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PHYSIOLOGICAL QUALITY OF PAPAYA SEEDS (*CARICA PAPAYA* L.) AS AFFECTED BY KNO_3 PRIMING AND STORAGE DURATION

Abi Malik[1] , Agus Wartapa[2*] , Elea Nur Aziza[3]
[1,2,3] Polytechnic of Agricultural Development Yogyakarta Magelang / Yogyakarta
Corresponding Email: aguswartapayogya@gmail.com [2*]

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Abstract

This study investigates the effects of KNO_3 priming timing and storage duration on the physiological quality of papaya seeds (Carica papaya L.). A factorial randomized block design was used with two factors: priming timing no priming (P0), priming before germination (P1), after seed extraction (P2), and after drying (P3); and storage duration 1 month (L1), 2 months (L2), and 3 months (L3). Observed parameters included growth uniformity, growth rate, vigour index, germination percentage, and maximum growth potential. Data were analysed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. Results showed that priming before germination (P1) significantly improved growth uniformity and growth rate, while storage for two months (L2) yielded the best physiological seed quality in most parameters. A significant interaction was observed in the vigour index, with the best results from priming before sowing (P1) combined with 2–3 months of storage. The findings suggest that KNO_3 priming, before germination and storage for two months, is optimal for maintaining seed vigour and viability.

Keywords: ***Priming, KNO3, Papaya, Dormancy***

INTRODUCTION

Papaya (Carica papaya L.) is a fruit crop originating from southern Mexico and Central America, widely distributed and cultivated in tropical regions, including Indonesia. Papaya production in Indonesia has continued to grow, increasing from 1,168,266 tons in 2021 to 1,238,692 tons in 2023 (BPS, 2024). Along with population growth and high market demand, producing quality papaya seeds is essential for supporting optimal fruit yield. Typically, papaya seeds can experience dormancy for 12-15 days due to the presence of the epidermis (sarcotesta) and phenolic compounds. This dormancy causes seeds not to germinate synchronously, slowing down the seedling process. Breaking papaya seed dormancy can be achieved through enrichment or priming. Seeds that have been proven to accelerate germination do so by activating cell metabolism. However, many farmers have not utilised this technique, resulting in suboptimal germination outcomes. Therefore, it is essential to develop a priming method using KNO_3, with a particular focus on the soaking time of KNO_3 application, which can be performed during seed cleaning after extraction (P2) or after drying (P3). Additionally, the priming technique can be combined with a seed storage period of three months under controlled temperature and relative humidity. This study aims to determine the effect of KNO_3 priming application time on papaya seeds during a storage period of up to 3 months in a storage warehouse. The primary focus is to maintain and improve the physiological quality of papaya seed viability and vigour. If this method proves effective, it can be recommended to seed business actors before distribution, making it more practical for farmers to use papaya seeds as a consumer product. Therefore, it is expected to support a sustainable increase in national papaya production.

LITERATURE REVIEW

Papaya seeds exhibit a dormancy period lasting approximately 12 to 15 days, attributed to the presence of aryl and phenolic compounds within the seed (Faustina et al., 2011). Seed dormancy poses a significant challenge to germination, even under optimal conditions, such as adequate humidity, temperature, and light. This phenomenon may result either from an intrinsic inability of the seed to germinate or from elevated physiological thresholds required to initiate germination. Seeds that remain viable yet fail to germinate under standard conditions are classified as dormant (Schmidt, 2002). In practical agricultural settings, farmers frequently encounter difficulties in propagating papaya seeds due to their inconsistent germination behaviour and generally low viability. These issues are often exacerbated by declines in physiological seed quality during post-harvest handling and storage by farmers or consumers. As a result, there is a critical need to improve seed performance through pre-sowing treatments, such as priming, to enhance both viability and vigour. Seed priming is a physiological enhancement technique designed to improve seed quality by initiating early metabolic processes while preventing radical protrusion. One common agent used for priming papaya seeds is potassium nitrate (KNO_3), which comprises potassium (K), nitrogen (N), and oxygen (O)—each playing distinct physiological roles. Potassium facilitates protein and carbohydrate metabolism, nitrogen supports the synthesis of vegetative tissues, proteins, and lipids, while oxygen is essential for cellular respiration, a prerequisite for embryonic organ development. Furthermore, KNO_3 is known to act as a germination promoter by activating gibberellins and alleviating dormancy in various plant species (Bukhari, 2013).

According to Salsabilah (2022), soaking papaya seeds in a 1.5% KNO_3 solution yielded superior outcomes in comparison to 1% and 2% concentrations, particularly in terms of germination rate, germination speed, synchronisation of seedling emergence, and vigour index. These findings serve as a critical reference point for the present study. To identify the most effective approach for improving papaya seed germination, various priming techniques warrant systematic evaluation. Priming is typically conducted after the seed cleaning and drying process and is expected to yield comparable improvements in germination performance. In addition to dormancy, seed deterioration represents another major factor necessitating priming interventions. Deterioration encompasses a series of physical, physiological, and biochemical changes that occur during storage, often resulting from the degradation of macronutrients such as lipids and carbohydrates into simpler metabolites (Sudrajat, 2018). These changes compromise membrane integrity, increasing membrane permeability and thereby leading to reduced germination rates, asynchronous seedling emergence, and heightened susceptibility to environmental stresses (Sadjad, 2015). Therefore, priming treatments are not only intended to overcome dormancy but also to mitigate the adverse effects of seed deterioration, particularly those induced by storage conditions. This forms the basis for enhancing the physiological quality of papaya seeds, thereby enabling farmers to achieve more consistent and successful cultivation outcomes..

METHOD

This research was conducted from November 2024 to May 2025 at CV Jogja Horti Lestari, located in Pedak, Sinduharjo, Ngaglik, Sleman, Special Region of Yogyakarta. The equipment utilized in this study included seedling trays, tampah (traditional winnowing trays), trays, germinators, thermometers, measuring cylinders, stove, pots, spray tools, digital scales, containers, pouch tiles, cool storage units, oven, gloves, buckets, sieves, blowers, blenders, aluminum foil, scissors, knives, calculators, cameras, and stationery. The materials used comprised Calina variety papaya seeds produced by CV Jogja Horti Lestari (used as the experimental material), potassium nitrate (KNO_3), water, germination media, plastic, and labelling materials. The study employed a Factorial Randomized Complete Block Design (RCBD) involving two factors. The first factor was the timing of seed priming, which consisted of four conditions: no priming (P0), priming before germination (P1), priming after seed extraction (P2), and priming after seed drying (P3). The second factor was seed storage duration, which included three levels: 1 month (L1), 2 months (L2), and 3 months (L3). The parameters measured in this study were: germination speed, germination synchrony, germination rate, maximum growth potential, and vigour index.

RESULTS AND DISCUSSION

The results of research on the priming treatment of papaya seeds (Carica papaya L.) at various priming application times and storage periods were obtained through observations of parameters such as growth synchrony, growth rate, vigour index, germination percentage, and maximum growth potential. These parameters are used to assess the physiological quality of papaya seeds at different priming times and storage durations. Data collected for each parameter were analysed using ANOVA and further tested with Duncan's Multiple Range Test (DMRT) at a 5% significance level. The summary of the analysis of variance for the observation variables is presented in the following table.

Table 1. Recapitulation of the results of the analysis of variance

Observation Variables	Priming Treatment (P)	Storage Time (L)	Interaction (P*L)	KK (%)

The Simultaneity of Growth	*	*	tn	13,386
Growth Rate	*	*	tn	11,213
Vigor Index	*	*	*	14,414
Germination Power	tn	*	tn	8,953
Maximum Growth Potential	tn	*	tn	8,291

The Simultaneity of Growth

Table 2. Analysis of Variance (ANOVA) Results for Germination Synchrony

Treatment Priming	Storage Period			Average
	L1	L2	L3	
P0	46.00	78.00	66.00	63.33 a
P1	75.33	78.67	74.67	76.22 b
P2	70.00	77.33	63.33	70.22 ab
P3	58.00	79.33	62.00	66.44 a
Average	62.33 a	78.33 b	66.50 a	(-)

Based on Table 2 regarding the growth simultaneity parameter, there was no significant interaction between the priming application time treatment and the seed storage duration. It indicates that the priming application time treatment and the seed storage duration did not have an interactive effect or significantly influence each other on the growth synchrony of papaya seeds. The priming application time treatment before germination (P1) showed a significantly different value compared to the treatment without priming (P0) and the priming treatment after the seeds were dried (P3). However, the P1 treatment did not differ significantly from the priming treatment after seed extraction (P2). It suggests that KNO3 priming is most effective for papaya seeds when performed just before germination or after seed extraction before drying. Priming is a controlled hydration process that activates seed metabolism up to the early germination stage without causing radicle emergence, making the seeds more prepared for growth when sown. According to Zanzibar et al. (2009), priming seeds after extraction and before re-drying enables them to undergo optimal metabolic activation, allowing primed seeds to be re-dried for storage or directly sown without losing vigour.

Growth Rate

Table 3. Analysis of Variance (ANOVA) Results for Growth Rate

Treatment Priming	Storage Period			Average
	L1	L2	L3	
P0	4.20	6.64	6.05	5.63 a
P1	6.87	7.46	7.21	7.18 c
P2	6.22	7.20	5.91	6.44 b
P3	5.13	7.11	5.77	6.00 ab
Average	5.61 a	7.10 c	6.24 b	(-)

Based on Table 3, the analysis of variance results show that there was no significant interaction between the priming application time treatment and the seed storage duration on the growth rate. The two treatment factors did not interact to increase papaya seed growth. The priming application time treatment before seed germination (P1) produced the highest growth rate. It was significantly different from the treatment without priming (P0), priming after seed extraction (P2), and priming after the seeds were dried (P3). These results indicate that the most effective priming time is when the seeds are about to germinate, as at this point, the seeds can optimise the imbibition process and initial metabolism, leading to a significant increase in growth rate and seed physiological quality compared to seeds that are not primed. These findings are also consistent with research by Utami et al. (2014), which states that priming before seed germination provides optimal hydration conditions that activate the seed's metabolic processes in a controlled manner, resulting in quicker, more uniform germination and higher vigour.

Germination Power

Table 4. Analysis of Variance (ANOVA) Results for Germination Rate

Treatment Priming	Storage Period			Average
	L1	L2	L3	
P0	62.00	81.33	73.33	72.22 a
P1	77.33	81.33	76.67	78.44 a
P2	73.33	84.00	70.00	75.78 a
P3	67.33	87.33	70.00	74.89 a
Average	70.00 a	83.50 b	72.50 a	(-)

Based on Table 4, the analysis of variance results show that there is no significant interaction between the priming application time and storage duration on the germination rate of papaya seeds. It means that the combination of priming application time and storage duration does not influence each other in determining seed germination ability. Therefore, each treatment can be analysed separately. The analysis of priming application time reveals no significant difference between treatments in terms of papaya seed germination rate. All priming treatments—before sowing (P1), after extraction (P2), after drying (P3), and without priming (P0)—produced similar results in seed germination rate. It suggests that the application of KNO_3 priming, with the method and concentration used in this study, has not significantly affected the percentage of normal sprouts formed. This finding contrasts with Salsabilah (2022), which reported that KNO_3 priming treatment significantly increased the germination rate in papaya seeds. This difference in results is likely due to several key factors. One of the main factors is the initial viability of the seeds used; seeds with high viability tend to show a less significant response to priming because their conditions are already optimal, whereas seeds with lower viability are more likely to experience a notable increase in germination power after priming (Yuanasari et al., 2015).

Maximum Growth Potential

Table 5. Analysis of Variance (ANOVA) Results for Maximum Growth Potential

Treatment Priming	Storage Period			Average
	L1	L2	L3	
P0	72.00	81.33	74.67	76.00 a
P1	77.33	82.00	80.00	79.78 a
P2	75.33	84.00	70.67	76.67 a
P3	68.67	87.33	75.33	77.11 a
Average	73.33 a	83.67 b	75.17 a	(-)

Based on Table 5, the analysis results indicate that there is no significant interaction between the treatment of priming application time and storage time on the maximum growth potential (PTM) of papaya seeds. This suggests that each treatment has an independent effect on maximum growth potential, with no significant reciprocal impact between them. The main effect of priming application time treatment, whether before sowing (P1), after extraction (P2), after drying (P3), or no priming (P0), did not produce significantly different results. These findings also align with the germination power parameters, as the measurement of maximum growth potential was conducted by observing all seeds capable of germinating, both usually and abnormally, under optimal conditions during a specific observation period. Therefore, the priming application time did not significantly impact the maximum germination capacity of the seeds. This suggests that priming at different stages does not directly increase the number of seeds that can germinate optimally, but instead affects other factors, such as growth rate (Table 2), growth synchrony (Table 3), and seed vigour (Table 6). This conclusion is supported by Lestari (2024), which indicates that priming effectively improves seed physiological quality, especially vigour and germination rate, but does not significantly increase maximum growth potential. Regarding storage duration, there is a significant difference between treatments. A storage period of 2 months (L2) yields the highest PTM value, significantly higher than storage for 1 month and 3 months.

Vigor Index

Table 6. Analysis of Variance (ANOVA) Results for Vigor Index

Treatment Priming	Storage Period			Average
	L1	L2	L3	
P0	0.00 a	56.67 cd	56.00 cd	37.56
P1	33.33 b	75.33 ef	82.00 f	63.56
P2	46.67 c	67.33 de	64.00 de	59.33
P3	22.67 b	61.33 de	62.00 de	48.67
Average	25.67	65.17	66.00	(+)

Based on Table 6, the analysis of variance results for the seed vigour index show a significant interaction between the priming application time treatment and seed storage duration. This indicates that the seed response to priming treatment is affected by the duration of seed storage, meaning the two factors influence the papaya seed vigour index together. The priming treatment before sowing (P1) combined with a storage period of 3 months (L3) yielded the highest vigour index, which was significantly higher than that of other treatment combinations. Conversely, the treatment without priming (P0) and a storage time of 1 month (L1) yielded the lowest vigour index, which was statistically different from that of the other treatments. This suggests that KNO_3 priming before sowing, especially when combined with 2 to 3 months of storage, can optimally improve seed physiological performance, as reflected in the high vigour index. These findings also support Salsabilah (2022), who states that KNO_3 priming can accelerate germination and improve seed vigour in various plants, including papaya. The presence of this significant interaction highlights the importance of considering not only individual factors but also the combined effects of treatments that can work together to enhance seed quality, particularly for tropical plants like papaya, which are known to exhibit post-extraction physiological dormancy.

The storage period of papaya seeds for 2 months (L2) had a significant effect on growth rate, growth simultaneity, germination power, and maximum growth potential (PTM), which were notably different from those for storage periods of one month (L1) and three months (L3). The notable results during the 2-month storage period are believed to be related to the physiological maturation process, also known as after-ripening, a phase where the internal activity of the seeds gradually increases after drying. According to Indria Rini et al. (2025), after-ripening, which can last several weeks, can break dormancy and significantly enhance seed viability and vigour. This idea is supported by Fatdillah (2019), who states that storing papaya seeds for a specific period can accelerate the physiological ripening process, but seed quality declines after the optimal duration has passed. The positive effects observed in the 2-month storage are also reinforced by the ongoing activity of priming in the second month, which helps improve seed metabolism and physiological quality. However, continued storage into the third month results in a decline in seed quality, caused by physiological ageing—such as the accumulation of free radicals, damage to cell membranes, and decreased energy reserves —as explained by Sahputri (2024).

CONCLUSION

This study aims to investigate the effect of KNO_3 priming timing on the physiological quality of papaya seeds during storage. The results showed that priming was most effective when the seeds were about to be sown (P1), especially if stored for 2–3 months under controlled conditions. This treatment was able to improve growth speed, growth rate, and seed vigour index. Meanwhile, germination power and maximum growth potential did not show significant differences. The combination of P1 treatment with 3 months of storage produced the best vigour results. Seed producers can use this technique to make papaya seeds more ready for planting when they reach farmers. In the future, this method can be developed as a standard seed treatment to sustainably increase papaya production.

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