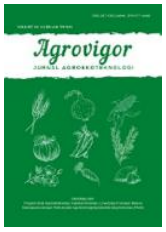
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Article

Invigoration of Expired Local Rice Seeds with Organic Priming Treatment of Noni Fruit Extract and Soaking Period

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ABSTRACT

Rice is the primary staple food for most of the Indonesian population. Seed deterioration during storage reduces germination ability and threatens rice production. Seed invigoration through priming can restore seed quality by activating pre-germinative metabolism before radicle emergence. This study aimed to determine the best combination of organic priming using noni fruit extract and soaking period on the invigoration of expired local rice seeds. The research used a Completely Randomized Design (CRD) factorial experiment with a separate control was used, comprising 12 treatment combinations each repeated three times (39 experimental units). The first factor was the concentration of noni fruit extract (M) with four levels (0%, 1.5%, 3%, and 4.5%), and the second factor was the soaking period with three levels (12, 24, and 48 hours). Seeds were germinated using the UKDdp method with 50 seeds per roll. Organic priming with noni fruit extract combined with a soaking period significantly improved all measured germination parameters, including maximum growth potential, simultaneity of growth, germination capacity, vigor index, and growth speed of the deteriorated local rice seeds (variety Buyung Banjar). The best treatment combination was 4.5% noni fruit extract with a 24-hour soaking period (M_3T_2), which increased germination capacity by 1.6-fold and vigor index by 2.13-fold compared to the untreated control.

INTRODUCTION

Rice is a popular food crop because it is the main food for many of the world's population (Anggraini et al., 2013). In Indonesia, rice is the main commodity to support people's food. Rice is a food crop that is consumed by approximately 90% of the entire Indonesian population as a staple food. As a country with a large population, Indonesia faces challenges in meeting the population's food needs, so rice becomes a crop that has high prospects (Anggraini et al., 2013). As a staple food, rice is difficult to replace by other staple foods, so the existence of rice is the main priority for society in meeting the need for carbohydrate intake which can be filling and is the main source of carbohydrates which are easily converted into energy. The nutritional value composition per 100 grams of rice is 360 kcal of energy, 6.6 grams of protein, 0.58 grams of fat, and 79.34 grams of carbohydrates (Suliartini et al., 2011). However, there was a decline in rice production in South Kalimantan from 2020 to 2022. Based on data from the Central Statistics Agency (2022), it was explained that rice production in 2020 was 1,150,306 tons, while in 2021 and 2022, it experienced decreased to 1,016,313 tons and 819,419 tons respectively. One of the factors causing the decline in rice production is because the available seeds still have deficiencies in terms of quality, resulting in a lack of availability of high quality seeds.

High quality seeds are an important factor in increasing rice production because the use of quality seeds can increase production yield by 15% compared to using low quality seeds (Santoso et al., 2005). The higher the quality of the seeds used, the better the plants produced can grow and will increase plant productivity (Oktaviana et al., 2016). As the starting material for plant propagation, seeds should have high physical, genetic, and physiological quality, so that the resulting plants have high production capacity, especially for local variety seeds (Siyum et al., 2022).

Local rice seeds of the Buyung variety originating from South Kalimantan are still popular with farmers because of their good adaptive ability and good taste, but there are drawbacks, namely the potential for low yields of around 2 tonnes of milled dry grain/ha (Malik, 2017). For planting local varieties of rice, farmers tend to use seeds that come from the previous year's rice harvest which has undergone a long storage process. Thus, as long as the storage stage lasts for a long duration until past its shelf life, the seeds have the potential to experience deterioration or decrease in seed quality. This is an obstacle in providing high quality seeds (Ernawati et al., 2017). Deterioration will cause a low ability of seeds to germinate and can result in non-uniformity of seeds which has the potential to reduce production yields. In addition, long storage can cause seed deterioration (Wulandari & Setiono, 2022).

Seed deterioration is a process that occurs when seed quality decreases due to physiological changes, causing changes in the seed in physical, physiological, and biochemical terms which cause a decrease in seed viability and vigor which correlates with seed deterioration (Finch-Savage & Bassel, 2016). According to Ali et al. (2003), seed deterioration can occur when seeds are in storage. The rate of seed deterioration is influenced by environmental conditions, temperature, and humidity (RH). In addition, seed deterioration or decrease in seed quality may also occur due to free radicals, which are correlated with alteration in cellular metabolism and chemical that adversely affect seed perfomance (Mahjabin & Abidi, 2015). The process of seed deterioration can not be prevented and is irreversible or cannot be completely repaired (Raganatha et al., 2014).

Seed deterioration can be suppressed by one method, namely seed invigoration using the priming technique. According to Purnawati et al. (2014), priming treatment is effective in seed invigoration. Priming is carried out to increase the viability of seeds by hydrating them before the seeds are germinated, with the aim of ensuring that the water potential of the seeds reaches balance to activate metabolic activities so that the seeds are ready to germinate and can start the germination process more quickly (Rouhi et al., 2011). Priming seeds makes the germination process faster and more uniform than seeds without priming treatment (Dawood, 2018). Priming can use organic material extracts, called organic priming, which can come from fruit extracts (Ramadhani et al., 2018). One fruit that can be used for organic priming is noni fruit.

Organic priming of noni fruit contains ascorbic acid, which is a source of antioxidants (Ardiansyah et al., 2014). In addition, noni fruit also contains phenolic compounds, according to Andarwulan et al. (1999), who said that noni fruit contains phenolic compounds as antioxidants which can inhibit the formation of free radicals, resulting in a decrease in seed quality. Noni fruit was identified as containing gibberellin from terpenoid compounds

(Levand & Larson, 1979). Gibberellin, which is classified as a terpenoid compound, can play a role in regulating growth as a plant hormone. As a growth regulator, gibberellin can increase the rate of seed germination because it can break seed dormancy (Vaistij et al., 2013). The research results of Saputra et al. (2023) said that the use of noni fruit extract priming with soaking for 2 hours can increase the viability of expired red chili seeds.

The purpose of soaking for a long time is to give the seeds the opportunity to absorb water, thus triggering germination in the seeds. Different soaking durations are aimed at identifying the right time to increase the germination capacity of the seeds (Nurshanti as cited in Mubarok et al., 2021). However, the duration of soaking has certain limits. If it is too long, it can reduce the germination rate, as respiration is hampered due to the seeds being too saturated (Djamhuri & Hasmaliah, 2014). Based on the research by Saputra et al. (2023), using noni fruit extract priming on chili seeds at a concentration of 20% with a soaking time of 2 hours can increase the simultaneous growth to 70.67%, germination capacity to 81.33%, and seed vigor to 61.33% and also decrease yield when concentration and soaking time are increased. The research results of Afdharani et al. (2020) explained that rice seeds soaked in coconut water with a soaking time of 24 hours produced a growth rate of 49.33%, higher than the soaking time of 48 hours which only produced 38.00%. The choice of concentration is related to the duration of soaking. If the duration of soaking is excessive, even though the concentration given is correct, this may cause plant growth to be hampered (Hamzah et al., 2016).

However, the use of noni fruit extract as an organic priming agent combined with different soaking durations for rice seed invigoration has not been previously reported. The only related study by (Saputra et al., 2023) applied noni fruit extract to red chili seeds using a blender-based extraction method and soaking durations of 2, 4, and 6 hours. The present study differs in several important aspects. First, it applies noni fruit extract to evaluates the response of local rice seeds (*Oryza sativa* L. var. Buyung Banjar) rather than chili seeds. Second, the noni fruit extract was prepared through maceration using 96% methanol, which is expected to produce a more concentrated and standardized extract than the blender extraction method. Third, this study systematically investigated three different soaking durations (12, 24, and 48 hours). Therefore, this study provides novel information on the combined effects of noni fruit extract concentration and soaking duration for the invigoration of deteriorated local rice seeds, effectively filling a gap in the literature regarding organic seed priming.

MATERIALS AND METHODS

The research was conducted from May to August 2023, and is located at the FMIPA Analytical Chemistry Research Laboratory, the Integrated Laboratory and the Production Laboratory of the Major of Agroecotechnology, Faculty of Agriculture at Lambung Mangkurat University. The materials used in this research are noni fruits, local rice seeds expired variety of Buyung Banjar, distilled water, steril distilled water, and 96% methanol. The tools used in this research are a digital scale, knife, jerry cans, measuring glass, spatule, oven, grinders, funnel glass, rotary evaporator, tweezers, CD/opaque papers, germinator, clear plastic, flannel cloth, label sticker paper, rubber band, hand sprayers, plastic cups, erlenmeyer glass, handphone, tray, aluminum foil, and stationery.

This research used Completely Randomized Design (CRD) factorial pattern with separate control. The first factor is the concentration of noni fruit extract (M) which consists of 4 levels, namely: M0= concentrations of noni fruit extract 0%, M1= concentrations of noni fruit extract 1.5%, M2= concentrations of noni fruit extract 3%, and M3= concentrations of noni fruit extract 4.5%. The second factor is the soaking period, which consists of three levels: T1= 12 hours, T2= 24 hours, and T3= 48 hours. Thus, obtained 12 combinations of treatments with each treatment repeated three times and one separate control so that there are 39 units of experiment.

The research is conducted by preparing the seeds. The seeds used are local rice seeds varieties of Buyung Banjar with a condition that has expired for 10 months with the initial DB of 77% from UPT BBTPH Banjarbaru City, South Kalimantan. The used seeds are those that have deteriorated but have not experienced physical damage. Seeds were stored at controlled air-conditioned room temperature ≤ 25ºC in an open storage cabinet with plastic clip packaging (*Ziplock*). Seeds are soaked for 1 minute in distilled water to sort the seeds in good condition, namely seeds that are drowned (i.e., have contents, not empty), and after that the seed is dried and the ready seeds have been treated.

In the meantime, floating seeds will be discarded. In this research, each unit of experiment required as many as 50 seeds, with the total number of seeds needed being 1950 local rice seed variety of Buyung Banjar.

Next, the making of noni fruit extract was done by washing fresh and ripe noni fruit using running tap water. Next, it was cut into small pieces and then dried in the oven at 50ºC for 48 hours (Purwantiningsih & Suranindyah, 2014). The dried noni fruit was then ground using a grinder to become powder, then extracted by maceration using 96% methanol, for 3×24 hours (Fakhrudin et al., 2013), stirred for 2–3 minutes (Firdaus et al., 2015). The ratio of powder and solvent used was 1:5; 10g of powder was dissolved in 50 ml of methanol (Jayaraman et al., 2008). A total of 700g of noni fruit powder was put into an erlenmeyer flask, dissolved in 3500 ml of methanol. After the noni fruit extract was obtained, it was filtered using filter paper, then the extract was concentrated using a rotary evaporator at a temperature of 45–50°C with a rotation speed of 50–60rpm (Lebang et al., 2016), until a concentrated extract solution was obtained. The filtrate was then separated into plastic jars and then diluted with distilled water until it became 100 ml with the concentration of each treatment.

Next, for the priming treatment, the seeds were put into plastic cups containing noni fruit extract with concentrations of 0%, 1.5%, 3%, and 4.5%. Then, the seeds were soaked for 12, 24, and 48 hours. Afterwards, the seeds were washed with running tap water and cured using a flannel cloth. The sowing of local rice seeds was carried out using the UKDdP method using CD/opaque paper media. Before use, the CD/opaque paper was first moistened by spraying water until all parts of the paper were wet, using a hand sprayer. After that, the CD/opaque paper was spread out on a flat surface on top of clear plastic with two sheets of CD/opaque paper. Seeds were sown on 50 CD/opaque paper. After all the seeds have been sown and the paper have been rolled up following that, they were tied using a rubber band, then labeled according to the treatment, and then the rolls were placed and arranged standing in the germinator.

The observation parameters in this research include maximum growth potential, simultaneity of growth, germination capacity, vigor index, and growth speed. The observation data was analyzed by analysis of variance (ANOVA) to examine whether there was an effect of treatment on the observed variables. If the results are significantly different, then a 5% DMRT test is used.

RESULTS AND DISCUSSION

Based on the recapitulation of variance analysis results, the effect of invigorating expired local rice seeds with organic priming of noni fruit extract and soaking period significantly increased the yield on all parameters. A recapitulation of analysis results of the various effects of invigorating expired local rice seeds with organic priming of noni fruit extract and soaking period is presented in Table 1.

Table 1. Recapitulation of analysis of variance results of the various effects of invigorating expired local rice seed variety Buyung Banjar with organic priming treatment of noni fruit extract and soaking period.

Source of Variation	Parameter				
	MGP	SoG	GC	VI	GS
Treatment vs Control	**	**	**	**	**
M	**	**	**	**	**
T	**	**	**	**	**
MxT	*	*	**	*	*

Note: *: significant, **: very significant, M: concentration of noni fruit extract, T: soaking period, MGP: maximum growth potential, SoG: simultaneity of growth, GC: Germination capacity, VI: Vigor index, GS: growth speed

The analysis of variance showed that the concentration of noni fruit extract (M) and soaking time (T) each had a highly significant effect on all observed parameters, whereas the interaction between the two factors (M×T) was significant only for some parameters. This is consistent with the findings of Silaen et al. (2024), who reported that the combination of soaking time and sulfuric acid concentration significantly affected some parameters but not others. This pattern suggests that the physiological response of seeds is influenced more strongly by the main effect of each factor than by specific synergies between treatment combinations.

Increasing the concentration of noni fruit extract (M) provides active compounds that support seed metabolism, while soaking time regulates imbibition, enzyme activation, and the mobilization of food reserves during early germination. However, once one factor reaches its optimum level, increasing the other factor does not always produce a proportional response because of the seed's limited absorptive capacity, imbibition saturation, oxygen constraints, and reduced respiratory efficiency. Thus, interactions that are significant only for some parameters indicate that the treatment effects are primarily additive rather than synergistic. In other words, the best combination depends more on how well each factor matches the physiological needs of seeds that have deteriorated during storage. This interpretation is also supported by several seed studies showing that a single factor may significantly affect seed performance without a consistent interaction across all observed parameters (Srilaba et al., 2018; Vijratun et al., 2022).

Maximum Growth Potential

Based on the analysis of variance, the results showed that the organic priming treatment of noni fruit extract and soaking period and single factors had a significant and very significant effect on the maximum growth potential of local rice seeds of the Buyung Banjar variety. The average percentage of maximum growth potential of local rice seeds of the Buyung Banjar variety when given organic priming noni fruit extract and soaking period is presented in Figure 1.

Based on Figure 1, maximum growth potential in the organic priming treatment of local rice seeds of the Buyung Banjar variety with a soaking treatment of 12 hours without giving noni fruit extract (M_0T_1) gave results that were not significantly different from the control (M_0T_0). Treatments M_0T_2, M_0T_3, M_1T_1, M_1T_2, M_1T_3, M_2T_1, M_2T_2, M_2T_3, M_3T_1, and M_3T_3 showed results that were not significantly different from each treatment but produced an increase ranging from 1.3-fold–1.57-fold compared to the control. The most significant difference was shown by the combination treatment of noni fruit extract with a soaking period of 24 hours (M_3T_2) with an of 1.6-fold increase compared to the control.

Maximum growth potential refers to the ability of seeds to grow normally or abnormally under optimum conditions (Harsono et al., 2021). Invigoration of local rice seeds of the Buyung Banjar variety with a combination of organic priming treatment with 4.5% noni fruit extract soaked for 24 hours (M_3T_2) produced the highest maximum growth potential value with a percentage of 94%. There was an increase in the percentage of maximum growth potential of seeds by 45.33% when compared to the control (M_0T_0). This is thought to be due to the gibberellin hormone contained in noni fruit extract which plays a role in the seed growth process, namely accelerating the process of seed germination. Seeds soaked in gibberellin can make the seed coat softer and more permeable, thus making it easier to pass water and oxygen and as a result, the substances contained in the extract solution enter more quickly (Farida, 2017), thereby triggering the development of cells in the seeds, so that the seeds germinate more quickly, and increased germination is in line with the increase in seed growth potential (Adnan & Zaini, 2017). According to Dawood (2018), these results illustrate the fundamental principle of seed priming wherein controlled hydration activates pre-germination metabolism and brings seed water potential to the level required to initiate metabolic activity before radicle emergence. Furthermore, the bioactive compounds present in noni fruit extract soften the seed coat, facilitating faster and more uniform water uptake. Consequently, primed seeds achieve greater physiological readiness for germination compared to untreated seed. The higher the concentration of noni fruit extract given, the higher the percentage of maximum growth potential of the seeds. If the concentration is increased, more hormones will be contained, thereby increasing the number of seeds that germinate. This is in accordance with the research by Putra et al. (2022) which explained that the more the

concentration of extract used increases, the more sprouts will grow, both normal and abnormal.

A combination of giving noni fruit extract with long soaking treatment can speed up the seed germination process in accordance with the statement of Bajang et al. (2015) which explained that the seed germination process can be accelerated by increasing the seed soaking time. The more the soaking time increases, the more water will enter the seed endosperm, thus making the imbibition process runs optimally. However, too long of a soaking time can result in seed damage or seed rot, which may reduce the maximum growth potential of the seed. Soaking for too long causes oxygen loss or anoxia, thereby limiting the respiration process and inhibiting germination (Yuanasari et al., 2015). Previous research was conducted by Afdharani et al. (2020) regarding the effect of KNO_3 invigoration material and soaking time on expired rice (*Oryza sativa* L.) seeds with soaking duration levels of 12, 24, and 48 hours on the parameters of maximum growth potential. The highest yield was found at 24 hours soaking time and there was a decrease in yield at 48 hours soaking, which was thought to occur because the seeds have lost oxygen, thereby inhibiting germination.

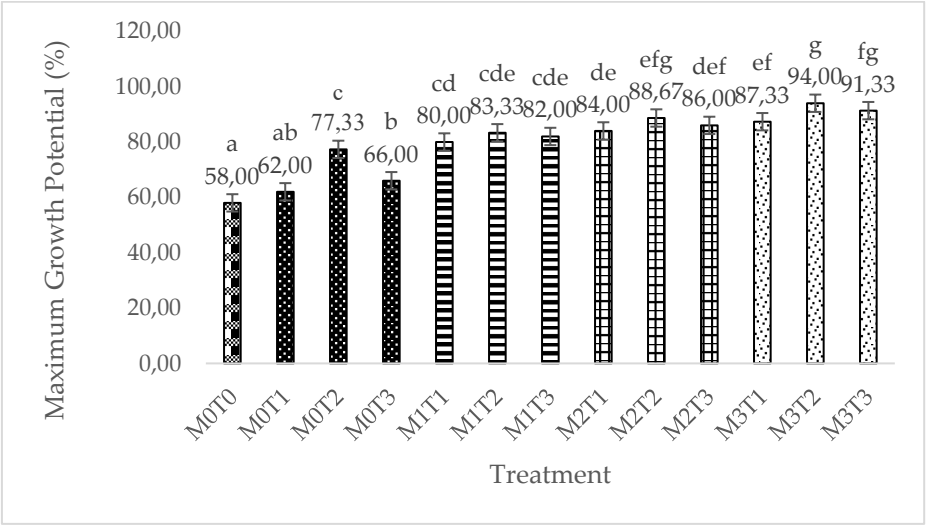


Figure 1. Average Percentage of Maximum Growth Potential of Local Rice Seeds of the Buyung Banjar Variety.
Note: M_0= concentration 0%; M_1= concentration 1.5%; M_2= concentration 3%; M_3= concentration 4.5%. T_0= 0 hour; T_1= 12 hours; T_2= 24 hours; T_3= 48 hours. Numbers accompanied by the same letters in the mean values are not significantly different on the *Duncan's Multiple Range Test* (DMRT) test at the 5% level.

Simultaneity of Growth

Based on the analysis of variance, the results showed that the organic priming treatment of noni fruit extract and soaking period and single factors had a significant and very significant effect on the simultaneity of growth of local rice seeds of the Buyung Banjar variety. The average percentage of simultaneity of growth of local rice seeds of the Buyung Banjar variety when given organic priming noni fruit extract and soaking period is presented in Figure 2.

Based on Figure 2, simultaneity of growth in the organic priming treatment of local rice seeds of the Buyung Banjar variety only with a soaking treatment without giving noni fruit extract nor treatment with combination soaking period and noni fruit extract gave results that were significantly different from the control (M0T0). Treatments M0T1, M0T2, M0T3, M1T1, M1T2, M1T3, M2T1, M2T2, M2T3, M3T1, and M3T3 showed results that were not significantly different from each treatment but produced an increase ranging from 1.15-fold–1.77-fold compared to the control. The most significant difference was shown by the combination treatment of noni fruit extract with a soaking period of

24 hours (M3T2) with an increase of 1.77-fold compared to the control.

Simultaneity of seed growth is the percentage of normally strong sprouts calculated at a certain germination time. For rice seeds, the calculation of growth simultaneity is carried out on the 6th day after planting (Tefa, 2017). Based on Lesilolo et al. (2012), the growth simultaneity value for good seeds is in the range ≥ 40–70%, with a growth simultaneity value ≤ 40% indicating that the seed vigor is not high enough and a growth simultaneity value ≥ 70% indicating that the seed vigor is very high.

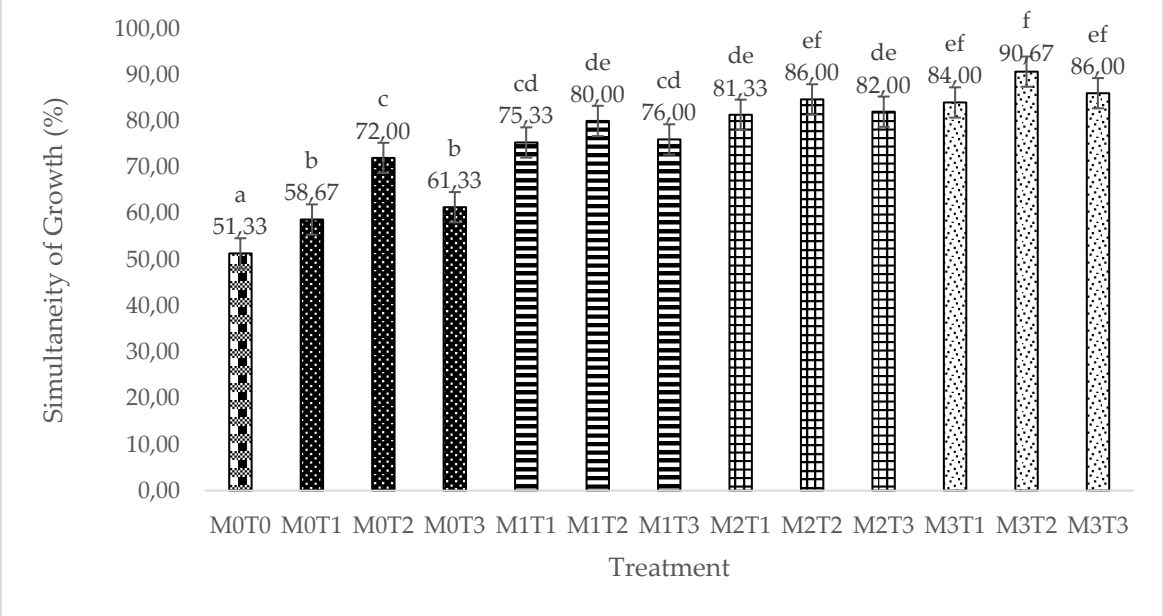


Figure 2. Average Percentage of Simultaneity of Growth of Local Rice Seeds of the Buyung Banjar Variety.

Note: M_0= concentration 0%; M_1= concentration 1.5%; M_2= concentration 3%; M_3= concentration 4.5%. T_0= 0 hour; T_1= 12 hours; T_2= 24 hours; T_3= 48 hours. Numbers accompanied by the same letters in the mean values are not significantly different on the Duncan's Multiple Range Test (DMRT) test at the 5% level.

However, the single factor of soaking time and the combination of noni extract priming treatment with soaking time may increase the value of simultaneous seed growth. Noni fruit extract contains ascorbic acid which acts as an antioxidant and has a role in warding off free radicals which can inhibit metabolic processes and seed structure. Therefore, rice seeds can grow uniformly, thereby increasing the value of simultaneous seed growth (Ardiansyah et al., 2014). The 1.77-fold enhancement in growth simultaneity attained through the M_3T_2 treatment clearly demonstrates the effectiveness of seed priming. The fundamental principle of priming is to facilitate simultaneous attainment of uniform physiological readiness across the entire seed population, thereby ensuring homogeneous crop establishment. This synchronization is achieved through the imbibition phase, where optimal soaking duration allows uniform absorption of organic priming solution and synchronized progression to the same metabolic stage. These results corroborate Dawood (2018), who demonstrated that priming treatments specifically target and improve seed germination uniformity. A certain soaking time can have an influence on the simultaneous growth of seeds because the right soaking time can stimulate the imbibition process, namely the stage of absorption of water and dissolved substances contained in a material that will be absorbed into the seed (Saputra et al., 2023). The noni fruit extract solution that enters the seeds has the function of forming enzymes and triggering the enzymes that are already in the seeds (Fatikhasari et al., 2022), thus with the right soaking time the seeds can perfect the metabolic process and can facilitate the activity of enzymes so that they can increase the germination process and produce strong seeds (Arthawijaya et al., 2022). The rapid and simultaneous

growth of normal sprouts cannot be separated from the involvement of the imbibition process. With imbibition running smoothly, the metabolic process of the seeds can also run smoothly because the water needs for the seeds can be met (Juhanda et al., 2013).

Germination Capacity

Based on the analysis of variance, the results showed that the organic priming treatment of noni fruit extract and soaking period and single factors had very significant effect on the germination capacity of local rice seeds of the Buyung Banjar variety. The average percentage of germination capacity of local rice seeds of the Buyung Banjar variety when given organic priming noni fruit extract and soaking period is presented in Figure 3.

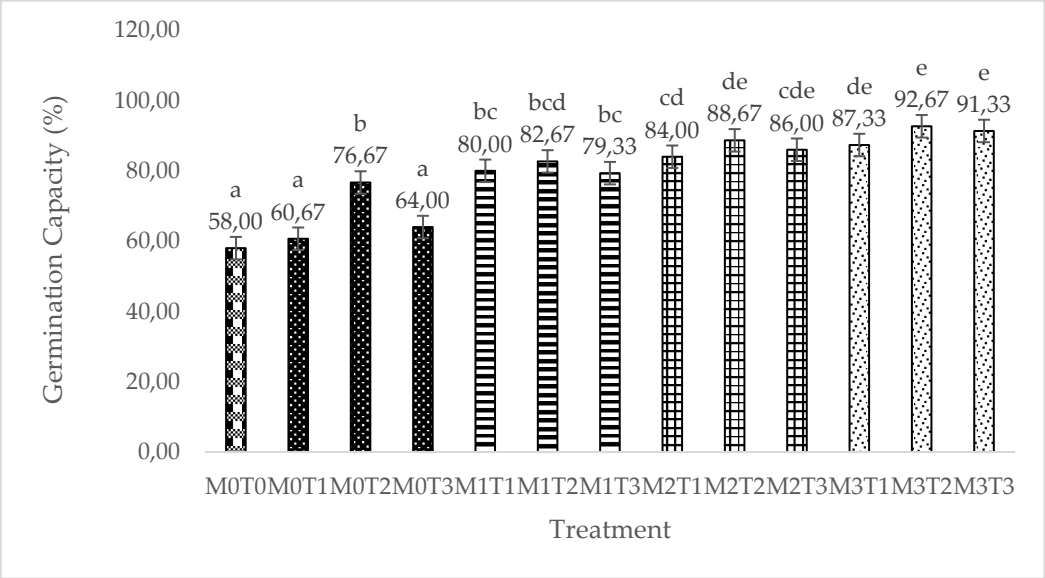


Figure 3. Average Percentage of Germination Capacity of Local Rice Seeds of the Buyung Banjar Variety
Note: M_0= concentration 0%; M_1= concentration 1.5%; M_2= concentration 3%; M_3= concentration 4.5%. T_0= 0 hour; T_1= 12 hours; T_2= 24 hours; T_3= 48 hours. Numbers accompanied by the same letters in the mean values are not significantly different on the *Duncan's Multiple Range Test* (DMRT) test at the 5% level.

Based on Figure 3, germination capacity in the organic priming treatment of local rice seeds of the Buyung Banjar variety on control (M_0T_0) were not significantly different from the soaking period of 12 hours (M_0T_1) and 48 hours (M_0T_3) treatment but it is significantly different from other treatments. Treatments M_0T_2, M_1T_1, M_1T_2, M_1T_3, M_2T_1, M_2T_2, M_2T_3, M_3T_1, and M_3T_3 showed results that were not significantly different from each treatment but produced an increase ranging from 1.3–1.6x compared to the control. The most significant difference was shown by the combination treatment of noni fruit extract with a soaking period of 24 hours (M_3T_2) with an increase of 1.6x compared to the control.

Germination refers to the process of emergence and development of important structures from the seed embryo, and the sprout indicates the capability to grow into a normal plant under optimum or supportive environmental conditions (Sopian et al., 2021). Based on Ministry of Agriculture of the Republic of Indonesia 2020 concerning technical instructions for food crop seed certification, the minimum germination percentage for seeds to pass certified seed testing is 80%.

Based on Figure 3, it can be seen that the control and single factor treatment of soaking time have not met the minimum value for germination according to Ministry of Agriculture of the Republic of Indonesia 2020, while the combination of treatment for long soaking with noni fruit extract priming has met the minimum value for germination according to Ministry of Agriculture of the Republic of Indonesia 2020 standards. This happened because priming with a noni fruit extract solution can encourage an increase in seed

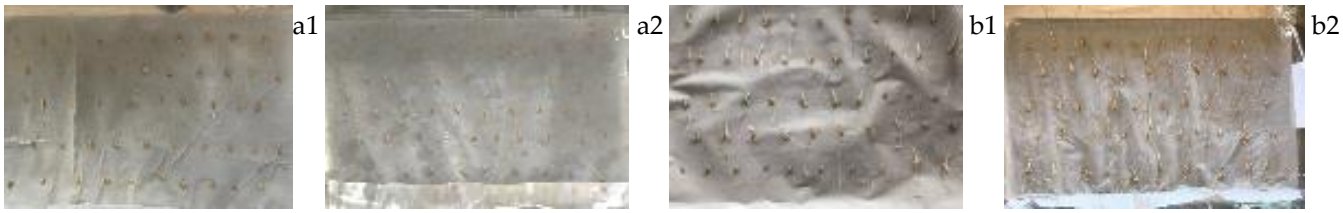


Figure 4. Germination Capacity Results of Local Rice Seeds with Organic Priming Treatment of Noni Fruit Extract and Soaking Period, a1. M_0T_0 (control) 5 HSP, a2. M_0T_0 (control) 7 HSP, b. M_3T_2 5 HSP, b2. M_3T_2 7 HSP.

germination. According to Taiz & Zieger (in Bajafitri & Barunawati, 2018), gibberellins may play a role in stimulating active hydrolytic enzymes and work faster, especially α-amylase, which then enters the endosperm of the seeds and then hydrolyzes starch as a food source, and so the seeds have enough energy so that the seed growth process takes place more quickly and produces normal sprouts (Mitropi in Maryani & Irfandi, 2008). Imbibition has an important role in the germination of a seed. The greater the amount of water absorbed by the seed, the more it encourages the acceleration of enzymatic reactions in the process of breaking down the food reserves contained in the seed so that the germination process can take place. Gibberellin regulates the synthesis of hydrolytic enzymes during seed germination. It also enhances embryonic growth potential and can overcome mechanical barriers to germination imposed by the seed coat, thereby maximizing the seed's absorption of the noni fruit extract (Kucera et al., 2005).

Based on Figure 3, the data presented has a tendency, namely an increase in seed germination results as the concentration level was increased. This is shown in Figure 4. It can be seen that there is a difference in the germination results of expired local rice seeds of the Buyung Banjar variety between those treated with a combination of organic priming noni fruit extract and soaking time and those without treatment (control). The higher the concentration of the extract given, the higher the hormone levels that will be available, thereby contributing to increasing seed germination. The use of higher extract concentrations may increase the germination capacity of seeds (Ridha et al., 2017), but concentrations above a certain limit can cause a decrease in the germination process (Melyani & Sujarwati, 2021). In accordance with Wiraatmaja's opinion (in Sari et al., 2021), if the concentration used is correct and appropriate, it can be effective in speeding up the germination process, but if it is too high, it has the potential to inhibit germination because it can become an inhibitor. According to Susanto (2002), the application of organic materials should be adjusted to the needs of the plants. Organic materials given in excessive concentrations may have bad effects, namely being toxic to plants and inefficient, while those given in concentrations that are too low do not produce significant effects on plant yields. Low concentrations may result in imbibition of seeds that exceed their optimal limits or are excessive (Lewar et al., 2023).

The average percentage of germination capacity of Buyung Banjar rice seeds soaked with noni fruit extract for 24 hours was not statistically different (DMRT test) with 48 hour soaking, but the resulting percentage decreased compared to 24 hour soaking. This could be due to inhibited seed germination as the seeds have lost oxygen. Excessive water can hinder seed respiration, creating anaerobic conditions that inhibit germination (Kusuma et al., 2020). When seeds imbibe too much water, they will lose space to contain oxygen, which ultimately inhibits the respiration process. The duration of seed soaking, whether too long or too short, has practical limits, since inappropriate soaking can cause damage to seeds (Pratamawati et al., 2025). However, a soaking time that is too short also has problems, namely that the water entering the seeds is not optimal (Afdharani et al., 2020), thus the results of 12 hour soaking have an average value of the percentage of seed germination that is still below standard compared to the results of 24 and 48 hours of soaking.

Soaking seeds for too long may reduce the quality of the seeds. Excessive soaking time may have a bad effect, namely making the seeds damaged and rotten. Soaking seeds for too long may cause them to become waterlogged and start to rot. This happens because the seed coat becomes too permeable, therefore allowing microorganisms and water to seep into the seed, causing damage and rot due to fungus (Bajang et al.,

2015). Based on the research results of Sudarwati et al. (2022), *Indigofera arrecta* seeds that are soaked for more than 3 hours cause a decrease in seed quality because the seed coat becomes torn more easily, so the seeds are more easily at risk of being infected by fungus. Priming with a combination of noni fruit extract and soaking time has the effect of increasing the average percentage of germination value. Choosing the right soaking time can maximize the germination process and maintain seed quality. These findings underscore that seed invigoration through organic priming requires a precise balance. A 24-hour soaking period represents the optimal priming window, during which bioactive compounds from noni extract are sufficiently absorbed to stimulate germination without exceeding the seed's physiological limits. Beyond this optimal window, the benefits of seed invigoration are reversed due to anoxia (Afdharani et al., 2020; Lubis et al., 2018). Prolonged seed soaking can induce oxygen deficiency, thereby disrupting physiological processes and the accumulation of metabolites. According to Corbineau (2022), oxygen is a critical factor in seed germination because it facilitates the resumption of respiration and the reactivation of metabolism during imbibition; this ultimately leads to the production of reducing power and ATP. Consistent with these findings, Siahaan et al. (2025) found that a 24-hour seed soaking duration optimized germination compared to 48 hours, confirming that excessive soaking durations inhibit germination by restricting oxygen availability

Vigor Index

Based on the analysis of variance, the results showed that the organic priming treatment of noni fruit extract and soaking period and single factors had a significant and very significant effect on the vigor index of local rice seeds of the Buyung Banjar variety. The average percentage of vigor index of local rice seeds of the Buyung Banjar variety when given organic priming noni fruit extract and soaking period is presented in Figure 5

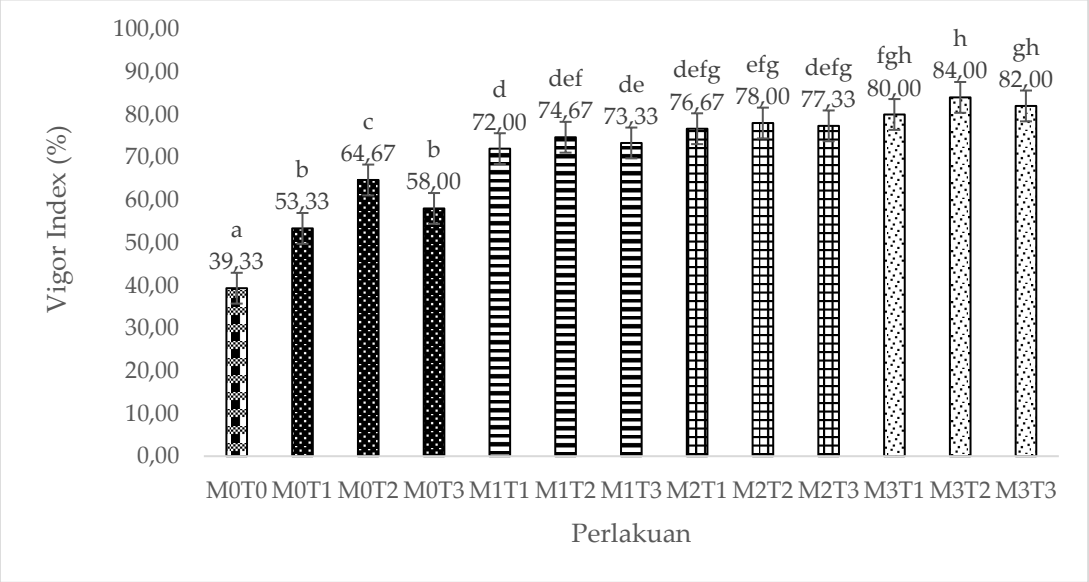


Figure 5. Average Percentage of Vigor Index of Local Rice Seeds of the Buyung Banjar Variety

Note: M_0= concentration 0%; M_1= concentration 1.5%; M_2= concentration 3%; M_3= concentration 4.5%. T_0= 0 hour; T_1= 12 hours; T_2= 24 hours; T_3= 48 hours. Numbers accompanied by the same letters in the mean values are not significantly different on the *Duncan's Multiple Range Test* (DMRT) test at the 5% level.

Based on Figure 5, vigor index in the organic priming treatment of local rice seeds of the Buyung Banjar variety only in all treatments was significantly different from the control (M_0T_0). However, treatments M_1T_1, M_1T_2, M_1T_3, M_2T_1, M_2T_2, M_2T_3, M_3T_1, and M_3T_3 showed results that were not significantly different

from each treatment but produced an increase ranging from 1.84–2.13-fold compared to the control. The most significant difference was shown by the combination treatment of noni fruit extract with a soaking period of 24 hours (M_3T_2) with an increase of 2.13-fold compared to the control.

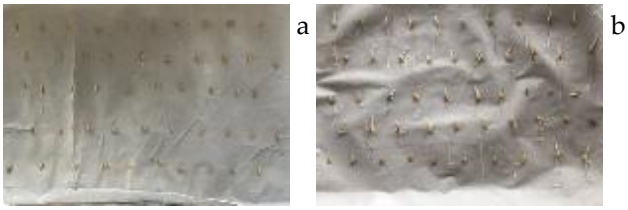


Figure 6. Vigor Index Results of Local Rice Seeds with Organic Priming Treatment of Noni Fruit Extract and Soaking Period, a. M_0T_0 5 HSP, b. M_3T_2 5 HSP.

Vigor index is calculated based on the number of normal sprouts on the first count, namely on the 5th day (Internasional Seed Testing Association [ISTA], 2010). Vigor is the potential of a seed to grow and produce normally in conditions that are less than optimal or sub-optimal (Siyum et al., 2022). According to Yudono & Purwanto (as cited in Subantoro & Prabowo, 2013), vigor is the condition of seeds that have healthy seed aspects so that the germination process will produce sprouts that are strong, uniform, and adapt quickly to the surrounding environment.

Seeds with vigor percentage value below 40% are classified as low vigor seeds, which exhibit sub-optimal growth perfomace (Zulmi et al., 2024). Seeds with low vigor tend to show a decreased ability to utilize energy compared to seeds with high vigor (Nugraheni et al., 2023). As seen from Figure 5 indicates that the vigor index for the control remained still low, at 39.33%, whereas soaking treatment raised the index up to 84.00%. However, several treatments were still deemed suboptimal, which may be attributable to seed ageing or expiry leading to physiological deterioration. This is thought to be because expired seeds experience seed setbacks, thus the seed germination being less than optimal. According to Juanda et al. (2017), seed deterioration results in decreased seed quality because seeds that have passed their shelf life or have expired may experience cell membrane leaks. The impact of this cell membrane leak is reducing the supply of materials to be converted into energy for protein synthesis, which is very important for the growth and formation of cells. As a result, abnormal sprout growth is often found. Some seeds cannot even germinate at all, or the seeds require a longer time to germinate, seeds with low vigor exhibit sub-optimal metabolic activity, thereby delaying the germination process. The failure of untreated controls to reach the maximum value is entirely predictable, as it reflects cellular damage associated with prolonged seed storage. This finding aligns with Sutopo's (2002) statement that low-vigor seeds take longer to germinate. Therefore, the vigor index in this study serves as a direct measure of invigoration success: the M_3T_2 combination achieved a relatively high vigor index of 84%, demonstrating that organic priming with noni fruit extract can effectively restore the physiological competence of deteriorated seeds.

As can be seen in Figure 6, there is a difference in the vigor index results of expired local rice seeds of the Buyung Banjar variety between the best treatments (M_3T_2) and without treatment or control (M_0T_0) 5 days after harvest. Expired local rice seeds of the Buyung Banjar variety that were given the best treatment with noni fruit extract of 4.5% and soaking for 24 hours produced relatively more seeds that germinated compared to the control at 5 days after harvest.

This is because noni fruit extract contains antioxidants, namely ascorbic acid and phenolic compounds. According to Sen et al. (2013), phenolic compounds found in noni fruit have the ability to act as antioxidants. The presence of ascorbic acid as an antioxidant is intended to suppress accumulation of free radicals that can damage seed lipids and cellular membranes, thereby preventing their deleterious effects and preserving seed vigor while inhibiting further physiological deterioration (Akram et al., 2017). Accumulated free radicals can cause damage to cell membranes and leakage of metabolites such as sugar, therefore the ascorbic acid and phenolic content in noni extract can improve the performance of seeds that have damaged cell membranes so that they can make the metabolic process of seeds run smoothly as the seeds get

a supply of materials for converted into energy so that the germination process occurs without obstacles and the seeds can grow into strong sprouts, thereby increasing the seed vigor index value. This is in line with research results by Utami (2023), the results demonstrate that application of the antioxidant ascorbic acid (vitamin C) can enhance germination rates of physiologically deteriorated seeds as well as seeds planted under suboptimal conditions.

Based on research results, increasing the concentration of noni fruit extract organic priming given to rice seeds is in line with increasing germination results, because as the concentration increases, the total content of available hormones or compounds also increases, thereby increasing germination. Based on Johari & King's statement (in Dewantara et al., 2021), the higher the total phenolic content, the stronger the antioxidant effect, thus the seeds are better able to fight the bad effects of free radicals. Therefore, seed germination can be supported which can be seen in Figure 6(b). Giving noni fruit extract organic priming with the highest concentration of noni fruit extract, namely 4.5%, produced the highest total number of seeds that germinate.

Research conducted by Saputra et al. (2023) stated that the combination of giving noni fruit extract with a soaking time of 2 hours was effective in increasing the vigor index compared to a soaking time of 4 hours. Based on this, the soaking time also had an influence in increasing the vigor index value. According to Saputra et al. (2023), because soaking time can influence how much water and substances enter the seeds, water can speed up the continuity of the seed respiration process. The respiration stage in seeds plays a role in the production of energy needed for cell division and biochemical processes that ultimately lead to germination. However, soaking for too long can cause a decrease in oxygen levels which can inhibit the respiration stage. According to Lasopo et al. (2024), prolonged soaking reduces oxygen absorption, which can delay seed germination. Because this lack of oxygen minimizes the production of food reserves, the available energy is limited, ultimately extending the overall germination process. Consequently, choosing the right soaking time may contributes significantly to achieving maximum seed vigor index values. Therefore, in this study, the best combination of noni fruit extract concentration and soaking time which relatively increased the vigor index value of Buyung Banjar rice seed variety was the combination of treatment with a noni fruit extract concentration of 4.5% and a soaking time of 24 hours.

Growth Speed

Based on the analysis of variance, the results showed that the organic priming treatment of noni fruit extract and soaking period and single factors had a significant and very significant effect on the growth speed of local rice seeds of the Buyung Banjar variety. The average percentage of growth speed of local rice seeds of the Buyung Banjar variety when given organic priming noni fruit extract and soaking period is presented in Figure 7.

Based on Figure 7, the growth speed of seeds in the control (M_0T_0) and the treatment without organic priming of noni fruit extract by soaking for 12 hours (M_0T_1) was not significantly different. Treatments M_0T_2, M_0T_3, M_1T_1, M_1T_2, M_1T_3, M_2T_1, M_2T_2, M_2T_3, M_3T_1, and M_3T_3 showed results that were not significantly different from each treatment but produced an increase ranging from 1.4-fold–4.1-fold compared to the control. The most significant difference was shown by the combination treatment of noni fruit extract with a soaking period of 24 hours (M_3T_2) with an increase of 4.1-fold compared to the control.

Seed growth speed is the process of seeds growing quickly with supporting environmental conditions and metabolic stages running without obstacles so that growth occurs optimally (Lesilolo et al., 2012). Seed growth speed is calculated by adding up the increase in seeds that grow normally every day (Ridha et al, 2017). According to Lesilolo et al. (2012), good seed growth rate ranges from 25% - 30%.

Based on the results in Figure 7, seeds that were not treated or controlled (M_0T_0) did not reach the standard value for good seed growth speed, while seeds that were treated with the single factor of soaking time and the combined factor of organic priming, noni fruit extract, and soaking time were able to reach the standard speed growth value. This means that organic priming of noni fruit extract combined with long soaking is able to increase the growth speed of local rice seeds of the Buyung Banjar variety experiencing setbacks due to expiration. Therefore, it is suspected that noni fruit extract contains gibberellin which plays a

role in accelerating the germination stage in seeds. This is in line with the research by Rashid et al. (2010), which explained that increase of the speed of seed growth and germination may occur by administering the growth regulator gibberellin. Giving gibberellin can speed up seed germination as it contributes to triggering the formation of the amylase enzyme, which is an enzyme responsible for breaking down starch compounds in the endosperm or plant food reserves (Asra, 2014). Gibberellin can mobilize these food reserves for use at the beginning of seed growth (Hopkins, 1995), thus breaking dormancy in seeds, and so gibberellin may accelerate germination (Vaistij et al., 2013). Although seeds can produce the hormone gibberellin naturally (endogenous hormone), the amount is relatively small (Murrinie et al., 2021).

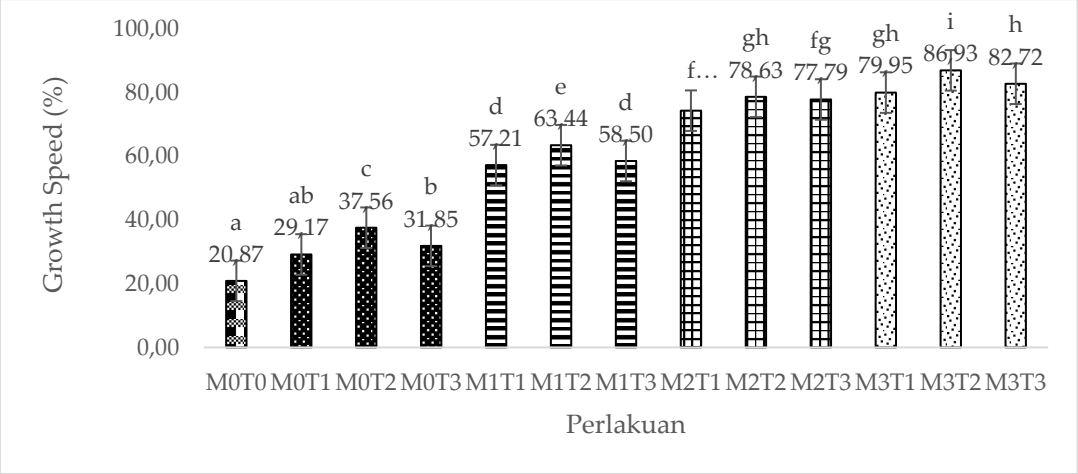


Figure 7. Average Percentage of Growth Speed of Local Rice Seeds of the Buyung Banjar Variety.
Note: M_0= concentration 0%; M_1= concentration 1.5%; M_2= concentration 3%; M_3= concentration 4.5%. T_0= 0 hour; T_1= 12 hours; T_2= 24 hours; T_3= 48 hours. Numbers accompanied by the same letters in the mean values are not significantly different on the *Duncan's Multiple Range Test* (DMRT) test at the 5% level.

Therefore, administration of gibberellin from outside (exogenous hormone) can increase the availability of gibberellin levels found in seeds which act as a trigger to accelerate the germination phase (Asra, 2014). This suggests that the success of seed invigoration via organic priming stems not only from the structural benefits of hydration, but also from the biochemical mechanisms triggered during treatment. Specifically, the introduction of exogenous gibberellins through organic priming helps compensate for depleted endogenous hormone reserves in deteriorating seeds (Murrinie et al., 2021), thereby overcoming the hormonal barriers that limit germination rates.

The research results that have been obtained shows that increasing the concentration of noni extract can increase the percentage of seed growth speed. The interaction of soaking time organic priming with noni fruit extract can also increase seed growth speed, but the increase in soaking time is not directly proportional to the increase in seed growth speed. This can be seen in the research results presented in Figure 7, which shows that there was a decrease in results in the treatment with a soaking time of 48 hours compared to a soaking time of 24 hours. Based on the research by Bajang et al. (2015), excessive soaking time can have a negative effect, namely causing the seeds to become damaged and rotten. If seeds are soaked for too long, they may become waterlogged and start to rot. This happens because the seed coat is too permeable and therefore allows microorganisms from the extract solution to seep into the seed and cause damage and rot due to fungus. In line with the research results of Sudarwati et al. (2022), *Indigofera arrecta* seeds that are soaked beyond 3 hours of soaking cause deterioration as the seed coat becomes more easily torn, thus the seeds become vulnerable to fungal attacks. Another impact caused by

seeds being waterlogged for too long is limiting the oxygen supply to the seeds as the presence of water dominates the space in the seeds. In accordance with the research results of Lubis et al. (2018), anoxia or loss of oxygen caused by soaking for too long prevents seeds from respiration and germination because oxygen is needed for the process to run smoothly. Therefore, if the respiration rate of seeds decreases, the speed of the seeds will also slow down.

CONCLUSION

Based on the research results, it was concluded that there was an interaction effect between the organic priming concentration of noni fruit extract and the soaking period on the invigoration of expired local rice seeds of the Buyung Banjar variety on maximum growth potential, simultaneity of growth, germination capacity, vigor index, and growth speed. Also, the best combination of maximum growth potential, simultaneity of growth, germination capacity, vigor index, and growth speed is found in the M_3T_2 treatment with a noni fruit extract concentration of 4.5% and a soaking period of 24 hours.

AUTHORS CONTRIBUTIONS

AS suggested the research topic. NAH planned and conducted the research. NS provided advice in terms of research. NAH collected data and interpreted the data. AS and NS provided guidance, criticism, and suggestions on research, data analysis, interpretation, and writing of the manuscript.

CONFLICT OF INTEREST

No conflict of interest

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