0.014	-0.250
Survival	-0.488**	0.484**	0.065
Fresh weight	-0.531**	0.511**	0.052
Dry matter weight %	-0.525**	0.501**	0.050

*** Correlation is significant at the 0.01 level (2-tailed).; * Correlation is significant at the 0.05 level (2-tailed)* final yield components and survival exhibited greater sensitivity to temperature and humidity fluctuations than vegetative growth parameters.

3.2.3 Height of transplanted pechay

Plant height measurements revealed varying treatment effects across growth stages (Table 4). At 10 DAT, *F. nota* extract produced the tallest plants (2.19 cm) compared to banana water extract (1.60 cm), while control and coconut water treatments showed intermediate heights (1.90 cm and 1.80 cm). This early growth advantage aligns with Taer (2024) findings that *F. nota* water treatments enhance early vegetative growth characteristics. Knothe et al. (2019) attribute this effect to *F. nota*'s phytochemical composition, including bioactive compounds such as polyunsaturated fatty acids, squalene, and pentacyclic triterpenes. By 20 DAT, the control treatment emerged superior (6.54 cm) compared to banana water extract (4.74 cm), with *F. nota* (6.15 cm) and coconut water (4.89 cm) showing intermediate performance. This shift suggests that simpler priming solutions better support sustained growth by avoiding complications from complex bioactive compounds. The temporary loss of statistical significance at 30 DAT, despite numerical differences ranging from 7.80 cm to 11.16 cm, indicates a period of growth rate equilibration among treatments. This pattern supports Oliveira and Gomes-Filho (2016) findings that priming effects involve complex physiological changes, including membrane repair, enhanced protein synthesis, and improved antioxidative activities. At 40 DAT, significant differences re-emerged, with *F. nota* extract producing the tallest plants (13.15 cm) compared to banana water extract (8.49 cm). This response pattern supports Wazeer et al. (2024) findings about the complex nature of plant-based biostimulants in improving plant growth. Cheng and Cheng (2015) explain these effects through allelopathic mechanisms, where biochemicals influence growth through membrane permeability, oxidative systems, and growth regulation systems.

Environmental factors modulated priming effects on height development. The weak negative correlation between early height and precipitation (r = -0.391) indicates sensitivity to moisture conditions during initial establishment (Table 3). However, the absence of significant correlations with meteorological parameters in later stages suggests that priming treatments influenced plants' ability to maintain growth regardless of environmental fluctuations. This resilience was particularly evident in *F. nota* extract and control treatments. The comparable performance between *F. nota* extracts and water priming aligns with Raj and Raj (2019) observation that effective priming methods should be simple. The lower performance of banana water extract, despite its beneficial compounds identified by Islam et al. (2022), suggests that optimal concentration and application timing are crucial for maximizing growth benefits, as excessive bioactive compounds may interfere with normal developmental processes. This highlights the importance of concentration optimization in priming treatments for optimal plant height development.

3.2.4 Leaf index of transplanted pechay

Leaf area index development showed significant treatment effects across measurement periods (Table 5). At 20 DAT, *F. nota* extract demonstrated the highest index (36.30) compared to banana water extract (18.97), while distilled water and coconut water showed intermediate indices (31.02 and 26.80).

Table 4. Plant height development of pechay (*B. rapa*) at 10-day intervals after transplanting as influenced by different seed priming treatments

Treatment	Plant height @ 10-DAT (cm)	Plant height @ 20-DAT (cm)	Plant height @ 30-DAT (cm)	Plant height @ 40-DAT (cm)
Distilled water	1.90^{ab}	6.54^{b}	11.16	13.10^{ab}
F. nota water extract	2.19^{b}	6.15^{ab}	10.95	13.15^{b}
Banana water extract	1.60^{a}	4.74^{a}	7.80	8.49^{a}
Coconut water	1.8^{ab}	4.89^{ab}	8.62	10.31^{ab}
Chi-square	10.938	9.923	6.649	9.624
Asymp. Sig.	0.012**	0.019*	0.084^{ns}	0.022*

*^{ab}Column means of different letters are statistically different at 0.05 levels; **Highly significant at 0.05 level; * Significant; ^{ns}Not Significant*

This early superior performance aligns with Taer (2024) findings that *F. nota* water treatment promotes broader leaf development compared to non-primed controls. Treatment effects intensified at 30 DAT, with distilled water showing the highest index (110.65), significantly exceeding banana water extract (66.19) and coconut water (72.65) treatments. By 40 DAT, control maintained the highest index (135.49), followed closely by *F. nota* extract (133.45). These findings contrast with Fernandez and Andigan (2017) work, which reported that growth regulator combinations increased leaf width by 39%. Our results suggest that simpler priming solutions better support sustained leaf development. The relatively poor performance of banana water extract (LAI: 18.97 to 83.78) differs from Islam et al. (2022) findings, where 10% banana pseudostem sap increased chlorophyll content by 17.4%. Similarly, our results with 100% coconut water (LAI: 26.80 to 89.30) contrast with Soujanya et al. (2024) observations, where 50% coconut water concentration showed optimal effects on seedling vigor. These differences highlight the importance of concentration optimization, suggesting that the 100% concentration used in our study exceeded beneficial thresholds.

The positive correlation with relative humidity and negative correlation with temperature indicate that moisture conditions were crucial for optimal leaf expansion, while higher temperatures induced potential stress responses. The superior performers (control and *F. nota* treatments) maintained better leaf development across varying environmental conditions, suggesting enhanced stress resilience. The dynamic shift in performance patterns, where distilled water treatment emerged superior by 30 DAT (LAI: 110.65) and maintained advantage through 40 DAT (LAI: 135.49), adds nuance to Wazeer et al. (2024) observations about plant-based biostimulants. While these compounds can enhance growth parameters, our findings suggest that simpler priming solutions provide more consistent long-term benefits for leaf development. This indicates that appropriate priming treatments may improve plant adaptability to field conditions, an important consideration for practical applications.

3.2.5 Survival rate

Survival rates showed highly significant differences among treatments ($p < 0.001$) (Table 6). *F. nota* water extract demonstrated the highest survival rate (93.33%), statistically similar to the distilled water control (90.00%), while banana water extract showed the lowest (70.00%), followed by coconut water (76.67%). Oliveira and Gomes-Filho (2016) state that these differences stem from priming-induced improvements in seed physiological quality through multiple biochemical changes, including nucleic acid repair, enhanced protein synthesis, and improved antioxidative activities. The lower survival rates in banana and coconut water treatments suggest complications from high-concentration usage. While Islam et al. (2022) identified beneficial compounds in banana extracts with optimal effects at 5-15% concentration, and Agampodi & Jayawardena (2007) documented low concentrations of growth regulators in coconut water (IAA: 0.088 mg L^{-1}, GA: 0.076 mg L^{-1}, kinetin: 0.044 mg L^{-1}), the 100% concentration used likely exceeded optimal levels. This interpretation aligns with Goran (2020) and Islam et al. (2022), who demonstrated that lower concentrations were more effective for seed priming. The physiological basis for survival differences relates to membrane integrity and enzyme activities. Pandey and Umesha (2017) observed that effective priming reduces electrical conductivity and enhances dehydrogenase and

Table 5. Leaf area index development of pechay (*B. rapa*) at 20, 30, and 40 days after transplanting as influenced by different seed priming treatments

Treatment	Leaf index @ 20-DAT (cm^2)	Leaf index @ 30-DAT (cm^2)	Leaf index @ 40-DAT (cm^2)
Distilled Water	31.02^{ab}	110.65^{b}	135.49^{c}
F. Water Extract	36.30^{b}	100.07^{ab}	133.45^{bc}
Banana Water Extract	18.97^{a}	66.19^{a}	83.78^{a}
Coconut Water	26.80^{ab}	72.65^{a}	89.30^{a}
Chi-square	10.673	15.218	16.309
Asymp. Sig.	0.014*	0.002*	0.001**

*[abcd]Column means of different letters are statistically different at 0.05 levels; * Significant; **Highly significant at 0.05 level*

amylase activities. The similar high survival rates in water-primed and *F. nota*-treated plants suggest optimal activation of these protective mechanisms. This aligns with Choudhury and Bordolui' (2023), Hussain et al. (2023), and Ahmed et al. (2023) observations regarding phytohormone-mediated stress tolerance through hormonal regulation.

The negative correlation with temperature (r = -0.488) and positive correlation with humidity (r = 0.484) indicate that environmental stress tolerance was crucial for plant survival (Table 3). Treatments showing higher survival rates enhanced plant resilience to environmental fluctuations, possibly through improved physiological conditioning during the priming phase. From a management perspective, these findings indicate that while distilled water and *F. nota* extract are effective, the additional effort for extract preparation should be evaluated against marginal benefits. The consistently poor performance of banana water extract suggests it should be avoided for pechay seed priming. Critical management periods for maximizing survival appear concentrated in the early growth stages. Future research should focus on optimizing extract concentrations and priming durations to maximize survival benefits while minimizing input costs. For immediate practical application, these results support using simple distilled water priming as a cost-effective and reliable method for optimizing pechay survival.

3.2.6 Fresh weight yield

Table 6 show that distilled water-primed plants achieved the highest yield (97.63 g), statistically similar to *F. nota* water extract (86.40 g), with both treatments significantly outperforming other plant extracts (Table 6). According to Oliveira and Gomes-Filho (2016), this superior performance results from enhanced physiological processes, including protein synthesis, membrane repair, and antioxidative activities, collectively contributing to improved biomass accumulation. The comparable performance between water priming and *F. nota* extract reflects optimal activation of growth-promoting mechanisms. Fernandez and Andigan (2017) attributes such effects to balanced phytohormone levels that enhance leaf development and fresh weight by stimulating cell division, nutrient uptake, and utilization. Knothe et al. (2019) suggest that *F. nota*'s effectiveness stems from its composition of polyunsaturated fatty acids, squalene, and various bioactive compounds influencing these growth processes. The lower yields in other treatments contrast with previous research findings. While Islam et al. (2022) reported that 10% banana pseudostem sap increased biomass by 32%, our study using 100% concentration showed reduced yields. Similarly, Hamd & Hamza (2023) found optimal results with lower concentrations (25-35%) of banana peel extract. These differences emphasize the importance of concentration optimization. Our results also differ from Soujanya et al. (2024) and Catada et al. (2016), who reported enhanced seedling fresh weight with 50% coconut water concentration, suggesting that our 100% concentration exceeded beneficial thresholds.

The negative correlation with temperature (r = -0.531) and positive correlation with humidity (r = 0.511) indicate that environmental stress tolerance affected biomass accumulation (Table 3). Treatments showing higher fresh weight yields (control and *F. nota*) enhanced plant resilience to environmental fluctuations, likely through improved physiological conditioning during the priming phase. The effectiveness of simpler priming solutions supports Raj & Raj (2019) assertion that effective priming methods should be simple and adequately regulated. The high yields achieved with water priming demonstrate that, while potentially beneficial, complex botanical compounds require careful optimization to avoid adverse effects on yield. This finding has practical implications for commercial production systems where environmental conditions cannot be fully controlled.

3.2.7 Dry matter yield

Control treatment produced the highest dry matter content (37.96%), statistically matched by *F. nota* water extract (35.31%), while coconut water showed intermediate content (32.62%), and banana water extract yielded the lowest (26.14%) (Table 6). These patterns contradict Islam et al. (2022) findings that 10% banana pseudostem sap increased dry biomass by 32.0% compared to control, suggesting possible inhibitory effects at higher concentrations. The physiological basis for enhanced dry matter accumulation in water-primed plants supports Zhang et al. (2015) findings. Their research demonstrated that effective priming strengthens antioxidant activities and increases compatible solutes, including reducing sugars, proline, soluble sugars, and protein. This aligns with Kaur et al. (2005) observations on enhanced sucrose metabolism in primed plants, where increased activities of sucrose-cleaving enzymes and sucrose phosphate synthase facilitated better dry matter accumulation. Treatment effects differed from previous research outcomes. Hamd & Hamza (2023) reported optimal seedling dry weight with 35% banana peel extract, while our study using 100% concentration showed inhibited dry matter accumulation. Similarly, coconut water's intermediate performance (32.62%) contrasts with Dunsin et al. (2016) observations of superior effects at lower concentrations. The negative correlation with temperature ($r = -0.525$, $p < 0.01$) and positive correlation with humidity ($r = 0.501$, $p < 0.01$) indicate that environmental conditions substantially affected dry matter accumulation efficiency. Control and *F. nota* treatments enhanced plant resilience to environmental stresses, suggesting improved resource use efficiency and better assimilate partitioning under varying conditions.

3.2.8 Correlation of pre- and post-transplant growth in pechay (*B. rapa*) under various seed priming treatments

Early germination characteristics significantly correlated with subsequent plant performance metrics (Table 7). Days to 50% germination exhibited a perfect positive correlation with mortality ($r = 1.000$), indicating that delayed germination directly corresponded to increased seedling mortality. Seedling emergence showed an inverse relationship with mortality ($r = -0.661$), where higher emergence rates corresponded to improved seedling survival. Root development displayed moderate but significant correlations with germination parameters. Root length negatively correlated with days to 50% germination ($r = -0.312$, $p < 0.01$) and positively correlated with seedling emergence ($r = 0.312$). Plant height measurements revealed dynamic correlation patterns across growth stages. Early and mid-growth measurements (20 and 30 DAT) showed weak positive correlations with

Table 6. Survival rate, fresh weight yield, and dry matter content of pechay (*B. rapa*) at harvest as influenced by different seed priming treatments

Treatment	Survival rate (%)	Fresh weight yield (g)	Dry matter content (%)
Distilled Water	90.00^{b}	97.63^{b}	37.96^{c}
F. Water Extract	93.33^{b}	86.40^{b}	35.31^{bc}
Banana Water Extract	70.00^{a}	53.27^{a}	26.14^{a}
Coconut Water	76.67^{a}	65.27^{a}	32.62^{b}
F-value	24.353	17.697	26.127
P-value	<0.001**	<0.001**	<0.001**

*^{abc}Column means of different letters are statistically different at 0.05 levels; **Highly significant at 0.05 level*

Table 7. Pearson correlation coefficients between pre- and post-transplant growth parameters of pechay (*B. rapa*) as influenced by different seed priming treatments

Parameter	Days to 50% germination	Seedling emergence
Mortality	1.000**	-0.661**
Root length	-0.312**	0.312**
Shoot length	0.108	-0.108
Plant height @ 10 DAT	0.099	-0.100
Plant height @ 20 DAT	0.222*	-0.222*
Plant height @ 30 DAT	0.227*	-0.227*
Plant height @ 40 DAT	-0.287**	0.286**
Leaf index @ 20 - DAT	0.184*	-0.185*
Leaf index @ 30 - DAT	0.284**	-0.284**
Leaf index @ 40 - DAT	0.273**	-0.273**
Survival	0.442**	-0.444**
Fresh weight	0.503**	-0.503**
Dry matter weight %	0.588**	-0.589**

*** Correlation is significant at the 0.01 level (2-tailed).; * Correlation is significant at the 0.05 level (2-tailed).*

germination timing (r = 0.222 and 0.227) and negative correlations with emergence. This relationship reversed at 40 DAT, showing a negative correlation with germination timing (r = -0.287) and a positive correlation with emergence (r = 0.286). Leaf index measurements demonstrated progressively stronger correlations with germination parameters over time. The correlation between leaf index and germination timing increased from r = 0.184 at 20 DAT to r = 0.273 at 40 DAT, maintaining corresponding negative correlations with seedling emergence throughout the growing period. Final yield components showed the strongest correlations with initial germination characteristics. Survival rate (r = 0.442), fresh weight (r = 0.503), and dry matter content (r = 0.588) exhibited significant positive correlations ($p < 0.01$) with germination timing and corresponding negative correlations with emergence rates. These relationships demonstrate that early germination patterns significantly influenced final plant development and yield performance.

4. CONCLUSION

The study established the comparative efficacy of different priming treatments on pechay development and productivity. Distilled water and *F. nota* water extract emerged as the most effective priming agents. Distilled water achieved optimal germination timing (28.86 days) and emergence percentage (78.67%), while *F. nota* extract demonstrated comparable effectiveness with the highest survival rate (93.33%). Both treatments produced superior fresh weight yields, being 97.63 g and 86.40 g, respectively and dry matter content, being 37.96% and 35.31%, respectively.

Correlation analyses revealing critical relationships between early development and final crop performance further support the strength of these treatments. The perfect positive correlation between germination timing and mortality (r = 1.000) underscores how these effective priming treatments promoted crop success through rapid, uniform germination. Additionally, environmental response patterns showed that distilled water and *F. nota* treatments enhanced plant resilience, as evidenced by their sustained performance despite negative temperature correlations with survival (r = -0.488) and yield parameters (r = -0.531).

The effectiveness of *F. nota* extract, particularly in survival rate and vegetative growth, suggests its potential as a locally-sourced priming alternative to distilled water. However, other plant extracts (banana and coconut water) at 100% concentration produced suboptimal results, indicating the need for concentration optimization. These findings establish distilled water as a reliable, cost-effective priming solution while highlighting *F. nota* extract as a promising botanical alternative that merits further development for commercial application.

5. RECOMMENDATIONS

Investigate the optimal concentrations e.g., 5%, 10%, 25%, 50% of *F. nota*, banana water, and coconut water extracts for pechay seed priming. This should include a detailed analysis of phytohormone levels and bioactive compounds at each concentration to establish effective thresholds for enhanced germination and growth performance.

Examine the interaction between priming duration e.g., 15, 30, 45, 60 minutes and plant extract concentrations on seed performance. This should evaluate both immediate effects on germination and long-term impacts on crop productivity to determine the most efficient priming protocols for commercial application.

Study the molecular mechanisms underlying plant extract priming effects through gene expression analysis during different priming stages, quantification of stress-response proteins and antioxidant enzyme activities, and valuation of hormone signaling pathways affected by different priming treatments.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENT

The authors sincerely thank their research advisors for their guidance and mentorship. Appreciation is also extended to the Management of Surigao del Norte State University – Mainit Campus for providing facilities and resources in SNSU Horticultural Gardens.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Agampodi, V. A., & Jayawardena, B. (2007). Identification and characterization of plant growth regulators present in coconut (*Cocos nucifera*) water using HPLC (High Performance Liquid Chromatography). *Proceedings of the Annual Research Symposium*, Faculty of Graduate Studies, University of Kelaniya, 118.

Ahmed, S., Khan, M., & Sardar, R. (2023). Glutathione primed seed improved lead-stress tolerance in *Brassica rapa* L. through modulation of physio-biochemical attributes and nutrient uptake. *International Journal of Phytoremediation, 25*(12), 1614-1624.

Bryksová, M., Hybenová, A., Hernández, A. E., Novák, O., Pěnčík, A., Spíchal, L., Diego, N. D., & Doležal, K. (2020). Hormopriming to mitigate abiotic stress effects: A case study of N9-substituted cytokinin derivatives with a fluorinated carbohydrate moiety. *Frontiers in Plant Science, 11*, 1-17.

Catada, M., Campos, J. P., & Zamora, A. (2016). Utilization of naturally occurring seed priming agents in enhancing seed germination and seedling emergence of rice (*Oryza sativa* L.). *Prism, 21*, 1-9.

Cheng, F., & Cheng, Z. (2015). Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. *Frontiers in Plant Science, 6*, 1-16.

Choudhury, A., & Bordolui, S. K. (2023). Stimulatory effect of hormonal seed priming in plant tolerance to resist abiotic stress. *Journal of Agricultural, Food Science and Biotechnology, 1*(3), 140-152.

Dunsin, O., Aboyeji, C. M., & Nayan, G. (2016). Influence of Moringa leaf extract and coconut water as priming agent to improves the emergence and early seedling growth in cucumber. *International Journal of Organic Agriculture Research & Development, 12*, 39-46.

Fernandez, A., & Andigan, A. M. (2017). Stimulate hormones for higher yield of pechay (*Brassica pekinensis*). *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae, 6*, 95-108.

Goran, Y. A. R. (2020). Allelopathic assessment by interaction effect of coconut water (*Cocos nucifera* L.), and dipping time on seed germination of four cereal seeds. *Zanco Journal of Pure and Applied Sciences, 32*(4), 122-134.

Hamd, A. H., & Hamza, J. H. (2023). Effect of stimulate of sorghum seeds with banana peel extract and citric acid on seeds viability and vigour. *IOP Conference Series: Earth and Environmental Science, 1214*(1), 012039.

Hussain, S., Ahmed, S., Yasin, N. A., Akram, W., Sardar, R., Ahmad, A., & Li, G. (2023). In vitro and in silico study of salt stress resilience in *Brassica rapa* through selenium seed priming. *South African Journal of Botany, 160*, 504-515.

Ignat, I., Stingu, A., Volf, I., & Popa, V. I. (2009). Natural bioactive compounds as plant growth regulators. *Lucrări Ştiinţifice, 52*, 1-6.

Indurugalla, Y., Manimekala, D., & Galahitigama, G. A. (2023). Biostimulatory impacts of seed priming through botanical extracts on crop production: A critical review. *Asian Journal of Agricultural and Horticultural Research, 10*(4), 559-579.

Islam, M. S., Kasim, S., Amin, A. M., Hun, T. G., Alam, M. K., & Haque, M. A. (2022). Banana-pseudostem sap growing media as a novel source of phytochemicals and mineral nutrients: Influence on seedling growth of sweet corn. *Chilean Journal of Agricultural Research, 82*(1), 135-145.

Kaur, S., Gupta, A. K., & Kaur, N. (2005). Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. *Journal of Agronomy and Crop Science, 191*, 81-87.

Knothe, G., Razon, L. F., & de Castro, M. E. G. (2019). Fatty acids, triterpenes and cycloalkanes in ficus seed oils. *Plant Physiology and Biochemistry, 135*, 127-131.

Nacua, A. E., Macer, M. C., & Pascual, A. B. (2019). Urban farming using upcycling technique of *Brassica rapa L. Cv* (Pechay Tagalog) in Ermita, Manila, Philippines. *Modern Concepts & Developments in Agronomy, 4*(2), 1-8.

Nakaune, M., Hanada, A., Yin, Y. G., Matsukura, C., Yamaguchi, S., & Ezura, H. (2012). Molecular and physiological dissection of enhanced seed germination using short-term low-concentration salt seed priming in tomato. *Plant Physiology and Biochemistry, 52*, 28-37.

Oliveira, A. B., & Gomes-Filho, E. (2016). How are germination performance and seedling establishment under abiotic stress improved by seed priming?: A review. *Australian Journal of Crop Science, 10*, 1047-1051.

Pandey, P., & Umesha, K. (2017). Effect of seed priming on biochemical changes in fresh and aged seeds of cucumber. *Journal of Animal Science, 5*, 62-74.

Qihe, Y. (2015). Effects of allelochemicals on seed germination. *Chinese Journal of Ecology, 12*, 1459.

Raj, A. B., & Raj, S. K. (2019). Seed priming: An approach towards agricultural sustainability. *Journal of Applied and Natural Science, 11*(1), 227-234.

Sen, A., & Puthur, J. T. (2020). Seed priming-induced physiochemical and molecular events in plants coupled to abiotic stress tolerance: An overview. In *Priming-mediated stress and cross-stress tolerance in crop plants* (pp. 303-316).

Soujanya, P., Sathappan, C., & Dhanasekaran, D. (2024). Effect of organic seed priming on germination and growth of bhendi (*Abelmoschus esculentus* L. Moench) in coastal saline soil. *Crop Research, 59*(1 and 2), 47-51.

Suriyagoda, L. D., Sirisena, D. N., Kekulandara, D., Bandaranayake, P. C., Samarasinghe, G., & Wissuwa, M. (2020). Biomass and nutrient accumulation rates of rice cultivars differing in their growth duration when grown in fertile and low-fertile soils. *Journal of Plant Nutrition, 43*, 251-269.

Taer, E. C. (2024). Hormopriming and duration of priming interaction on germination, emergence and subsequent growth productivity performance in pechay. *Ceylon Journal of Science, 53*(4), 03-511.

Wazeer, H., Shridhar Gaonkar, S., Doria, E., Pagano, A., Balestrazzi, A., & Macovei, A. (2024). Plant-based biostimulants for seeds in the context of circular economy and sustainability. *Plants, 13*(7), 1004.

Zhang, F., Yu, J., Johnston, C. R., Wang, Y., Zhu, K., Lu, F., Zhang, Z., & Zou, J. (2015). Seed priming with polyethylene glycol induces physiological changes in sorghum (*Sorghum bicolor* L. Moench) seedlings under suboptimal soil moisture environments. *PLoS ONE, 10*(10), e0140620.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/127862