
Research Article

The effect of iron coating on stabilizing rice direct seeding onto puddled soil on growth and production

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Article history:

Submitted 03 June 2022

Accepted 26 July 2022

Published 22 August 2022

Keywords:

Iron coating

Productivity

Variety of rice

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Abstract

Rice is a food-crop commodity that plays an important role in Indonesia's economy. This research aims to analyze the following aspects: 1) the response of several rice varieties to the growth and production of rice and 2) the effect of iron coating on the growth and production of rice. This study was conducted in Borongloe Village, Bontomarannu District, Gowa Regency, from March to December 2021. The split-plot design was applied for two factors. The main plot was used to test for the first factor, namely variety, for Inpari 32, Cigeulis, and Mekongga, and the subplot was used to test for the second factor, namely coating, uncoating, 25% coating, and 50% coating. The two factors were combined to create 9 treatment combinations. Each treatment combination was repeated four times. The Inpari 32 variety was found to be the best variety for coating based on the number of pithy seeds (82.04 per panicle), the weight of the seeds per panicle (2.50 g), and production (4.04 t h⁻¹). Significant plant height was also seen in the Mekongga variety (121.39 cm). Furthermore, the 25% coating treatment was the best treatment for increasing crop yields based on the character of the number of tillers (24.32 tillers per clump) and the number of productive tillers (19.31 stem).

Introduction

Rice is a food-crop commodity that plays an important role in Indonesia's economy. Indonesia's population growth every year tends to increase along with the level of rice consumption. Data from the Central Statistics Agency (CSA) showed that according to the Population Census in Indonesia, the country has a total

population of 238.52 million people in 2015. Five years later, the country's population has increased to 270.20 million people. In 2020, Indonesia's rice consumption reached 82.20 kg per capita per year. The potential for rice production in 2020 was also 31.63 million tons (BPS, 2020). This indicates that along with the

How to cite:

Ramli, Kaimuddin, Riadi, M., & Rasyid, B. (2022). The effect of iron coating on stabilizing rice direct seeding onto puddled soil on growth and production. *Journal of Agriculture and Applied Biology*, 3(2): 108 - 117. doi: 10.11594/jaab.03.02.04

increase in population, the demand for rice also increases.

Therefore, to keep up with the public's demand for rice, the country strives to increase its rice production every year. One of the important factors in supporting increased production in rice cultivation is the use of an appropriate rice planting system. This is supported by Lita et al. (2014) who concluded that the growth and yield of rice plants are influenced by many factors, one of which is the cropping system. Rice is typically grown using the organic direct seed planting and the System of Rice Intensification (SRI) methods to produce yield components (weight of grain content per clump, number of grains per clump, and number of panicles per clump). These methods have been proven to obtain higher yields than the direct seed planting method.

The constraints associated with shifting cropping patterns from transplanting to direct seed planting are the emergence of tall weeds, the evolution of stunted rice, increase in soil-borne pathogens (nematodes), nutritional disturbances, formation of infertile plants, shelter, blast incidence, brown leaf spot, etc. By overcoming these constraints, direct seeding has proven to be a very promising, technically feasible, and economically viable alternative to transplanting systems (Kaur & Singh, 2017). Blast and nematode disease are other important problems associated with direct seed planting. This study reviews an integrated cultivation technology package related to direct seed planting, as well as the advantages, constraints, and possibilities of direct seed planting in the future of rice cultivation in Nepal (Bista, 2018).

According to Makmur et al. (2020), rice plant growth is influenced by many factors, one of which is the cropping system. The study found that the direct seed cropping system showed significant results compared to other cropping systems. These results suggest that the prolongation of coleoptile stimulation is partly due to the increased availability of soluble sugars from the seed to the coleoptile. Therefore, the use of prime rice seeds is very effective for the stability of the emergence and formation of rice seeds using direct sowing systems (Mori et al., 2012). The direct seed

planting method has several advantages such as less manpower during planting, effectiveness, and efficiency because the planting time is fast, does not experience stagnation (stress), and planting costs can be reduced due to the efficient fertilization process because it is only done in a row.

An important issue related to direct seed planting in the field is the level of pest and disease attacks from birds, stem borers, and weeds. One solution that can be applied is coating the seeds with iron. Seed coating is the most widely used seed breeding method. It is a process of wrapping seeds with certain substances which aims to protect seeds from the interference or the influence of environmental conditions during storage or during the germination period. Moreover, seed coating maintains seed moisture content and extends the shelf life of seeds. Research conducted with current technological developments has shown that iron-coated rice seeds showed maximum growth, increased root growth, and resistance to sparrow attacks and diseases (Yamauchi, 2017).

Iron is a microelement needed by certain plants in very limited quantities. At high doses, this substance will poison the plant. Plants that are intolerant to iron have their own mechanisms to avoid poisoning. Whereas tolerant rice plants need to obtain dissolved iron from their roots to ensure that their rice grains are rich in iron, which is very beneficial for health (Utama, 2015). In this study, the use of iron filings to form a layer of iron coating showed results during seeding and transportation. Past studies have also found that iron powder is unlikely to damage rice seeds and is easy to handle. Thus, it can be used for coating rice seeds (Kawano et al., 2013).

The adhesive/coating material could maintain the viability and vigor of rice seeds compared to seeds without the coating when germinated under conditions of aluminum poisoning in all observed variables. The results showed that the coating treatment with 3% alginate + 1% peat + *P. diminuta* A6 and *B. subtilis* 5/B was the best in increasing crop yields based on the highest percentage of weight, the number of pithy grains, percentage of empty grain weight per panicle, and percentage of

total grain. It also had the lowest empty grain per panicle (Palupi et al., 2013).

The accumulation of cadmium (Cd) in grains needs to be reduced, and vice versa for Fe content in rice. An understanding of the different cellular mechanisms of Fe/Cd accumulation in rice provides a guide for cultivating Fe-enriched rice and has paved the way for developing Cd-stress tolerant rice which aims to breed Fe-rich but Cd-free rice (Gao et al., 2016).

Tillage and direct cultivation are also other potential alternatives with savings in water inputs and high cultivation costs, with no yield calculation. However, alternative practices reduce methane emissions but increase nitrous oxide emissions. Soil texture also plays a key role in relative yield gains, and therefore practical activities are conducted according to specific agroecosystems (Chakraborty et al., 2017).

Thus, direct research will be conducted by investigating the effect of iron coating on stabilizing rice by direct seeding to puddled soil on growth and production

Materials and methods

Location and time

This research was conducted in Borongloe Village, Bontomarannu District, Gowa Regency, and took place from March to December 2021.

Materials and equipment

The materials used in this study were seeds of different rice varieties (Inpari 32, Cigeulis, and Mekongga), Konabijin (iron), gypsum, and inorganic fertilizers N (urea), P (SP36), K (KCl), Bokashi fertilizers, cow dung, and pesticides.

The equipment used were ropes, tape measures, hand sprayers, basins, buckets, wooden blocks, bamboo, sickles, plastic containers, sacks, scales, labels, hoes, machetes, nails, and writing utensils.

Research design

This study used a split-plot design and consisted of two factors. The main plot was used for the first factor, namely variety, for Inpari 32 (v1), Cigeulis (v2), and Mekongga (v3), and the subplot was used for the second factor namely the coating, uncoating (c0), 25% coating (c1), and 50% coating (c2). The two factors were combined to form 9 treatment combinations. Each treatment combination was repeated four times. The data obtained were analyzed using analysis of variance and if it had a significant effect, a further test of 0.05 BNT was conducted (Gomez and Gomez, 1983).

Research implementation

Soil tillage for rice was done using the direct seed planting method, starting from land sanitation and plowing using a two-wheel tractor two weeks before planting. This is then muddy ground, and then the soil was leveled and ready for the experimental plots.

The experimental plots were made before planting and were 4m long and 2m wide. They were made separately from all experimental plots and were bordered by bunds with the distance between the treatments being 1m and the distance between the ditches being 0.5 m. A total of 36 experimental plots were used.

The seeds were coated before planting. Iron was used as the coating which also served as an adhesive for the gypsum material. The dosage concentrations were without coating (c0), 25% coating (c1) with 1 kg rice seed: 250 g iron: 25 g gypsum: 150 ml water, and 50% coating (c2) with 1 kg rice seed: 500 g iron: 25 g gypsum: 150 ml of water. We had groups with coating and a group without coating to investigate the performance of the seed treatment in this study, as shown in Figure 1



Before coating



After coating

Figure 1. Rice seeds before coating and after coating with Fe

The following seed coating ratio was used; seed: iron: gypsum ratio = 1:0.5:0.05 (Sashi et al., 2014). After manually coating the seeds, they were aired at room temperature for 7 days.

This study used certified seeds obtained from the Seed Center of South Sulawesi Province of the Inpari 32, Cigeulis, and Mekongga varieties. The seeds that were given and not given an iron coating were ready to be planted.

Planting was done using the direct seeded rice (DSR) process. The planting system used had 3-5 seeds per planting hole with a spacing of 25 cm x 25 cm.

To obtain a maximum population, after planting, replanting was conducted on seedlings that did not grow or died. The viability and speed of germination of rice seeds in early germination did not differ in the field. Embroidery was done at the age of 7-14 days after planting. The seedlings that were prepared for embroidery were seeds that were planted together with experimental plants.

This study used inorganic fertilizers which followed site-specific recommendations. A total of 5 tons ha⁻¹ or the equivalent of 500 g per m² of organic fertilizer was first applied to all experimental plots. The use of inorganic fertilizers in each experimental plot of urea fertilizer was 200 kg ha⁻¹, SP 36 100 kg ha⁻¹, and KCl 100 kg ha⁻¹.

An integrated pest control system was applied by placing a pest kit on a bottle that has been smeared with adhesive so that flying pests would stick to them until they die. In addition, organic pesticides that consist of natural ingredients to repel pests were also used.

Rice plants can be harvested after 95-120 days. Rice plants that are ready to be harvested are 90% physiologically ripe, meaning that 90% of the grain has changed color from green to yellow. When calculated from the flowering period, the plant has reached 30-35 days, and harvesting was done by cutting the stems of the rice plant.

Observation parameter

1. Plant height (cm) measurements were taken from the base of the stem to the longest leaf 2 weeks after planting (WAP), 4 WAP, 6 WAP, 8 WAP, and 10 WAP. Measurements were made on fourteen plant clumps which were randomly selected from each experimental plot unit.
2. The number of tillers (stems) consists of the total number of tillers that grew on the plant 2 weeks after planting (WAP), 4 WAP, 6 WAP, 8 WAP, and 10 WAP. Calculations were done on fourteen plant clumps that were randomly selected from each experimental plot unit.
3. The number of productive tillers (stems) was calculated as the total number of productive tillers on the plant during the generative phase. Calculations were done on fourteen plant clumps that were randomly selected from each experimental plot unit.
4. The number of pithy seeds was obtained from fourteen clumps that were randomly selected from each experimental plot unit.
5. The seed weight (g) per panicle was obtained from weighing fourteen panicles that were taken at random from each experimental plot unit.
6. Rice production ha⁻¹ was measured from the harvested dry grain from each experimental plot.

Results and discussion

The diversity of plant height exhibited in Figure 2 suggests that the varieties, coating, and treatment interactions between coating varieties did not significantly affect plant height.

Figure 2 shows that the treatment of the Mekongga variety with 50% coating (v3c2) gave the highest plant height of 121.39 cm, followed by the Cigeulis variety treatment with 25% coating (v2c1), while the lowest plant height was found in the Inpari 32 variety with no coating (v1c0).

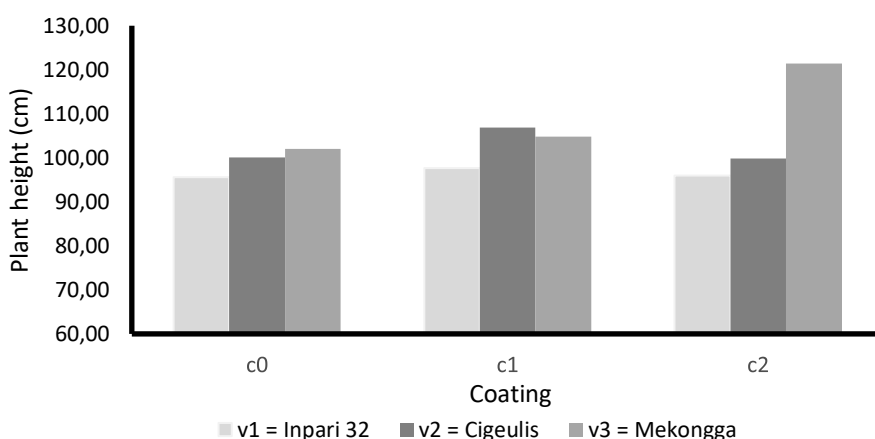


Figure 2. Average plant height

Table 1 indicates that the coating treatment had a significant effect on the number of rice tillers, while the various treatments and the in-

teractions between the coating and rice varieties did not significantly affect the number of tillers.

Table 1. The average measuring number of rice tillers

Variety	Coating		
	No coating (C0)	25% Coating (C1)	50% Coating (C2)
Inpari 32 (V1)	21.88	23.04	22.59
Cigeulis (V2)	22.79	24.39	23.30
Mekongga (V3)	24.71	25.52	23.63
Average	23.13 ^b	24.32 ^a	23.17 ^b
Different Value of Lead Significant different (LSD) α 0.05		0.73	

Note: The numbers in the same line (ab) have significant differences in LSD α 0.05.

Table 1 shows that 25% Coating (c1) gave the highest number of rice tillers at 24.32 tillers per clump and this did not differ from the no coating plants (c0) but was significantly different from the plants given the 50% coating treatment (c2).

Next, the results in Figure 3 indicate that the varieties, coatings, and the interactions between the coating and rice varieties did not significantly affect the number of productive tillers.

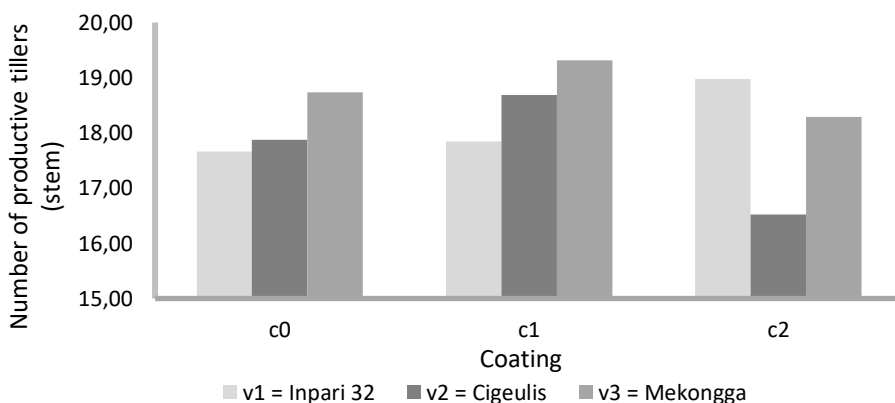


Figure 3. Average number of productive tillers

According to Figure 3, the treatment of the Mekongga variety with a 25% coating (v3c1) gave the highest number of productive tillers at 19.31 stems, followed by the treatment of the Inpari 32 variety with a 50% coating (v1c2), while the lowest number of productive tillers

was found in the Cigeulis variety with a 50% coating (v2c2).

Figure 4 shows that the rice varieties, coatings, and the interactions between the coating and rice varieties did not significantly affect the number of pithy seeds.

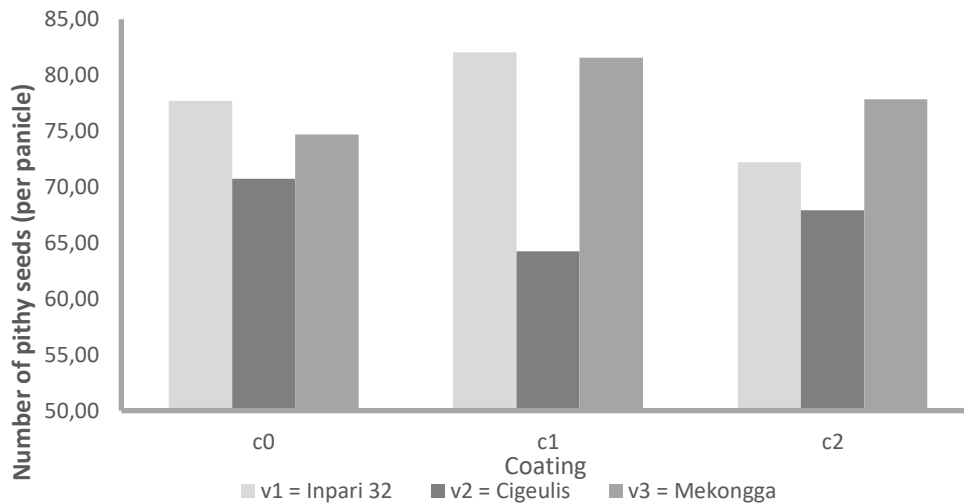


Figure 4. Average number of pithy seeds

As shown in Figure 4, the treatment of the Inpari 32 variety with a 25% coating (v1c1) gave the highest number of pithy seeds at 82.04 pithy seeds per panicle, followed by the treatment of the Mekongga variety with a 25% coating (v3c1), while the lowest number of pithy seeds per panicle was found in the Cigeulis variety with a 25% coating (v2c1).

The results of the seed weight per clump are shown in Figure 5. It indicates that the rice varieties, coatings, and interactions between the coating and rice varieties did not significantly affect the seed weight per panicle.

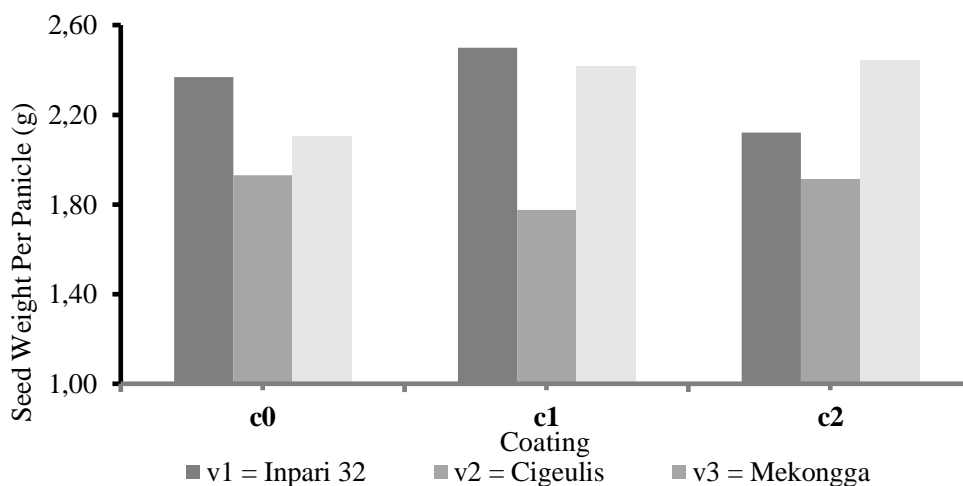


Figure 5. Average seed weight per panicle

Figure 5 shows that the Inpari 32 variety with a 25% coating (v1c1) produced the highest seed weight per panicle, at 2.50 g, followed by the Cigeulis variety with a 50% coating (v3c2), while the lowest seed weight per panicle was found in the Cigeulis variety with a 25% coating (v2c1).

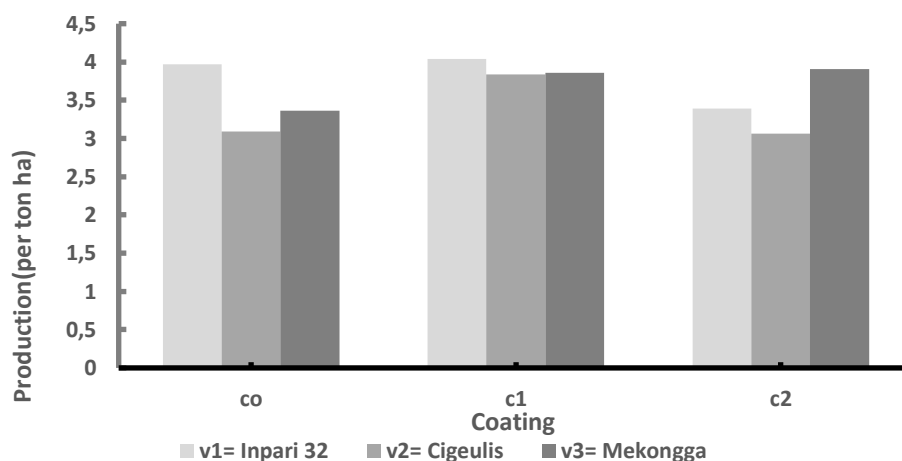


Figure 6. Average Production

Figure 6 shows that the Inpari 32 (v1) variety produced 4.04 tons per hectare of dry grain, but this was not different from the Mekongga variety (v3) and is significantly different from the Cigeulis variety (v2).

Discussion

The iron coating consists of a mixture of reduced Fe powder and calcined gypsum and is given to pre-germinated seeds. Fe powder on the seed's surface would oxidize to produce rust which acts as a binder for the formation of a hard film. To improve seed quality and protect them from declining, they need to be treated before storage. Moreover, to maintain the seeds' viability and vigor, a good storage environment is required such as through an aluminum foil storage media and ethylene plastic bags (Sari and Faisal, 2017).

The longest plumule length was measured from the seed before storage (6.37 cm) and was found to be significantly different from the length of the plumule in the storage period of 1 month and 3 months, as well as 2 months and 4 months. The longer the seeds are stored, the length of the seed germination plumule decreases. This is believed to be caused by the

seeds' reduced reserves. According to Prihatiningsih et al. (2019), plumule length could be increased by using 8 competent rice rhizosphere bacteria as biological agents of Xoo. Somagede 3 isolate was the best rhizosphere bacteria capable of inhibiting Xoo with a zone of inhibition of 10 mm with a bacteriostatic mechanism and produces the highest level of IAA at 84.12 ppm. Rice seed germination and seedling height also increased by 16.31% and 35.23% in the treatment of Sumbang 4 and Somagede 3 isolates.

The uncoated seeds obtained the longest plumule length and the longest seed germination period (5.55 cm). However, this plumule length was not significantly different from the length of the seeds with 50% coating (5.36 cm) and 25% coating (5.33 cm). These results indicate that increasing the percentage of coating results in a decrease in the length of the plumule. However, the iron coating did not increase shoot and root length. This may be due to the physical barriers caused by the iron coating on the seeds (Mori et al., 2012).

The uncoated seeds also obtained the longest root length and the longest seed germination period (7.92 cm). This result is

significantly different from the root length of seeds with 50% coating (7.29 cm) and 25% coating (7.09 cm). This indicates that increasing the coating percentage results in a decrease in root length. According to [Onwimol et al. \(2016\)](#), the cumulative germination curve pattern of radicle emergence and normal germination showed better normal germination. There was no significant difference in germination time between the radicle elongation and normal germination of rice seeds. Therefore, it is possible to develop an automated procedure for verifying the quality of rice seeds by using calculating the average emergence of radicles.

Next, the uncoated seeds obtained the highest dry weight of sprouts (4.09 g), which was significantly different from the dry weight of seeds with 25% coating (3.90 g) and very significantly different from the dry weight of sprouts with 50% coating (3.44 g). These results indicate that increasing the percentage of coating resulted in a decrease in the dry weight of the sprouts. The results of research by [Widajati et al. \(2013\)](#) also showed that their coated and control seeds were able to maintain the viability of hybrid rice seeds of varieties DG-1, SL-8, and Intani-2 during a storage period of 15 weeks based on germination benchmarks. The average germination value for seeds of the DG-1 variety was 95.2%, SL-8 was 89.6% and Intani-2 was 85.6%.

The Mekongga variety with 25% coating also had the highest growth and development of rice plants at almost every observation. This shows that the treatment of the Mekongga variety with 25% coating can affect the growth and development of this rice plant variety. This follows [Macaisa's et al. \(2017\)](#) study, which found that iron powder produces a positive effect on seedlings in several growth parameters such as the emergence index, the average time of emergence, shoot length, root length, and dry weight.

Furthermore, [Zhou Nian-Bing et al. \(2021\)](#) showed that the effect of changes in solar radiation and temperature were the main environmental factors influencing the yield of good quality rice in the lower reaches of the Huai River. With the delay in the sowing date, the results of the field experiment of two treatments of medium-maturing japonica rice (MMJR) and

late-maturing japonica rice (LMJR) showed a significant decrease along with a decrease in nutrient absorption in the soil. This is thought to be caused by the reduced reserves of nutrients in the available soil for plant development. Moreover, the results of research by [Wahyuti et al. \(2013\)](#) concluded that the high yield is also related to the character of the upper three-leaf angles, flag leaf area, chlorophyll content, and flag leaf sugar. Where the contents of the green leaf and sugar in flag leaves in the generative and seed filling phase would affect the yield.

[Le Xu et al. \(2021\)](#) also showed that there was no significant difference in the efficiency of agronomic Nitrogen use between direct planting or double-season rice (DSD) and transplanted double-season rice (TPD). These results indicate that DSD with early maturing varieties is a promising alternative to TPD in central China for maintaining high grain yields and for the efficient use of Nitrogen fertilizers with less labor.

According to [Hendarto et al. \(2021\)](#), the morphological characteristics that play a role in diversity are flag leaf length, flag leaf width, leaf length, and harvest age. Plant height and length of flag leaf are effective selection criteria for calculating the weight of 10 grains of filled grain. The reproductive stage in rice plants occurs before and after the panicle emerges. The latter is known as the ripening period. Agronomically, the life cycle has three stages of growth, namely vegetative, reproductive, and ripening. The vegetative stage starts from germination to the panicle primordia, the reproductive stage starts from the panicle primordia to the heading (out of the panicle), and the ripening stage starts from the heading to aging ([Yoshida, 1981](#)).

The results showed that the coating treatment had no significant effect on the morphology of the rice plant. This shows that the coating treatment only affects the germination rate but does not affect the growth and production of rice plants. The coating only helps to bind water and prevents the rice plant from diseases that attack during the germination process. After this germination phase, the coating treatment does not support the growth and production of rice plants.

In this study, the increases in production for each variety differed and the results showed that the Inpari 32 variety produced 4.04 t ha⁻¹, but this outcome was not obtained from the Mekongga variety and was significantly different from the Cigeulis variety. This is in line with the results of Maulana et al. (2017) who found that the response of each rice plant variety differs according to the population of the *walang sangit* pest and the rice stem borer. The Gorontalo variety showed a lower attack rate against the *walang sangit* pest at 10.07% and the Inpari 13 variety showed the highest yield of 5.38 t ha⁻¹.

Lastly, the adoption rates of technology are closely related to people's level of knowledge. In addition, there is a need to target poor farmers to provide them with better resources by improving the channels of information diffusion about agricultural practices. An example would be how organizations have taken the lead in increasing the technology adoption of rice farmers in Bolivia (Martinez et al., 2021).

Conclusion

1. The Inpari 32 variety is the best variety for coating based on the number of pithy seeds (82.04 per panicle), the weight of seeds per panicle (2.50 g), production (4.04 t h⁻¹), and significant plant height in the Mekongga variety (121.39 cm)
2. The 25% coating treatment is the best treatment for increasing crop yields based on the characteristics of the number of tillers (24.32 tillers per clump) and the number of productive tillers (19.31 stem).

Acknowledgment

This work was supported by the research team at the Research Laboratory of the Gowa Agricultural Development Polytechnic, Hasanuddin University, and Ministry of Agriculture Republic Indonesia

Author's declaration

Authors declare that there is no conflict of interest. All authors read and approved the final version of the manuscript.

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