

Original Article

Bamboo Wood Vinegar Seed Priming Improves Germination and Early Seedling Growth in Eggplant

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Abstract. This study evaluated the impacts of hydropriming and the use of comparatively lower-concentration wood vinegar solutions on the initial stages of germination and seedling morphology of eggplant (*Solanum melongena* L.). The study was conducted due to a lack of data on precise concentrations of bamboo wood vinegar required to maximize seedling vigor without causing toxicity. The experiment employed a one-factorial design system in Completely Randomized Design (CRD), with 11 treatments consisting of a control (T1), 2 hydropriming durations (12 and 24 hours), and wood vinegar concentrations (0.5%, 1%, 1.5%, and 2%), which were diluted in different volumes of water. The outcomes revealed that priming treatments significantly improved germination performance, with percent germination ranging from 94% to 99% compared to the T1 control (94%). The mean germination time (T50) decreased significantly with increasing doses of wood vinegar, from T1 (198.7 hours) to T11 (102.4 hours). The fastest treatment was T11 (102.4 hours), achieving the shortest time compared to the control T1 (198.7 hours). Priming with wood vinegar significantly enhanced plant vigor during early seedling growth. The highest shoot fresh weight (7.60 g and 8.07 g), shoot dry weight (0.27 g and 0.31 g), root fresh weight (2.27 g and 2.37 g), and root dry weight (0.074 g and 0.078 g) were obtained in T6 and T11 at 2% wood vinegar concentration. Although leaf number and color did not show much variation, T6 and T11 showed the largest stem diameter (2.1 cm and 2.2 cm). In general, the study generated various quantitative values that showed seed priming, especially with the use of 2% wood vinegar, a very good and cost-effective way to accelerate germination and improve early seedling growth for better crop performance.

Keywords: Eggplant; Emergence; Germination; Hydropriming; Wood vinegar.

Modern agricultural methods increasingly adopt strategies to enhance sustainability and limit reliance on synthetic chemical inputs used to counter soil degradation, environmental pollution, and the unpredictability of climate change. This shift has focused research on methods that protect the environment while improving plant productivity and resilience, and ecological balance (Pareek et al., 2020). Among the methods that have the potential to meet these requirements is seed priming, a pre-sowing treatment that pre-conditions seeds to initiate a series of pre-germinative metabolic activities, promising to enhance seed viability, hasten germination, and improve seedling robustness in varying conditions (Bortolin et al., 2020; Tombegavani et al, 2020). In the lineup of new natural priming agents, pyroligneous acid (PA), popularly known as wood vinegar, has emerged as a “clean technology” and a sustainable biostimulant with potential to improve crop productivity and soil health (Pinter & Salomón, 2022).

Wood vinegar is a clear reddish-brown liquid produced by the pyrolysis of plant materials under a restricted supply of oxygen (Shen et al., 2020). It is chemically complex as it consists of phenolics, alcohols, alkanes, and several organic acids that act as natural growth regulators and antioxidants (Kumar et al., 2025; Ouattara et al., 2025). One of the significant bioactive ingredients of pyroligneous acid has been identified as 3-methyl-2H-furo[2,3-c]pyran-2-one, also known as butenolide, which belongs to a class of compounds referred to as karrikinolides or karrikins.

Many processes regulated by the KAI2 receptor, including seed dormancy, the formation of root architecture, and various plant responses to stresses, have been shown to be steered by karrikin signaling (Fedeli et al., 2022). Job's tears (*Coix lacryma-jobi* L.) have also been shown to remain effective within a range of concentrations, which has drawn increasing interest for its use as a growth regulator to help plant tissues capture more light energy, as well as increase the levels of chlorophyll, and alleviate the adverse effects of salinity and drought stresses (Lu et al., 2020).

In a plant's life cycle, the seedling stage is the most tenuous, and the phase in which the use of growth regulators becomes largely evident. The establishment of a seed largely depends on how germination is uniformly and promptly achieved, which is facilitated by seed priming along with the reduction of the imbibition time and activation of germination-controlling enzymes (Tombegavani et al., 2020). In the Philippines, eggplants (*Solanum melongena* L.) occupy a crucial economic role as key vegetable crops and are also widely used in staple foods like pinakbet and dinengdeng. In addition to nasunin, which is an antioxidant, and altaicopotassium, an important mineral, eggplants are also characterized by slow and often irregular seed germination (Business Diary PH, 2020; Guzman & Cababaro, 2021). In addition to an increase in height and leaf growth, the use of wood vinegar as a nutrient enhancer has also been shown to have positive effects, but it has been shown by biological testing to have the potential to be toxic due to the various effects caused by different wood vinegar concentrations (Guzman & Cababaro, 2021; Siriwardena et al., 2020).

While the positive effects of wood vinegar on a variety of crops have been acknowledged, more research is needed on using bamboo-derived mokusako wood vinegar as a seed priming for eggplants. While some recent research assesses its usefulness in corn and rice (Torres et al., 2025), little research systematically examines how bamboo wood vinegar affects the early physiological stages of eggplant germination. Given the growing need for sustainable agricultural practices, this potential deserves thorough exploration. This research focuses on how the early germination of eggplant and the initial growth of seedlings respond to mokusaku wood vinegar to propose a substantive organic substitute to seed treatments based on chemicals and promote sustainable farming development.

Methodology

Research Design

A one-factorial study with a Completely Randomized Design (CRD) was conducted to test 3 replications of eleven priming treatments using dry seeded (control), hydropriming, and wood vinegar diluted as priming agents for application to seeds. Treatments include: T1, control; T2, 12 hours hydropriming (distilled water); T3, 12 hours of soaking in 0.5% wood vinegar; T4, 12 hours of soaking in 1% wood vinegar; T5, 12 hours of soaking in 1.5% wood vinegar; T6, 12 hours of soaking in 2% wood vinegar; T7, 24 hours hydropriming (distilled water); T8, 24 hours of soaking in 0.5% wood vinegar; T9, 24 hours of soaking in 1% wood vinegar; T10, 24 hours of soaking in 1.5% wood vinegar; T11, 24 hours of soaking in 2% wood vinegar. The experimental procedures were held in a greenhouse because of the homogeneous environment at Barangay Payawan, Lamut, Ifugao. This location was chosen because of the local microclimate and agricultural topography.

Data Gathering Procedure

The preparation of research materials was conducted first. Disposable canisters were thoroughly washed and labeled to contain the different concentrations of wood vinegar soaking solution and distilled water. A graduated cylinder was used to measure the distilled water, while a medicine cup was used to measure the wood vinegar. The different concentrations were prepared in properly labeled soaking bottles and diluted with distilled water for each treatment. Fortuner F1 variety seeds were rinsed with distilled water three times to remove residues and surface-dried with filter paper to make seed separation easier. Eggplant seeds were treated by soaking in solutions of wood vinegar (0.5%, 1%, 1.5%, and 2%) for 12 hours and 24 hours. The pH level of each solution was as follows:

0.5% (4.05), 1% (3.50), 1.5% (3.33), 2% (3.17), and hydro priming (distilled water) at 6.28. After the seeds were primed, they were rinsed with distilled water to remove any remaining priming solution and surface-dried.

After priming the seeds in Experiment 1, all germination boxes were labeled and lined using moistened filter paper to maintain properly hydrated conditions for the entire priming period. Eggplant seeds were properly sown in the germination boxes and placed in a dark room with regulated temperature and humidity for observation and recording of germinants. Moisture was maintained by spraying distilled water as needed. Protrusion of the radicle in seeds is considered germination. Germination was recorded every 24 hours and counted cumulatively. The collected data comprised the final germination percentage, determined by the ratio of germinated seeds to the total seeds sown. Additionally, mean germination time (T_{50}) was calculated from time-based counts, while the mean spread of germination time ($T_{90}-T_{10}$) was used to measure germination uniformity.

For experiment II, the greenhouse served as the experimental area for seedling emergence and growth. The greenhouse and its surroundings were kept clean, secured, and organized in preparation for the experiment. A mixture of vermicompost and garden soil served as the soil media. The garden soil was obtained from the Nueva Vizcaya State University (NVSU) compound and cleaned to remove the surface debris and stones. The soil vermicompost mixture was analyzed in the soils laboratory, showing a slightly acidic pH of 5.82. Nutrient levels were recorded as follows: 0.049 ppm of Nitrogen, 0.61% available Phosphorus, 0.55 ppm available Zinc, and a Manganese content of 0.299 ppm. Seedling trays were procured to serve as the container for the plug seeds. Each tray consists of 105 holes. Primed seeds were sown at a depth of 5 mm in a seedling tray. Watering was done just after sowing to keep the seed in close contact with the soil using a handheld atomizer. Sown seeds were watered every day to maintain soil moisture. A soil survey instrument was used to determine soil moisture and temperature, while a thermometer and hygrometer were used to monitor greenhouse temperature (25-32°C) and humidity (50-70%). Data collection focused on several key growth metrics. Initial emergence was recorded seven days after sowing. At two weeks after emergence, the total number of leaves per seedling was documented. Final assessments at 25 days included mean shoot length, stem diameter (measured 1 cm from the base via caliper), and leaf color based on a SPAD meter. Biomass data were also gathered at 25 days by measuring fresh and dry weights for both shoots and roots; dry weight was determined after oven-drying samples at 70°C for 24 hours.

Data Analysis

Quantitative analysis used Analysis of Variance (ANOVA) to compare means for differences between treatments using Sirichai Statistics Version 6. Means of each treatment were compared to each other at a 5% level of significance by means of the Least Significant Difference (LSD) test. A Completely Randomized Design (CRD) helped ensure validity. Reliability and trustworthiness were achieved through consistent implementation of procedures, replication, and standardization of measured characteristics.

Ethical Considerations

The present investigation was designed and performed in accordance with the common ethical standards for agricultural research. An institutional review board approval was not needed because no human subjects were utilized; only plant materials were used to conduct this research. In addition, participant protection and informed consent did not apply to this study; however, because the source of seeds for Fortuner F1 eggplant was obtained from authorized distributors, it was concluded that an ethical responsibility had been met. Confidentiality of all collected data was maintained through accurate recording, secure storage, and honest reporting of all experimental results. Safe handling and proper disposal of wood vinegar and any other research-related waste were performed in order to protect the environment from contamination of either the soil or the water. Throughout the research process, transparency, accuracy, and reproducibility were maintained.

Results and Discussion

This section presents the impact of different concentrations of wood vinegar, along with varying soaking durations, on the germination performance and seedling growth of the Fortuner F1 eggplant variety.

Percent Germination

Germination percentage is a measurement of the total number of viable seeds that germinate when the conditions are optimal (Theerakulpisut et al., 2015). The untreated control (T1) exhibited a germination rate of 94%. In contrast, many of the priming treatments (T3-T11, except for T1 and T2) consistently achieved a higher

germination percentage, reaching 99%. This suggests that the priming treatments, if wood vinegar is included, were effective in enhancing the overall germination capacity of the seeds. The statistically significant increase from 94% to 99% indicates that wood vinegar, when applied as a priming agent, could potentially break dormancy or activate metabolic processes leading to a higher successful germination rate (Zhang et al., 2018). The high values across the wood vinegar treatments are also supported by Tobias et al. (2007), who demonstrated that low concentrations of vinegar did not negatively affect, and often enhanced, the germination ability of eggplant seeds.

Table 1. Summary Matrix for Germination Parameters of Eggplant Seed as Influenced by Priming Water and Different Concentrations of Wood Vinegar

Treatments	Percent Germination	Mean Germination Time (T50,h)	Mean Spread Germination (T50-T10,h)
T1	94 ^b	198.7 ^a	92.22 ^a
T2	97 ^{ab}	156.0 ^b	92.06 ^a
T3	98 ^{ab}	118.3 ^{cd}	83.75 ^{ab}
T4	99 ^a	120.8 ^{cd}	81.96 ^{ab}
T5	98 ^{ab}	118.3 ^{cd}	80.69 ^{ab}
T6	99 ^a	114.4 ^{cd}	79.32 ^{ab}
T7	97 ^{ab}	130.8 ^{bcd}	78.81 ^{ab}
T8	99 ^a	137.6 ^{bc}	78.66 ^{ab}
T9	99 ^a	131.8 ^{bcd}	77.56 ^{ab}
T10	99 ^a	141.8 ^{bc}	67.51 ^{ab}
T11	99 ^a	102.4 ^d	61.54 ^{ab}
CV (%)	2.39	13.89	15.68

Mean Germination Time (T50, h)

The Mean Germination Time, which is the time required for 50% of the seeds to germinate, was reduced from the control, T1: (198.7) to the primed treatments, with the lowest time recorded by T11: (102.4), followed by T3 and T5: (118.3). This substantial decrease is the primary physiological benefit of priming, where the seed enters the initial stages of germination prior to sowing. This effect is consistent with research by Sultana et al. (2014), who noted that priming significantly accelerated germination time in eggplant. The 24-hour hydro priming combined with the highest wood vinegar concentration, T11: (2%), is concluded to be the optimal treatment for the fastest and most synchronized germination of eggplant seeds. The reduced mean germination time (MGT) indicates that seed priming (possibly using wood vinegar) influences the rate of germination. Faster germination can result in earlier seedling establishment and become more competitive against weeds (Xu et al., 2012).

Mean Spread of Germination (T90- T10, h)

Mean Germination Spread (MSG or T50-T10) presents information on germination uniformity and the time required for germination to continue from 10% and 50%. A lower value for MSG reflects a greater degree of synchrony or uniformity in germination (Rahman et al., 2019). The MSG for T1 untreated control = 92.22. Although some of the priming treatments had varying MSG values, several of the treatments recorded substantially lower MSG values than T1 (the untreated control). Among the priming treatments, T6: (79.32) and T11: (61.54) exhibited lower MSG values than T1 (the untreated control), indicating that seed priming with wood vinegar promotes more uniform germination. Uniform germination produces a more synchronized seedling stand and helps improve the ability to manage irrigation, fertilization, and harvest (Singh et al., 2015).

Table 2. Summary Matrix of Seedling Growth Parameters of Eggplant Seeds as Influenced by Hydro Priming and Different Concentrations of Wood Vinegar

Treatments	Percent of Emergence	Number of Leaves	Leaf Color	Mean Shoot Length (cm)	Stem Diameter (mm)	Shoot Fresh Weight (g)	Shoot Dry Weight (g)	Root Fresh Weight (g)	Root Dry Weight (g)
T1	88 ^b	2.30 ^b	13.29	7.2 ^{abc}	1.9 ^{bc}	6.3 ^{cd}	0.19 ^c	1.47 ^d	0.048 ^c
T2	93 ^{ab}	2.63 ^{ab}	13.54	7.3 ^{abc}	1.9 ^{bc}	6.27 ^{cd}	0.19 ^c	1.57 ^d	0.052 ^{bc}
T3	98 ^{ab}	2.77 ^a	13.43	7.0 ^{bc}	2.0 ^{bc}	6.17 ^d	0.20 ^c	1.67 ^{cd}	0.055 ^{bc}
T4	96 ^a	2.90 ^a	13.52	8.0 ^a	2.0 ^b	6.43 ^{bcd}	0.20 ^c	1.80 ^{cd}	0.055 ^{bc}
T5	98 ^{ab}	2.83 ^a	13.44	6.9 ^c	2.0 ^c	5.90 ^d	0.20 ^c	1.67 ^{cd}	0.055 ^{bc}
T6	98 ^a	2.97 ^a	13.57	7.7 ^{ab}	2.1 ^a	7.60 ^{abc}	0.27 ^b	2.27 ^{ab}	0.074 ^a
T7	96 ^{ab}	2.67 ^a	13.54	6.9 ^c	1.9 ^{bc}	6.47 ^{bcd}	0.20 ^c	1.57 ^d	0.05 ^{bc}
T8	97 ^a	2.87 ^a	13.52	6.9 ^c	1.9 ^{bc}	6.30 ^{cd}	0.21 ^c	1.70 ^{cd}	0.055 ^{bc}
T9	98 ^a	2.97 ^a	13.52	7.8 ^c	1.9 ^c	6.67 ^{bcd}	0.21 ^c	1.80 ^{cd}	0.057 ^{bc}
T10	98 ^a	2.87 ^a	13.50	6.7 ^c	2.0 ^{bc}	7.67 ^{ab}	0.27 ^b	2.0 ^{bc}	0.061 ^b
T11	99 ^a	2.93 ^a	13.45	7.1 ^{abc}	2.2 ^a	8.07 ^a	0.31 ^a	2.37 ^a	0.078 ^a
CV(%)	2.96	7.16	1.42	5.58	3.17	11.45	10.22	10.73	10.09

Final Percentage of emergence

The percentage of emergence was consistently high, with T11 (2% wood vinegar in a hydropriming solution for 24 hours) having the highest emergence rate at 99%, which is statistically very similar to most other treatments of wood vinegar (98%). The overall high emergence of the seeds from the wood vinegar treatments, especially when combined with hydropriming (T9, T10 and T11), was likely due to the synergistic effect of the priming process and the presence of beneficial substances found in the wood vinegar. In support of this finding, research carried out by Tobias et al. (2007) shows that low levels (2-3% concentration) of vinegar as a priming agent did not inhibit germination ability and, to some extent, positively influenced the germination ability of eggplant seed by pre-activating germination metabolism and increasing the absorption of water by the seeds.

Number of leaves

The highest number of leaves (2.97) was achieved in two treatments, T6 and T9. T6 refers to using 2% wood vinegar for 12 hours as a hydropriming treatment, and T9 refers to using 1% wood vinegar for 24 hours as a hydropriming treatment. Therefore, it can be concluded that both treatments promote vegetative growth by using wood vinegar as a priming agent, regardless of the time of application. This was supported by the research of Siriwardena et al. (2020) on *Solanum melongena* L., where they found that the application of pyroligneous acid, an analogue of wood vinegar, at a concentration of 1%, resulted in significantly greater mean leaf number than the control. The wood vinegar likely works as a biostimulant because of the growth-regulating compounds contained within, thereby increasing photosynthetic capability and leaf growth.

Leaf chlorophyll content

The LCC (Leaf Chlorophyll Content) of plants provides key information about their capacity for photosynthesis. The average LCC for the control was 13.29 (T1). Hydroprimed treatments produced marginally greater LCC values compared to the control; however, some of the wood vinegar treatments produced higher-than-expected LCC values. The LCC of T6 (2% wood vinegar) and T10 (1.5% wood vinegar) was 13.57 and 13.50, respectively, which were statistically significantly different than the control. In addition to T6 and T10 producing greater than control LCC levels, T11 (2% wood vinegar) produced the highest LCC of 13.45. These data suggest that the use of wood vinegar in conjunction with seedlings may enhance the amount of chlorophyll produced or slow its degradation, thereby enhancing seedlings' ability to trap light during photosynthetic processes (Akhtar et al., 2018).

Shoot length

In T4 (12 hours hydropriming with 1% wood vinegar), the shoot length of 8.0 cm was the highest compared to T6 and T11; therefore, the application of wood vinegar at appropriate concentrations will promote shoot cell elongation and division through either the promotion of growth compound synthesis and enhancement of nutrient uptake (Theerakulpisut et al., 2015). Siriwardena et al. (2020) also showed in eggplants that application of wood vinegar resulted in significantly greater height than those not treated, a measure that is directly related to shoot length. Lastly, Wang et al. (2014) showed that the use of wood vinegar promoted positive physiological and biochemical responses in plants, thereby improving their overall quality during vegetative growth.

Stem diameter (mm)

T11 attained the largest stem diameter (2.2mm) compared to the other treatments. The growth was stronger with a longer period of priming and higher concentrations of wood vinegar. The growth in diameter also corresponds to the findings of Siriwardena et al. (2020), who documented a 10% increase in the stem diameter of eggplants treated with pyroligneous acid. The organic acids found in wood vinegar most likely aided nutrient uptake, specifically nutrients necessary for building cell walls, producing thicker, stronger stems, and an essential characteristic of seedling quality. This increase in stem diameter is likely a combination of increased cell division and cell elongation due to better availability of carbohydrates and other growth-promoting substances as a result of the wood vinegar priming (Mungfu et al., 2019).

Shoot fresh weight (g)

The highest amount of shoot fresh weight was in T11 (8.07 g), T10 (7.67 g), and T6 (7.60 g). This indicates that there is considerable benefit from both high concentrations of wood vinegar and longer hydro-priming periods. The results support the hypothesis that wood vinegar acts as a plant growth regulator, which helps increase photosynthesis and water use efficiency, thus allowing for greater total production (Zhu et al., 2021). The greater

total production, as indicated by the total amounts of shoot fresh weight, is due to increased movement of water into the stems and accumulation of organic matter in the stems, indicating that there was strong early plant growth (Xu et al., 2012).

Shoot dry weight (g)

T11 provided the maximum shoot dry biomass (0.31g) compared to the T6 and T10 treatments and produced statistically similar results to them. These results clearly demonstrate the use of wood vinegar as an effective biostimulant to increase nutrient uptake and efficiency of metabolism in plants. Other researchers who have studied the effect of using wood vinegar to increase nutrient availability, such as Siriwardena et al. (2020), found that wood vinegar improves the total biomass of plants. The increase in total biomass indicates that there has been an increase in growth and distribution of resources in the seedling because of improved photosynthetic and nutrient uptake efficiency (Zhang et al., 2018).

Root fresh weight (g)

With T11 (2.37 g) and T6 (2.27 g), root fresh weight showed the greatest enhancement, with these two treatments achieving record output, which is considered critical for seedling vigor. As an auxin-like product that contains organic acids, wood vinegar influences root development, as they aid in rapid root and leaf growth (Guzman & Adalla, 2021). The combination of hydropriming with wood vinegar likely caused the synergistic effect on root growth. Therefore, this indicates the ability of wood vinegar to promote extensive root development that is essential for anchoring and acquiring resources efficiently from the soil (Singh et al., 2015).

Root dry weight (g)

T11 (0.078 g) and T6 (0.074 g) treatments showed the highest root dry weights. In support of the previously stated increase in root fresh weights, as well as demonstrating the quality of the roots' structures, the increase in root dry weights agrees with that found by Grewal et al. (2018) and Yavaş et al. (2023), which both describe using wood vinegar as a natural plant growth enhancer for overall plant development, including root length and biomass accumulation. Furthermore, the increases in root dry biomass are an excellent indicator of well-developed root systems necessary for successful seedling survival and later growth across a range of environmental conditions (Mungfu et al., 2019).

Conclusion

This research confirms that wood vinegar priming, particularly at higher concentrations, brings apparent improvements to the characteristics of seed performance and early vigor of seedlings in eggplants. In addition to the increased speed of germination and increased biomass, other results of this study indicate that wood vinegar may be used as a biostimulant that is available, inexpensive, and easy for farmers to implement, suggesting that the use of wood vinegar may increase seedling establishment in nurseries and the productivity of crops. Additionally, wood vinegar is an eco-friendly substitute for chemical growth enhancers. Practically, the use of wood vinegar in seed priming may enable farmers to ensure stronger seedlings and better crop stands, which are necessary to establish fields and sustain steady yields. Economically, the use of wood vinegar as an organic starter aligns with the policy paradigms of sustainable development and the goals of modern organic agriculture. In the area of education and research, this study aims to generate further interest in wood vinegar starter research. The extension services of this study will be the use of wood vinegar in different crops and different environments to determine the agricultural viability of wood vinegar in crop production.

Contributions of Authors

Author 1: Conceptualization, methodology, investigation, formal analysis, writing original draft preparation.

Author 2: Investigation, resources, data curation, writing review & editing.

Author 3: Investigation, data curation, validation.

Author 4: Investigation, data curation, project administration.

Author 5: Supervision, conceptualization, formal analysis, project administration, writing review & editing.

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Conflict of Interests

The authors declare no conflict of interest regarding the publication of this paper.

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