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Application of Moringa Leaf Extract (*Moringa oleifera*) During Post-Ripening Period on the Physiological Quality of Ciherang Rice Seeds (*Oryza sativa* L.)

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ABSTRACT

This research investigates the effects of Moringa leaf extract and post-ripening periods on the physiological quality of Ciherang rice seeds, which often exhibit dormancy after harvest. Effective methods are needed to break this dormancy to achieve optimal planting results. Moringa leaf extract, recognized as a sustainable and eco-friendly biostimulant, was tested for its potential to enhance seed quality. The study utilized a robust experimental design, testing four concentrations of Moringa leaf extract (0%, 20%, 60%, and 100%) across four post-ripening periods (0, 2, 4, and 6 weeks), with three repetitions for each treatment. A multiple observation data analysis was conducted, combining individual measurements with time-grouped assessments. Results revealed that both the concentration of Moringa leaf extract and the length of the post-ripening period significantly influenced the physiological quality of the seeds. The most effective treatments were identified as 60% Moringa leaf extract with a 4-week post-ripening period and 20% extract with a 6-week period. This research underscores the potential of Moringa leaf extract as an accessible and environmentally friendly method for breaking seed dormancy, offering valuable insights for farmers aiming to improve seed germination and enhance crop productivity in regions where Moringa is abundant.

1. INTRODUCTION

The physiological quality of rice seeds is crucial for ensuring optimal germination and seedling vigor, which directly impacts crop yield and food security. The post-ripening period is a critical phase where seeds undergo physiological changes that prepare them for germination. During this period, the application of natural extracts like Moringa may enhance seed quality by improving metabolic processes and stress resistance. Research has shown that various plant extracts can positively influence seed germination and seedling growth by enhancing antioxidant activity and modulating stress responses (Afzal *et al*., 2020; Joo *et al*., 2019; Saising *et al*., 2022). The interaction between Moringa leaf extract and rice seeds during the post-ripening period could lead to improved physiological traits such as increased germination rates, enhanced seedling vigor, and better stress tolerance. The bioactive compounds present in Moringa, including flavonoids and phenolic acids, known to exhibit antioxidant properties, which can mitigate oxidative stress in seeds and promote healthier seedling development (Galvin *et al*., 2022; Lidon & Ramalho, 2014; Maryono M *et al*., 2021). This is particularly relevant in the context of rice cultivation, where environmental stressors such as salinity, drought, and pathogens pose significant challenges to crop production (Ling *et al*., 2021; Taniguchi *et al*., 2023; Tseng *et al*., 2018). The Ciherang variety of rice is widely cultivated in Indonesia and is known for its high yield potential. However, like many rice varieties, it is susceptible to various abiotic and biotic stresses that can adversely affect its growth and productivity. The integration of Moringa leaf extract into the post-ripening process could serve as an eco-friendly approach to enhance the resilience of Ciherang rice seeds against these challenges. Studies have indicated that the application of natural plant extracts can improve the physiological and biochemical responses of rice plants, leading to better growth performance and yield (Ali *et al*., 2010; Muttagi & Ravindra, 2020; Sayekti & Taufiq Qurrohman, 2019).

The seeds used by farmers for rice cultivation are usually from the harvest of the previous crop. Harvested rice seeds that are directly used as a seed source for the next crop tend to give less than optimal results. This is due to the post-ripening nature of newly harvested rice seeds. The post-ripening period in rice seeds is a form of seed condition that is unable to germinate when just harvested and can only germinate after exceeding the dry storage period. Post-ripening is a physiological dormancy that occurs due to the performance of phytohormones contained in seeds inhibited by the presence of inhibitors abscisic acid (Murniati *et al*., 2017). Ciherang rice seeds include varieties that are in demand by farmers in the East Java Province. Inventory data on the distribution of varieties of UPT PSBTPH East Java Province (2023) shows that the area of use of ciherang rice seeds in East Java Province is 76,554 ha of the total planting area of 286,674 ha (UPT PSBTPH, 2023). The ciherang rice variety is in high demand because it has several advantages, namely suitable for planting in the lowlands resistant to pests and diseases, high productivity, quality and good rice taste.

The post-ripening period in rice seeds can vary among different varieties or types of seeds. Post-ripening conditions in rice seeds can provide advantages and disadvantages to farmers. The advantage of the post-ripening period is that it can facilitate storage, because it can limit germination and delay seed deterioration, while the disadvantages incurred can disrupt the smooth supply of seeds, because the seeds cannot be used immediately. Various methods of breaking dormancy at the laboratory level require expensive equipment and chemicals, making it impossible to be carried out by farmers, besides the number of seeds used by farmers tends to be more than the number of samples used by seed researchers. This condition causes the need to find effective methods/materials to break dormancy and easily done by farmers. An appropriate method of breaking dormancy is needed to get the correct interpretation of germination test results in seed quality testing and avoid delays in certification that can reduce vigor. It is expected that the time required for seed quality testing will be shorter.

Moringa leaves contain various nutrients and bioactive compounds that are beneficial to plants, such as proteins, carbohydrates, fats, vitamins, minerals and flavonoids. Moringa leaves have also been used as organic priming of rice seeds to increase viability, vigor, and plant growth. The average percentage of upland rice germination using organic priming of 50% moringa leaf extract can reach up to 85% and the average rate of germination is 2.36 days (Kadir *et al*., 2022). Moringa leaf extract (MLE) can act as a cheap, accessible, sustainable and environmentally friendly natural biostimulant that has the potential to spur plant growth, production and quality. It can also be extracted using water because it is safer, cheaper, easier to prepare, and easily applied by small-scale and commercial farmers (Mashamaite *et al*., 2022). This study aims identify the effect of moringa leaf extract concentration, post-ripening period and the combination between the two on the physiological quality of rice seeds (*Oryza Sativa* L.) Ciherang variety.

2. MATERIALS AND METHOD

2.1. Research Materials

This research was conducted at the Testing Laboratory and Screen house UPT PSBTPH East Java Province Working Area II Madiun from January to April 2024. The main materials used were newly harvested Ciherang rice seeds, as well as supporting materials such as moringa leaf extract, distilled water, test paper, soil, compost fertilizer, 20 x 20 cm polybags, and label paper. The equipment used in this research includes digital balance, moisture meter, oven, conductivity meter, beaker glass, tissue, screen house, tweezers, hand sprayer, sieve, spoon, tray, hoe, shovel, paddle, and ruler. This combination of materials and tools allowed for a comprehensive study to be conducted to examine the effects of Moringa leaf extract and post-ripening period on the physiological quality of Ciherang rice seeds.

2.2. Method

This study uses multiple observation data analysis where each experimental unit is measured individually (single factor) first and then combined with measurements measured in certain time groups in a combined variance analysis. The individual research design used in each group of observation time periods was a randomized complete block design (RCBD) with 4 (four) treatments of moringa leaf solution concentration (K) and 3 (three) replications. The observation time consisted of 4 (four) post-ripening periods (P). The combined design utilized a split plot design, with Moringa leaf solution concentration (K) as the main plot factor and post-ripening period (P) as the subplot factor. The 4 treatment levels of moringa leaf solution concentration were K1 = No treatment (control), K2 = Moringa leaf extract solution concentration of 20%, K3 = Moringa leaf extract solution concentration of 40%, K4 = Moringa leaf extract solution concentration of 60% with 3 replication. The 4 levels of observation time were P1 = Post-ripening period 2 weeks after harvest (WAH), P2 = Post-ripening period 4 WAH, P3 = Post-ripening period 6 WAH, P4 = Post-ripening period 8 WAH, so that the number of experimental units in this study was 48 experimental units.

2.3. Research Implementation

The implementation of this study included several important stages. Starting with the preparation of 4,800 grams, freshly harvested Ciherang rice seeds were then cleaned, dried to 13% moisture content, and stored in plastic packaging at room temperature during the post-ripening period of 2, 4, 6, and 8 weeks. Next, the seeds were soaked in Moringa leaf extract solution with concentrations of 20%, 40%, and 60% for 24 hours, washed, and oven-dried at 40°C for 2 hours. Seed quality testing was conducted in the laboratory during the post-ripening period using the UKDd method (test in rolled paper set up) with 300 seeds per treatment. Parameters tested included conductivity value, moisture content, maximum growth potential, germination, vigor index, growth rate, and biochemical content analysis, using a germinator with stencil paper media for seven days.

2.4. Field Testing

Field testing was carried out in the laboratory screen house of UPT PSBTPH East Java Province Working Area II Madiun during the post-ripening period of 2, 4, 6, and 8 weeks, using treated seeds. Parameters tested included plant height and number of tillers. The testing phase began with the preparation of planting media, which was mixture of soil and compost in a ratio of 1:1 that was then put into 20 x 20 cm polybags. Planting was done by placing 3 treated rice seeds in each polybag, followed by adequate watering. Plant maintenance included regular watering to maintain media moisture, weeding to reduce nutrient competition, and pest and disease control during the plant growth period.

2.5. Observation Parameters

2.5.1. Parameter of Quality Testing in Laboratory

a. Water content: every week, the moisture content of each variety tested was observed. Seed moisture content was determined by the rapid method using a calibrated moisture meter.

b. Electrical conductivity (EC) Conductivity Value: Rice seeds that have been treated are tested for electrical conductivity using a conductivity meter, which measures the seed soaking water. Biochemical analysis test was conducted in the testing laboratory. The electical conductivity (µS/g) was calculated using the formula (International Seed Testing Ascotiation, 2021):

$$\text{EC } (\mu\text{S/g}) = \frac{\text{Seed DHL value} - \text{Blank EC value}}{\text{Weight of each replicate (g)}} \tag{1}$$

c. Maximum Growth Potential (MGP): Maximum growth potential is calculated based on the percentage of the number of seeds that grow with minimal criteria for radicle growth at the end of observation, namely the seventh day, with the formula (Mewangi *et al*., 2019):

$$\text{MGP } (\%) = \frac{\sum \text{Normal Sprouts} + \sum \text{Abnormal Sprouts}}{\sum \text{Seeds Planted}} \times 100\% \tag{2}$$

d. Germination Rate (GR): Germination rate is calculated based on the number of normal sprouts at the first observation (day 5) and the final observation (day 7) after germination of each replicate. Germination rate (GR) was calculated using the following formula (International Seed Testing Ascotiation, 2021):

$$\text{GR } (\%) = \frac{\sum \text{Normal Sprouts Day 5} + \sum \text{Normal Sprouts Day 7}}{\sum \text{Seeds Planted}} \times 100\% \tag{3}$$

e. Vigor Index: Vigor index is measured based on the percentage of the number of normal sprouts on the first observation day, namely day 5. The vigor index (IV) is measured by the formula (Murniati *et al*., 2017):

$$\text{IV}\ (\%) = \frac{\sum \text{Normal Sprouts Day 5}}{\sum \text{Seeds Planted}} \times 100\% \tag{4}$$

f. Growth Speed: Observations were made of normal sprouts from the first to the seventh day after planting. Calculation by summing up the results of the division between the percentage of normal sprouts that grow in each observation with the observation time. Growth speed (GS) is measured by the formula (Murniati *et al*., 2017):

$$\text{GS}\ (\%\text{KN/etmal}) = \sum_{i=1}^{7} \frac{\%\ \text{Normal Sprouts to}-\text{i}}{\text{Observation hours to}-\text{i}/24} \tag{5}$$

g. Biochemical content: Biochemical analysis included the content of food reserves (starch and reducing sugar) and phytohormones (auxin, giberalin, cytokinin, absicic acid) in rice seeds. Biochemical content analysis was carried out by sending seed samples to the testing laboratory. Analysis of starch and reducing sugar content using the Luff school test method (Zulfisa *et al*., 2022). Analysis of phytohormone content using UV-VIS Spectrophotometry method (Hidayati, 2014; Rai *et al*., 2006; Wibowo *et al*., 2009).

2.5.2. Field Testing Observation Parameter

a. Plant height (cm): Measurement of plant height starts from the base of the stem to the tip of the longest leaf in a clump, measurement of plant length is done using a ruler. Plant height is measured after the end of the vegetative phase of the plant.
b. Number of tillers (stems): The number of tillers of rice plants was calculated on the last day of the vegetative phase. Tiller was calculated by counting the number of rice tillers that grew from the main stem of rice.

2.6. Data Analysis

The data obtained were analyzed for variance (F test) by comparing the calculated F value obtained with the F table. If the calculation results show the value of F count > F table, a treatment or combination of treatments has a significant effect, otherwise if the value of F count < F table is obtained, a treatment or combination of treatments has an insignificant effect. If the results of the analysis have a significant effect, the further test is continued using the Duncan Multiple Range Test (DMRT) at a significant level of 5%.

3. RESULT AND DISCUSSION

3.1. Result

The results of the single factor analysis of variance for each experimental parameter in each group of observation times for the post-ripening period (P1-P4) are shown in Table 1. The results showed that the effect of moringa leaf extract solution concentration (K1-K4) varied significantly depending on the post-ripening period (P1-P4) and the parameters measured. At 2 WAH (P1), significant effects were observed on most parameters except plant height and number of tillers. At 4 WAH (P2), a significant effect was still observed on most parameters, but no effect was observed on starch and sugar content, plant height and number of tillers. The period of 6 WAH (P3) showed a significant effect on several main parameters, but not on maximum growth potential, germination, plant height, and number of tillers. At 8 WAH (P4), the significant effect was limited to moisture content, electrical conductivity, and some biochemical contents. Overall, the single factor of moringa leaf extract solution concentration showed a significant effect on several parameters, although the effect tended to decrease as the post-ripening period increased.

A combined analysis of variance was conducted to see the effect of the interaction between the treatment of moringa leaf extract solution concentration (K1-K4) with the observation time group of the post-ripening period (P1-P4). A recapitulation of the results of the combined analysis of variance on the treatment of moringa leaf extract solution concentration (K), post-ripening period (P), and the interaction between the two treatments (K × P) on the observed parameters it shown in Table 2.

Table 1. Results of ANOVA of each experimental parameter in each group of observation time of post-ripening period (P1-P4)

Parameter		Average of each trial parameter							
		P1		P2		P3		P4	
1.	Water content	13.43	*	13.43	*	13.40	*	13.38	*
2.	Electrical conductivity	7.38	*	7.82	*	7.92	*	8.05	*
3.	Maximum growth potential	84.42	*	96.83	*	96.50	tn	96.08	tn
4.	Germination rate	81.83	*	95.08	*	94.58	tn	92.83	tn
5.	Vigor index	54.58	*	84.25	*	88.58	*	91.33	tn
6.	Growth rate	16.13	*	20.77	*	20.93	*	22.64	tn
7.	Biochemistry:								
	a. Starch	58.24	*	60.16	tn	60.95	*	60.48	*
	b. Sugar	0.25	*	0.27	tn	0.30	*	0.26	*
	c. Auxin	1.66	*	1.77	*	1.80	*	1.83	*
	d. Cytokinin	1.89	*	2.11	*	2.24	*	2.12	*
	e. Gibberellin	2.29	*	2.42	*	2.17	*	2.17	*
	f. Abscisic acid	1.35	*	1.37	*	1.45	*	1.46	tn
8.	Plant height	54.08	tn	54.33	tn	53.33	tn	52.92	tn
9.	Number of tillers	5.75	tn	5.92	tn	5.75	tn	5.50	tn

Notes: * = significantly different at 5% DMRT, *tn* = not significantly different at 5% DMRT

Table 2. Recapitulation of combined variance of the effect of moringa leaf extract concentration treatment (K) with post-ripening period (P) on the parameters observed

Parameter		Treatment				
		K	P	K × P	KK_k(%)	KK_p(%)
1.	Water content	**	tn	tn	0.39	0.62
2.	Electrical conductivity	**	**	**	2.47	2.57
3.	Maximum growth potential	**	**	**	2.60	2.94
4.	Germination rate	**	**	**	3.66	3.27
5.	Vigor index	**	**	**	3.72	5.18
6.	Growth rate	**	**	**	3.79	4.07
7.	Biochemistry:					
	a. Starch	**	**	**	0.19	0.34
	b. Reduction sugar	**	**	tn	8.16	8.44
	c. Auxin	**	**	**	1.80	1.58
	d. Cytokinin	**	**	**	3.40	4.91
	e. Gibberellin	**	**	**	2.27	2.10
	f. Abscisic acid	**	**	**	3.47	3.54
8.	Plant height	tn	tn	tn	3.27	2.67
9.	Number of tillers	tn	tn	tn	14.80	15.12

Notes: * = significantly different at the 5% level; ** = significantly different at the 1% level; tn = not significantly different.

3.2. Discussion

3.2.1. Effect of Treatment on the Physiological Quality of Seed

The observed seed physiological quality variables were moisture content, electrical conductivity, maximum growth potential, germination, vigor index and growth speed. The combined analysis of variance on the parameters of electrical conductivity, maximum growth potential, germination, vigor index and growth speed, showed significantly different results in the treatment of moringa leaf extract solution concentration (K), post-ripening period treatment (P), and the interaction between the two treatments (K × P), while the water content parameter showed significantly different results in the treatment of moringa leaf extract solution concentration (K), but not significantly different in the post-ripening period treatment (P), and the interaction between the two treatments (K × P) (Table 2). This shows that the treatment of moringa leaf extract solution concentration, post-ripening period treatment and the interaction between the two treatments affect the electrical conductivity, maximum growth potential, germination power, vigor index and growth speed, while the water content parameter is only influenced by the treatment of moringa leaf extract solution concentration.

Table 3 shows that in the same post-ripening period (P) treatment, the concentration of moringa leaf extract solution (K) tends to increase water content, maximum growth potential, germination power, vigor index and growth speed, but decreases electrical conductivity, while in the same moringa leaf extract solution concentration (K) treatment, the post-ripening period (P) treatment tends to increase electrical conductivity, maximum growth potential, germination power, vigor index and growth speed, but decreases water content.

Table 3. Mean values of water content, electrical conductivity, maximum growth potential, germination rate, vigor index and growth rate of each treatment of moringa leaf extract solution concentration (K) at each post-ripening period (P)

Concentration	Post-ripening Period (P)				Concentration	Post-ripening Period (P)			
(K)	P1	P2	P3	P4	(K)	P1	P2	P3	P4
	Water Content					Electrical Conductivity			
K1	13.20	13.17	13.13	13.10	K1	8.65 ^{f}	8.18 ^{de}	8.22 ^{de}	8.45 ^{ef}
K2	13.57	13.50	13.53	13.47	K2	7.16 ^{a}	8.07 ^{cd}	8.00 ^{cd}	8.13 ^{cde}
K3	13.50	13.57	13.43	13.50	K3	6.90 ^{a}	8.09 ^{cde}	7.94 ^{cd}	7.87 ^{cd}
K4	13.47	13.47	13.50	13.47	K4	6.82 ^{a}	6.96 ^{a}	7.52 ^{b}	7.75 ^{bc}
	Maximum Growth Potential					Germination Rate			
K1	68.67 ^{a}	91.33 ^{bc}	95.00 ^{cde}	95.67 ^{cde}	K1	65.33 ^{a}	89.00 ^{bcd}	92.00 ^{cdef}	90.67 ^{cde}
K2	93.33 ^{cd}	98.00 ^{de}	97.67 ^{de}	97.67 ^{de}	K2	90.67 ^{cde}	96.00 ^{ef}	96.67 ^{f}	94.67 ^{def}
K3	88.00 ^{b}	99.00 ^{e}	96.33 ^{cde}	95.00 ^{cde}	K3	86.67 ^{bc}	97.67 ^{f}	95.00 ^{ef}	92.33 ^{def}
K4	95.00 ^{cde}	99.00 ^{e}	97.00 ^{de}	96.00 ^{cde}	K4	84.67 ^{b}	97.67 ^{f}	94.67 ^{def}	93.67 ^{def}
	Vigor Index					Growth Speed			
K1	14.00 ^{a}	67.33 ^{b}	81.67 ^{cd}	87.00 ^{de}	K1	10.61 ^{a}	17.48 ^{bc}	18.66 ^{cd}	21.06 ^{fg}
K2	77.67 ^{c}	92.33 ^{e}	94.33 ^{e}	63.33 ^{b}	K2	19.56 ^{de}	22.72 ^{hi}	23.54 ^{i}	17.24 ^{bc}
K3	63.33 ^{b}	88.67 ^{de}	87.00 ^{de}	91.67 ^{e}	K3	17.24 ^{bc}	21.44 ^{fgh}	20.28 ^{ef}	22.50 ^{ghi}
K4	63.33 ^{b}	88.67 ^{de}	91.33 ^{e}	93.00 ^{e}	K4	17.11 ^{b}	21.44 ^{fgh}	22.74 ^{hi}	23.49 ^{i}

Notes: Mean values followed by different superscripts in the same parameter are significantly different at the 5% DMRT.

This study examined the effects of Moringa leaf extract and post-ripening periods on the physiological quality of Ciherang rice seeds. The research revealed significant variations in seed quality parameters across different treatments. Moisture content ranged from 13.10% to 13.57%, reflecting the seeds' hygroscopic nature (Murniati *et al*., 2017; Widajati *et al*., 2012). The lowest electrical conductivity (6.82 - 7.16 µS/g) was observed in treatments K4P1, K3P1, K4P2, and K2P1, indicating good cell membrane integrity. This was attributed to the relatively short post-ripening periods (2, 4, 6, and 8 weeks), which maintained membrane integrity. Conversely, higher conductivity (8.45 - 8.65 µS/g) in K1P4 and K1P1 treatments suggested potential membrane damage.

Maximum seed growth potential showed impressive results, with several treatments (K1P3, K3P4, K1P4, K4P4, K3P3, K4P3, K2P3, K2P4, K2P2, K3P2, K4P2) achieving 95.00 - 99.00%. The lowest potential (68.67%) was found in the K1P1 treatment. This enhancement was attributed to the vitamins and growth regulators in Moringa leaf extract, aligning with findings on Moringa's potential to increase seed viability (Rehman *et al*., 2017). Maximum growth potential as the percentage of seeds showing life symptoms, including both normal and abnormal sprouts (Tikafebrianti *et al*., 2019).

Seed germination rates were notably high in treatments K1P3, K3P4, K4P4, K2P4, K4P3, K3P3, K2P2, K2P3, K3P2, and K4P2, ranging from 92.00% to 97.67%. The lowest germination (65.33%) was observed in K1P1. These results corroborate research, which reported an 85% germination rate using 50% Moringa leaf extract on upland rice (Ferdiansyah *et al*., 2024). Similarly, soaking corn seeds in Moringa leaf extract for 12 hours yielded a 90.93% germination rate (Indriaty *et al*., 2022). The seed vigor index, crucial for field performance, was highest (87.00 - 94.33%) in treatments K1P4, K3P3, K3P2, K4P2, K4P3, K3P4, K2P2, K4P4, K2P4, and K2P3. The lowest index (14.00%) was in K1P1. Vigor reflects seed growth strength in field conditions. The improved vigor index was attributed to the nutrient-rich Moringa leaf extract enhancing seed food reserves (Murniati *et al*., 2017).

Seed growth speed, a measure of growth strength (Widajati *et al*., 2017), was highest (20.28 - 23.49 %KN/etmal) in treatments K2P3, K3P4, K2P2, K4P3, K4P4, and K2P4. The lowest speed (10.61 %KN/etmal) was in K1P1. These findings align that 2.36%/etmal germination speed using 50% Moringa leaf extract (Kadir *et al*., 2022), and 3.79%/etmal speed with 12-hour Moringa extract soaking (Indriaty *et al*., 2022). Overall, the study demonstrates that Moringa leaf extract treatment significantly enhances various physiological quality parameters of Ciherang rice seeds, particularly when combined with appropriate post-ripening periods. These findings suggest the potential of Moringa leaf extract as a natural biostimulant for improving rice seed quality.

3.2.2. Effect of Treatments on the Chemical Content of Seeds

Table 5 shows that the parameters of starch and reducing sugar content in the combined analysis of variance showed significantly different results in the treatment of moringa leaf extract solution concentration (K) and post-ripening period (P). The interaction between the two treatments (K × P) significantly affected the starch content parameter, while the reducing sugar content parameter was not significantly different. This shows that the soaking treatment with moringa leaf extract solution in various concentrations, and the post-ripening period treatment strongly affect the starch content and reducing sugar in the seeds, while the interaction between the two treatments only affects the starch content but does not affect the reducing sugar content. Table 5 shows that in the treatment period post-ripening (P) tends to increase the content of starch, reducing sugar, auxin, cytokinin, gibberellin and abscisic acid, while in the same treatment period (P) the concentration of moringa leaf extract solution (K) tends to increase the content of starch, reducing sugar, auxin, cytokinin, gibberellin and abscisic acid, but in the period of 8 WAH (P4) tends to decrease.

Table 4. Average values of starch content, reducing sugar, auxin, cytokinin, gibberellin and abscisic acid in each treatment of moringa leaf extract solution concentration (K) at each post-ripening period (P)

Concentration (K)	Post-ripening Period (P) P1	P2	P3	P4	Concentration (K)	Post-ripening Period (P) P1	P2	P3	P4
		Starch					**Reduction Sugar**		
K1	56.93 ^{a}	60.01 ^{d}	60.11 ^{d}	60.20 ^{de}	K1	0.21	0.23	0.24	0.23
K2	58.31 ^{b}	60.23 ^{de}	61.18 ^{gh}	60.30 ^{de}	K2	0.25	0.29	0.31	0.25
K3	58.95 ^{c}	60.29 ^{de}	61.24 ^{h}	60.56 ^{ef}	K3	0.27	0.26	0.30	0.27
K4	58.78 ^{c}	59.95 ^{d}	61.26 ^{h}	60.86 ^{fg}	K4	0.28	0.29	0.35	0.30
		Auxin					**Cytokinin**		
K1	1.52 ^{a}	1.68 ^{bc}	1.72 ^{cd}	1.78 ^{ef}	K1	1.68 ^{a}	1.89 ^{bc}	1.91 ^{bc}	2.05 ^{cde}
K2	1.65 ^{b}	1.78 ^{ef}	1.79 ^{ef}	1.82 ^{fg}	K2	1.80 ^{ab}	2.14 ^{de}	2.23 ^{ef}	2.10 ^{de}
K3	1.72 ^{cd}	1.82 ^{fg}	1.85 ^{g}	1.85 ^{g}	K3	1.99 ^{cd}	2.39 ^{fg}	2.40 ^{fg}	2.15 ^{de}
K4	1.75 ^{de}	1.78 ^{ef}	1.86 ^{g}	1.87 ^{g}	K4	2.10 ^{de}	2.04 ^{cde}	2.43 ^{g}	2.17 ^{de}
		Gibberellin					**Abscisic Acid**		
K1	2.08 ^{ab}	2.22 def	2.06 ^{a}	2.11 ^{abc}	K1	1.22 ^{b}	1.08 ^{a}	1.32 ^{c}	1.42 ^{de}
K2	2.28 ^{efg}	2.40 hi	2.11 ^{ab}	2.15 ^{bcd}	K2	1.32 ^{c}	1.40 ^{cd}	1.42 ^{de}	1.48 ^{defg}
K3	2.33 ^{gh}	2.53 j	2.22 ^{def}	2.20 ^{cde}	K3	1.42 ^{de}	1.49 ^{efg}	1.49 ^{efg}	1.42 ^{de}
K4	2.45 ^{i}	2.53 j	2.30 ^{fg}	2.21 ^{de}	K4	1.43 ^{def}	1.52 ^{fg}	1.56 ^{g}	1.51 ^{efg}

Notes: Mean values followed by different superscripts in the same parameter are significantly different at the 5% DMRT.

The highest starch content was found in the K2P3, K3P3 and K4P3 treatments with a range of values of 61.18 - 61.26%, while the lowest seed starch content was found in the K1P1 treatment with a value of 56.93% (Table 4). The highest reducing sugar content was found in the K4P3 treatment with a value of 0.35%, while the lowest reducing sugar content was found in the K1P1 treatment with a value of 0.21% (Table 5). The difference in the content of starch and reducing sugar in the seeds is thought to be due to the observation period P1-P3 is a period of early germination process where the seeds will imbibe water and nutrients as food reserves that will be used as energy for germination, while the observation period P4 seeds have entered the phase of enzyme reactivation and increased respiration that breaks down existing food reserves to produce energy that will be used for sprout growth. At the beginning of germination, the roots will begin to grow and absorb water and carbon sources in the soil so that during germination they can increase the total content of carbohydrate compounds (Gumelar & Fariyanto, 2020). In the advanced germination stage, the process of enzymatically breaking down food candles occurs to produce energy used for sprout growth until the sprouts are normal (Murniati *et al*., 2017).

This study examined the effects of Moringa leaf extract on hormone content in Ciherang rice seeds during different post-ripening periods. The highest auxin content (1.82-1.87 mg/g) was observed in treatments K2P4, K3P2, K3P3, K3P4, K4P3, and K4P4, while the lowest (1.52 mg/g) was in K1P1. Cytokinine levels peaked (2.39-2.43 mg/g) in K3P2, K3P3, and K4P3 treatments, with K1P1 showing the lowest (1.68 mg/g). Gibberellin content was highest (2.53 mg/g) in K3P2 and K4P2, and lowest (2.06-2.11 mg/g) in K1P3, K1P1, K1P4, and K2P3. Abscisic acid levels were highest (1.48-1.56 mg/g) in K2P4, K3P2, K3P3, K4P4, K4P2, and K4P3, and lowest (1.08 mg/g) in K1P2. The Moringa leaf extract treatment increased hormone content during P1-P3 observation periods but decreased in P4. This pattern is attributed to the early germination process (P1-P3), where seeds actively absorb water and nutrients, accelerating hormone uptake. The P4 period marks the enzyme reactivation and increased respiration phase, breaking down food reserves for sprout growth (Suparto *et al*., 2019). These phytohormones play crucial roles in seed germination. For example, auxin promotes cell division and elongation (Tetuko *et al*., 2015), cytokinin stimulates growth and breaks dormancy (Hidayati, 2014), gibberellin activates α-amylase and reduces abscisic acid activity (Gumelar & Fariyanto, 2020; Tikafebrianti *et al*., 2019), while abscisic acid regulates seed dormancy (Rosdiana & Maharany, 2020). The study highlights the potential of Moringa leaf extract in modulating hormone levels to enhance seed germination and vigor.

3.2.3. Effect of Treatments on Vegetative Growth

The parameters observed in the vegetative phase were plant height and number of tillers. The combined analysis of variance on the parameters of plant height and number of tillers showed results that were not significantly different in the treatment of moringa leaf extract solution concentration (K), post-ripening period (P), and the interaction between the two treatments (K × P) (Table 2). The effect of K × P interaction parameters of plant height and number of tillers can be seen in Table 5.

Table 5. Effect of concentration (K) of moringa leaf extract solution and post-ripening period (P) on the plant height and number of leaves of rice plant.

Concentration (K)	Post-ripening Period (P)				Concentration (K)	Post-ripening Period (P)			
	P1	P2	P3	P4		P1	P2	P3	P4
	Plant height (cm)					Number of tillers			
K1	54.67 ^{a}	54.67 ^{d}	54.33 ^{d}	52.00 ^{de}	K1	6.00	6.33	6.00	5.33
K2	54.00 ^{b}	55.67 ^{de}	53.00 ^{gh}	54.00 ^{de}	K2	6.00	5.67	6.33	6.00
K3	53.67 ^{c}	53.67 ^{de}	54.00 ^{h}	53.00 ^{ef}	K3	5.33	5.33	5.33	5.33
K4	54.00 ^{c}	53.33 ^{d}	52.00 ^{h}	52.67 ^{fg}	K4	5.67	6.33	5.33	5.33

The lowest average plant height in the K1P4 and K4P3 treatments was 52.00 cm, while the highest average in the K2P2 treatment was 55.67 cm (Table 5). The number of tillers with the lowest average in the K1P4, K3P1, K3P2, K3P3, K3P4, and K4P4 treatments was 5.33 stems, while the highest average in the K1P2, K2P3 and K4P2 treatments was 6.33 stems. Plant height characters are strongly influenced by genetic and environmental factors. The results of the research on plant height parameters were not significantly different for all treatments, presumably because the planting was carried out in polybags and in a screen house, thus creating the same and more controlled environmental conditions. Differences in the number of tillers that occur can be due to genetic or environmental factors such as rainfall, cultivation techniques, plant spacing, and nutrient availability (Yulina *et al*., 2021). The results of the research parameter of the number of tillers were not significantly different for all treatments because the planting was carried out in polybags and in a screen house, thus creating the same and more controlled environmental conditions.

4. CONCLUSION

This research produced some important conclusions regarding the effect of moringa leaf extract concentration and post-ripening period on the quality of Ciherang rice seeds. Moringa leaf extract concentration of 60% proved optimal for increasing electrical conductivity, maximum growth potential, germination, biochemical content (starch, reducing sugar, growth hormone), and number of tillers. Meanwhile, 20% concentration gave the best results for vigor index, growth speed, and plant height. The most effective post-ripening period was the 4th and 6th week after harvest. The best treatment interaction was found in the combination of 60% and 20% moringa leaf extract concentrations with post-ripening periods of the 4th and 6th weeks after harvest. These findings indicate that the use of moringa leaf extract with the right concentration and post-ripening period can significantly improve the physiological quality of Ciherang rice seeds. In summary, the application of Moringa leaf extract during the post-ripening period of Ciherang variety rice seeds holds promise for enhancing their physiological quality. By leveraging the beneficial properties of Moringa, it may be possible to improve germination rates, seedling vigor, and overall crop resilience, thereby contributing to sustainable agricultural practices and food security. Future research should focus on optimizing the concentration and application methods of Moringa extract to maximize its beneficial effects on rice seed quality.

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