Performance of six new superior varieties of rice on tidal swamp-land in South Kalimantan Province

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Abstract. Rice is the staple food for millions of people of Indonesia which produced from many agroecology including tidal-swamp. The contribution of swampland to the national rice production is still lower than 2%. One of the indigenous knowledge of the tidal-swamp farmers is the massive use of local varieties which have low yield. Therefore, efforts to increase rice production in tidal-swampland of Barito Kuala Regency should consider the use of superior varieties. The purpose of this study was to find out performance of seven superior varieties in tidal-swamp land in two planting seasons. This research was conducted from March 2020 to March 2021 in Karang Buah Village of Belawang District of Barito Kuala Regency, South Kalimantan Province. The research was arranged in two factors of Randomized Complete Block Design namely varieties and seasons. The first factor consisted of seven varieties: Inpari-42 (V1), Inpari-43 (V2), Inpari IR Nutri Zinc (V3), Inpara-8 (V4), Inpara-9 (V5), Inpara-10 (V6), and IR-42 (V7). The second factor, season consisted of season-1 which started from March to July 2020 and season-2 for planting period from November 2020 to March 2021. The result showed that swamp rice varieties had higher value for plant height variables than those of irrigated rice varieties with Inpari-8 as the highest one. However, all irrigated rice varieties performed better which had higher value for panicle number, filled rice grain, and yield with IR-42 as the highest one. All varieties except IR-42 showed higher values of filled grain numbers when cultivated in season-1 supported by good weather during the study.

1. Introduction
Rice is the staple food for millions of Indonesian people. The annual demand for rice reaches 29.6 million tons which can be fulfilled from national production [1]. In 2020, Indonesia rice production is recorded 31.6 million tons produced in 34 provinces [2] and involves around 15 million households [3]. Total area of rice production is 10.8 million ha consists of irrigated and non-irrigated rice fields, dry land, and swampland. The contribution of swampland to the national rice production is still lower than 2% but it is possible to increase it considering the large area of land that has not been utilized [4]. Therefore, swamp land is the future land for food production in Indonesia.

Indonesia has over 34 million ha of swampland [4, 5, 6, 7]. Converting swampland to agriculture use is a good strategy to face the scarcity of arable land and increasing demand for staple food in Indonesia.
especially for rice as an aquatic plant. Expansion of rice cultivation to swampland will enhance rice production and elevate the opportunity to strengthen food security due to the distribution of swampland in the western, central and eastern parts of Indonesia. In the central region, Kalimantan Island has the largest swampland with 10.02 million ha or 28.7% of Indonesia swampland [9].

Managing swamp-land for the sustainable agriculture should consider of using specific technologies which can produce efficiency and environmentally friendly [10, 11]. Various tidal swamp-land agricultural technologies are available, such as high-yielding varieties, land and water management, to agricultural tools and machinery. However, some challenges in managing tidal swamp-land such as variations in overflow and waterlogging, different soil types and different fertility between locations result in differences in the choice of suitable technology [5, 9, 12].

Indigenous people living in swamp areas have utilized swamplands for agriculture for hundreds of years [8, 13]. They use some indigenous technologies such as planting multi-commodities in one area, calculating planting period using climate or water behavior [10, 14, 15], and using local crops varieties. This indigenous knowledge has been proven to enable local communities to survive through agricultural activities. However, agricultural productivity in tidal-swamp land is mainly lower than other agroecosystem area. In South Kalimantan Province, tidal-swamp land can be found mainly in Barito Kuala Regency.

Barito Kuala Regency is the main central production of rice in South Kalimantan Province with contribution more than 21% to the province production in 2019 [16]. The total rice production was 322.185 tons with the productivity of 3.20 ton/ha (Figure 1). In the last 5 years rice productivity has shown a declining trend and is always below 4 tons/ha. This low productivity is influenced by the massive cultivation of local rice cultivars by farmers called Siam variety.

Therefore, efforts to increase rice production in tidal-swampland of Barito Kuala Regency should consider the use of superior varieties [18] besides increasing planting index. Superior variety may be able to produce more grains in shorter time which can be valuable for farmers. The purpose of this study is to investigate the performance of seven superior varieties in tidal-swamp land in two planting seasons.
2. Materials and Methods
This research was conducted from March 2020 to March 2021 in Karang Buah Village of Belawan District of Barito Kuala Regency, South Kalimantan Province. Karang Buah is an area with 100% tidal-swampland cultivated by farmers as agricultural area with rice and citrus as the two main commodities.

The research was arranged in Randomized Complete Block Design with two factors namely varieties and seasons. The first factor consisted of seven varieties: Inpari-42 (V1), Inpari-43 (V2), Inpari IR Nutri Zinc (V3), Inpara-8 (V4), Inpara-9 (V5), Inpara-10 (V6), and IR-42 (V7). These seven varieties are superior rice varieties released by the Indonesian Agency for Agricultural Research and Development (IAARD) with each superiority as listed in Table 1. The variety named Inpari stand for irrigated rice inbred while Inpara is an abbreviation of swamp rice inbred. The second factor, season consisted of season-1, starting from March to July 2020 and season-2 for planting period from November 2020 to March 2021. Some variables observed were plant height, panicles number, filled rice grain, and yield. All data were tested using ANOVA with 95% confidence level and continued with Duncan’s Multiple Range Test.

This research used an integrated crops approach with selected technology components, namely superior varieties, high quality of seeds, “jajar legowo 4:1” planting systems, and site-specific fertilizations. Existing rice tidal-swamp field was used and farmers participatory was involved during the study to encourage farmers using the same technologies in the future.

Table 1. List of superior varieties of rice used in this research

| Varieties          | Yield, average (t/ha) | Superiorities                  | Resistance (pest, diseases, and biotic stress) |
|--------------------|-----------------------|--------------------------------|-----------------------------------------------|
| Inpari-42          | 7.11                  | Adaptive in lowland rice field | Resistance to leaf blast                      |
| Inpari-43          | 6.96                  | Adaptive in lowland (fertile and infertile) rice field | Resistance to bacterial leaf blight and leaf blast |
| Inpari IR Nutri Zinc | 6.21                | Adaptive in lowland rice field | Resistance to blast (high content of Zn)     |
| Inpara-8           | 4.70                  | Adaptive in tidal-swampland and non-tidal swamp | Resistance to bacterial leaf blight          |
| Inpara-9           | 4.20                  | Adaptive in tidal-swampland dan non-tidal swamp | Resistance to bacterial leaf blight III, Tungro, and tolerant to Fe toxicity |
| Inpara-10          | 5.00                  | Adaptive in tidal-swampland dan non-tidal swamp | Resistance to blast disease and tolerant to Fe toxicity |
| IR-42              | 5.00                  | Adaptable to irrigated paddy field and tidal-swampland | Resistance to brown planthopper, bacterial leaf blight, Tungro, and tolerant to acid-soil. |

3. Result and Discussion
3.1. Weather
All tested superior varieties showed good performance on the field. The weather was good and supported plant growth during the study with performance almost as expected. The rainfall volume during research in 2020 was much higher than the previous years (Figure 1). Therefore, the water on irrigation tunnel was on the level where farmer can easily to watering their field. It was also supported by the natural
water cycle that flows naturally into swamp areas because of its lower position than other agroecologists [19].

![Figure 2. Rainfall in South Kalimantan and Barito Kuala Regency in the last 9 years (source: [16, 17])](image)

3.2. Soil characteristic

Soil fertility of the research site is in the low category indicated by the level of acidity which is considered acid, the availability of essential nutrients such as P and K is low, as well as high iron content (Table 2). According to [20] the low nutrient content in tidal swamp land is caused by the leaching process. Therefore, managing water and liming is recommended to increase soil pH and nutrient availability for plants.

Table 2. Soil characteristics of the research site

| Soil Properties | Value  | Criteria |
|-----------------|--------|----------|
| pH (H2O)        | 3.54   | Acid     |
| C-organic (%)   | 4.57   | High     |
| N-total (%)     | 0.25   | Medium   |
| P-Bray (ppm P2O5) | 0.04 | Very low |
| Ca-dd (Cmol(+)/kg) | 2.41 | Low     |
| Mg (Cmol(+)/kg) | 6.06   | Medium   |
| K (Cmol(+)/kg)  | 0.16   | Low      |
| Na (Cmol(+)/kg) | 0.46   | Low      |
| Al-dd (Cmol(+)/kg) | 13.36 | Medium  |
| KTK (Cmol(+)/kg) | 21.74  | -        |
| Fe (ppm)        | 1020.44| High     |

3.3. Varieties performance in the dry and rainy seasons

Swamp rice inbred (Inpara) varieties showed higher value for plant height, panicle length and empty grain number variables, while irrigated rice (Inpari) varieties were better for panicle number, filled grain number and yield variables (Table 3 and Table 4). However, the interaction between varieties and seasons only occurred in the filled grain number variable. The highest filled grain number numbers showed by Inpari-42 planted in the dry season of 2020 and significantly different from all tested varieties.
in both seasons. However, varieties performance in dry season were better in dry season. The similar result was found by [21] when tested Ciherang on irrigated rice field in dry season and rainy season of 2013/2014. Water availability has been mentioned by [22] as the closest factor that effect rice production.

### Table 3. Plant height, panicle number and panicle length of seven varieties in two planting seasons

| Varieties             | Plant height (cm) | Panicle number (unit) | Panicle length (cm) |
|-----------------------|------------------|-----------------------|---------------------|
|                       | Dry Season 2020  | Rainy Season 2020/2021| Dry Season 2020    |
|                       | Rainy Season 2020/2021 |                  | Rainy Season 2020/2021 |
| Inpari-42             | 88.23            | 89.00                 | 18.27               |
| Inpari-43             | 89.83            | 82.33                 | 19.70               |
| Inpari-IR Nutri Zinc  | 86.23            | 94.67                 | 15.57               |
| Inpara-8              | 115.77           | 113.33                | 13.70               |
| Inpara-9              | 114.00           | 105.67                | 14.77               |
| Inpara-10             | 103.00           | 103.33                | 15.67               |
| IR-42                 | 99.73            | 97.67                 | 19.67               |

### Table 4. Filled grain number, empty grain number, and yield of seven varieties in two planting seasons

| Varieties             | Filled grain number | Empty grain number | Yield (t/ha) |
|-----------------------|---------------------|--------------------|--------------|
|                       | Dry Season 2020     | Rainy Season 2020/2021 | Dry Season 2020    | Rainy Season 2020/2021 | Dry Season 2020    | Rainy Season 2020/2021 |
| Inpari-42             | 146.00^a            | 93.33^def         | 14.43         | 22.67               | 5.98              | 4.97            |
| Inpari-43             | 122.33^abcd         | 108.30^def        | 23.43         | 25.56               | 6.27              | 4.61            |
| Inpari-IR Nutri Zinc  | 111.60^def         | 118.27^bcde       | 14.43         | 9.89                | 6.19              | 5.18            |
| Inpara-8              | 116.33^bcde        | 113.43^def        | 33.87         | 30.00               | 5.33              | 4.86            |
| Inpara-9              | 110.53^def         | 102.20^def        | 34.73         | 15.33               | 5.18              | 4.39            |
| Inpara-10             | 87.50^f            | 98.43^def         | 32.93         | 21.67               | 5.47              | 4.68            |
| IR-42                 | 141.53^ab          | 127.90^abc        | 24.07         | 16.33               | 6.62              | 5.54            |

Note: Averages followed by the same letter are not significantly different from each other (DMRT α=0.05).

### 3.4. Varieties performance in all seasons

All three-swamp rice showed superior growth at vegetative phase as indicated by the plant height variables and Inpara-8 showed the highest value of plant height reached 114.55 cm. However, all three-swamp rice showed lower values of yield (Table 5) and plant height variable of the generative phase (data not shown).

Swamp rice varieties were superior variety specially assembled for swampland. As expected, all swamp rice showing the best performance for the vegetative variables over irrigated rice varieties except for IR-42. Among swamp rice varieties, Inpara-8 performed better by obtaining the highest value of plant height variable and significantly different from the other varieties. This result is consistent with the results of [20] which showed that Inpara-8 was the variety with the highest value of plant height.

Irrigated rice varieties, Inpari, showed superiority in all measured yield variables. Inpari Nutri Zinc as the superior variety with higher Zinc content, unexpectedly able to grow giving the highest yield
among other superior varieties reaching 5.69 t/ha. For the number of panicles, all Inpari showed a higher value than Inpara, with the highest yield was Inpari-42 with 18.97 panicles. Likewise, for the filled grain number and yield variables where all Inpari showed a higher value than swamp rice varieties. The IR-42 variety showed superiority with the highest values for the filled grain numbers and yield.

Table 5. Varieties performance on two seasons

| Varieties       | Plant Height (cm) | Panicles Number (unit) | Filled Grain Number (unit) | Yield (t/ha) |
|-----------------|-------------------|------------------------|---------------------------|--------------|
| Inpari-42       | 88.62 d           | 18.97 a                | 119.67 ab                 | 5.47 bc      |
| Inpari-43       | 86.08 d           | 18.02 a                | 115.32 b                  | 5.44 bc      |
| Inpari Nutri Zinc | 90.45 d         | 16.12 ab               | 114.93 b                  | 5.69 ab      |
| Inpara-8        | 114.55 a          | 14.52 b                | 114.88 b                  | 5.09 cd      |
| Inpara-9        | 109.83 ab         | 14.05 b                | 106.37 bc                 | 4.79 d       |
| Inpara-10       | 103.17 bc         | 14.83 b                | 92.967 c                  | 5.08 cd      |
| IR-42           | 98.45 c           | 18.67 a                | 134.72 a                  | 6.08 a       |

Note: Averages followed by the same letter are not significantly different from each other (DMRT α=0.05)

All swamp rice varieties growth were higher than those of non-swamp rice varieties, indicating their ability for adaptation to water level on swampland, therefore swamp rice was also known as deep-water rice [23]. The ability of plants to survive in standing water for a long time is one of the characteristics of local swamp rice that is widely cultivated by farmers in Barito Kuala Regency.

The highest yield obtained by IR-42 was a cultivar with wide adaptability. IR-42 was a superior variety released by the Ministry of Agriculture of Republic Indonesia in 1995. IR-42 has been accepted and widely cultivated by tidal-swamp farmers due to its resistance to swamp environmental stress and its rice quality is similar to that of local varieties. Grain length and grain shape is categorized medium which is similar to local rice grain. Furthermore, IR-42 rice grain is clear with 0% of lime content [24].

3.5. Effect of seasons on varietal performance

All variables measured from all varieties showed higher value in season-1 (Table 6). Plant height and panicle number of all varieties grown in season 1 and season 2 did not show differences. This result suggested us that all varieties could be cultivated in all planting seasons and would give a similar result. This condition was supported by the weather in which during these two seasons, the amount of water in the rice field is sufficient for plants growth. However, different responses were given by plants for filled grain numbers and yield.

The filled grain number and yield value in season-1 were higher than season-2. Season-1 of 2020 occurred from March to July 2020. There was rain in this period in the local and upper areas which gave sufficient amount of water for the rice field. Moreover, this area got good attention from the local government that could be seen from the drainage and irrigation canals in very good condition. Therefore, yield values for all varieties were higher in season-1 than season-2.

Table 6. The effect of seasons on varietal performance

| Varieties | Plant Height (cm) | Panicle Number (unit) | Filled Grain Number (unit) | Yield (t/ha) |
|-----------|-------------------|-----------------------|---------------------------|--------------|
| Season-1  | 99.54 a           | 16.76 a               | 119.41 a                  | 5.86 a       |
| Season-2  | 98.00 a           | 16.14 a               | 108.84 b                  | 4.89 b       |

Note: Averages followed by the same letter are not significantly different from each other (DMRT α=0.05)
Rice as the main crop planted by farmer in tidal-swamp field in Barito Kuala Regency had great contribution to the family income and food security. Therefore, the efforts to enhance rice production should consider many factors including the use of superior varieties, water and soil management, good quality of seeds, the availability of chemical fertilizers, and market. Among those factors, the use of high-yielding varieties is a sustainable and affordable strategies for both farmers and local government.

The Indonesian Agency for Agricultural Research and Development, IAARD, has released many high-yielding rice varieties for many categories including irrigated rice varieties, swamp rice varieties, hybrid rice varieties, and rice varieties with certain superiority. The seven varieties tested in this study are part of those released varieties by IAARD. Therefore, this research is also done to promote these high-yielding varieties to farmers as the end user of the technologies.

4. Conclusion

Swamp rice varieties performed better for plant height, while irrigated rice varieties showed higher values for panicles number, filled rice grain, and yield in tidal-swamp rice field. All varieties showed better growth and yield when cultivated in season-1 of 2020. This result supported by the good condition of weather during the study. IR-42 gave the highest yield and can be a good choice to be planted by swamp farmer to increase rice production. Inpari Nutri Zinc is another good option for farmer to be cultivated on tidal-swampland which yields 5.69 t/ha. This new superior rice variety has a special feature with high Zinc content.

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