# Yield performance of high-yield rice varieties in swamp lands of the West Kalimantan border area

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**Abstract.** The planting season has a significant impact on the rice yield in tidal type C. Farmers in Matang Danau Village, Paloh Sub-District, Sambas District, West Kalimantan Province, currently cultivate rice once a year during the rainy season (RS), using the Cilosari, which has a low yield of 2.35 t $ha^{-1}$. To increase the cropping index (CI), water pumping can be utilized during the dry season (DS), along with the use of high-yield varieties. This research aimed to evaluate the yield performance of various high-yield rice varieties in the swamp lands of the West Kalimantan border area. Conducted during the DS (March to July 2018) and RS (October 2018 to February 2019), the research used a randomized complete block design with three replications. The varieties tested included Inpara 1, 2, 3, 4, 6, 8, 9, Inpari 32, and control varieties Margasari and Cilosari. Results indicated significant yield differences among the varieties under swamp conditions, with Inpara 1 achieving the highest yield of 6.6 t $ha^{-1}$, while other varieties ranged from 3.98 to 5.90 t $ha^{-1}$. Inpara 1 showed the most notable yield improvement compared to Margasari and Cilosari. Additionally, yields during the RS were 89.4% higher than those during the DS.

## 1 Introduction

The development of border areas is closely linked to the national development mission, particularly in ensuring the integrity and sovereignty of the Republic of Indonesia, national defense and security, and improving the welfare of the people in the border areas [1]. The Ministry of Agriculture has designated border areas as export-oriented food barns, aiming to sustainably meet domestic food needs while strengthening national food competitiveness to seize export opportunities in the global market [2].

Agricultural development in border areas generally lags behind other areas. The challenges faced in developing the agricultural sector in border areas are relatively complex and vary between areas. Matang Danau Village is one of the border villages in West

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Kalimantan Province. It is located in Paloh Sub-District, Sambas District, 48 km from the district capital, covering an area of approximately 44.01 km².

The main problems in developing tidal swamp land in the border areas for agriculture include: 1) drought during the dry season (DS) and flooding during the rainy season (RS), 2) the use of crop varieties that are not well-adapted to local environmental conditions, 3) the application of fertilizers and soil amendments that do not align with soil nutrient availability or crop requirements, 4) inadequate pest and disease management practices, and 5) inefficient harvest and post-harvest techniques leading to significant yield losses. Implementing specific and integrated tidal swamp land management technologies is expected to increase rice productivity [3].

Currently, farmers in Matang Danau Village plant rice only once a year during the RS, depending entirely on rainfall. However, with the area's water potential, the cropping index (CI) could be increased to twice a year (CI 200) by utilizing tidal water entering the tertiary canals and implementing pumping and irrigation network improvements to distribute water to all rice fields [4]. The varieties currently planted were Cilosari, a high-yield variety released in 1996 by the National Nuclear Energy Agency (BATAN), and Karampai, a local rice variety, both of which produce low average yields of 2.5 t $ha^{-1}$. Additionally, farmers often use uncertified seeds from previous harvests, resulting in less uniform crops. To increase rice productivity in the area, it is necessary to improve plant management practices, including the use of high-yield adaptive varieties.

[5] stated that high-yield varieties are a key technological component in improving the quality and quantity of agricultural production. The development of rice in tidal swamp lands requires varieties that are adaptive to environmental stresses, especially soil acidity, iron toxicity, and water stress [6]. These issues are limiting factors in the development of rice in tidal swamp lands. [7] noted that iron toxicity can reduce yields by up to 75% in sensitive rice varieties, while tolerant varieties may experience a 30% reduction. Therefore, using tolerant varieties is essential for successful rice cultivation in these areas. In response, the Indonesian Agency for Agricultural Research and Development (IAARD) has developed adaptive rice varieties specifically for tidal swamp lands.

Inpara is a high-yield rice variety developed for swamp lands. Adaptation tests of Inpara varieties conducted by [8] in tidal type B in Barito Kuala District recorded yields ranging 2.3 to 4.3 t $ha^{-1}$, while in tidal type C in the same District, yields were lower at 1.26-2.82 t $ha^{-1}$ [9]. These results were obtained with an initial soil pH of 4.62 (acidic) in tidal type B and 3.99 (very acidic) in tidal type C. Among the varieties tested, Inpara 4 achieved the highest yields in both tidal types. Additionally, Inpari varieties, which are typically grown in irrigated lands, can also be introduced to swamp lands with moderate soil acidity, such as in Matang Danau Village.

The objective of this research was to evaluate the yield performance of high-yield rice varieties in tidal type C during both the DS and RS in the border area of West Kalimantan.

## 2 Materials and methods

The research was conducted in Matang Danau Village (1°35'57.26"N 109°12'4.43"E), Paloh Sub-District, Sambas District, West Kalimantan Province, during both the dry season (DS) (March to July 2018) and the rainy season (RS) (October 2018 to February 2019). Using a Randomized Complete Block Design with three replications, the experiment included eight rice varieties: Inpara 1, 2, 3, 4, 6, 8, 9, Inpari 32, along with the reference varieties Margasari and Cilosari. Margasari, an adaptive swamp land variety released in 2000 by Indonesian Swampland Agriculture Research Institute (BALITTRA), is still widely grown by farmers in South Kalimantan. Cilosari, an older high-yield variety introduced in 1996 by

National Nuclear Energy Agency of Indonesia (BATAN), remains the preferred variety for rice cultivation in Matang Danau Village, West Kalimantan.

The land preparation was carried out using a hand tractor, and the experimental plots were set up with dimensions of 10 meters by 30 meters. For land amelioration, dolomite was uniformly applied at a rate of 1.0 t $ha^{-1}$ across each plot. Seedbeds were prepared using the wet nursery method, with each variety sown separately to avoid mixing. Seedlings were transplanted at 25 days after sowing (DAS) using the 2:1 *Legowo* system, with a spacing of 50 cm x 25 cm x 12.5 cm. Fertilization was applied twice: the first application, at 7 days after transplanting (DAT), consisted of 50 kg Urea and 125 kg Phonska per hectare, followed by the same dose at 30 DAT. Pest and disease control was adjusted based on the infestation intensity. Harvesting was carried out when 90% of the grains had ripened uniformly yellow. Each plot was harvested, and the yield was then converted to per hectare. Post-harvest processing involved threshing, cleaning, and drying the grains to a water content of 14%.

The observed variables comprised (1) analysis of soil chemical properties such as pH $H_2O$, organic carbon (C), nitrogen total (N), P-Bray 1 as well as exchangeable cations including calcium (Ca), magnesium (Mg), potassium (K), aluminium (Al), and iron (Fe) conducted before the experiment, (2) the number of tillers during maximum vegetative phase and at harvest, (3) yield, and (4) changes in yield, whether decrease or increase. Observation data were tabulated and subsequently subjected to variance analysis by Minitab. Significant treatments were further assessed using Duncan's Multiple Range Test (DMRT).

# 3 Results and discussions

## 3.1 Soil characteristics

The soil profile indicated that the pyrite (FeS2) layer was located at a depth of > 95 cm from the soil surface, and the pH of the top layer (0-50 cm) was > 4.0. Considering the soil pH and the depth of the pyrite layer, this land was categorized as potential land typology [10]. The depth range of 20-120 cm was predominantly composed of clay texture, while the top layer (0-20 cm) exhibited a silty clay texture. Result from the topsoil analysis (Table 1), representing the root zone of rice plants, indicated acidic soil with a high content of organic matter. It has medium levels of N total, high levels of P-available, and medium levels of exchangeable K. Furthermore, the soil exhibited very low levels of exchangeable Ca and very high levels of exchangeable Mg [9].

According to [10], this land was classified as tidal type C, where spring tides can enter the tertiary canal that runs through the research area during both the rainy season (RS) and dry season (DS). Although the land itself is not inundated, the groundwater table in the RS remains within 50 cm of the surface. Water quality analysis indicated that the tidal water entering the canals is slightly acidic, with a pH of 5.7 and a conductivity of 0.52 mhos $cm^{-1}$ making it suitable for use as irrigation water. During the DS, when rainfall is inadequate to meet the water requirements of crops, farmers rely on tidal water as an alternative irrigation source.

**Table 1.** Initial soil of the research, Matang Danau Village, Paloh District, Sambas Regency, West Kalimantan Province, 2018

| Soil chemical properties | Value | Criteria* |
|---|---|---|
| pH $H_2O$ | 5.30 | Acid |

| | | |
|---|---|---|
| C-organic (%) | 4.31 | High |
| N-total (%) | 0.31 | Medium |
| P-Bray1 (ppm P) | 3.71 | Very low |
| Ca-exchangeable (cmol(+)$kg^{-1}$) | 2.19 | Very low |
| Mg exchangeable (cmol(+)$kg^{-1}$) | 12.30 | Very high |
| K exchangeable (cmol(+)$kg^{-1}$) | 0.44 | Medium |
| Al exchangeable (cmol(+)$kg^{-1}$) | 5.79 | - |

*) [11]

### 3.2 Growth and crop yield

Observations on the growth of ten rice varieties indicated that within a pH range of 5.3, rice crops showed vigorous growth, with vigor scores ranging from 1 to 2, indicating good to very good performance [12]. No symptoms of iron toxicity were detected due to the soil pH being 5.3. According to [13], iron toxicity in rice usually occurs in soils with a pH below 5.8 under aerobic conditions and below 6.5 under anaerobic conditions. The utilization of acid sulfate soils as agricultural land, particularly for rice cultivation, will face challenges such as soil acidity and iron toxicity. Although the pH was under 5.8, the use of ameliorants like lime successfully prevented the appearance of iron toxicity symptoms in the rice crops [14].

**Table 2.** The number of tillers during both the vegetative phase and at harvest in the DS of 2018 and the RS of 2018/19 in Matang Danau Village, Paloh District, Sambas Regency, West Kalimantan Province

| Variety | Number of tillers | | | |
|---|---|---|---|---|
| | Vegetative phase | | At harvest | |
| | DS 2018 | RS 2018/19 | DS 2018 | RS 2018/19 |
| Inpara 1 | 23.6 c | 26.2 ab | 21.7 cde | 16,4 cd |
| Inpara 2 | 29.3 b | 19.0 d | 26.3 a | 19.8 abc |
| Inpara 3 | 20.8 c | 25.2 ab | 19.2 f | 24.8 ab |
| Inpara 4 | 34.9 a | 27.2 a | 26.2 a | 16.6 cd |
| Inpara 6 | 20.1 c | 12.8 e | 20.1 ef | 12.2 d |
| Inpara 8 | 20.1 c | 24.4 abc | 23.9 b | 13.0 d |
| Inpara 9 | 22.8 c | 21.6 bcd | 23.7 b | 18.6 bcd |
| Inpari 32 | 26.1 ab | 26.6 a | 21.9 cd | 25.8 a |
| Margasari | 24.0 c | 26.4 ab | 21.2 de | 26.0 a |
| Cilosari | 24.0 c | 29.2 a | 23.0 bc | 24.8 ab |
| Average | 24.6 | 23.9 | 22.7 | 19.8 |

Note: Numbers in the same column followed by the same letter are not significantly different at the 5% level according to DMRT

The analysis of variance results showed significant differences in the number of tillers during the vegetative phase and at harvest in both the DS of 2018 and the RS of 2018/19 (Table 2). In the DS, the highest number of tillers during the vegetative phase was observed in Inpara 4 (34.9), while in the RS, Cilosari had the highest number (29.2). For productive

tillers at harvest, Inpara 2 (26.3) and Inpara 4 (26.2) showed the highest numbers in the DS, while in the RS, it was the Inpari 32 (25.8) and Margasari (26.0). [15], highlighted the importance of the number of productive tillers as a determinant of rice yield.

The analysis of variance results showed variations in rice yield for DS 2018 and RS 2018/19 (Table 3). In DS, the highest yield was obtained by the Inpara 1 (5.39 t $ha^{-1}$), whereas in RS, the Cilosari achieved the highest yield (8.0 t $ha^{-1}$). Notably, the yield in DS was lower than that in RS. Limited water availability during DS contributed to the reduced yield, despite irrigation efforts. Rice cultivation in the border area indicated that the farmer's planting index can be increased to IP 200 by adopting suitable varieties for DS, such as Inpara 1 and Inpari 32, and ensuring adequate water supply through irrigation. Previously fallow land can be effectively utilized for rice cultivation, yielding between 3.0 and 5.4 t $ha^{-1}$.

In both planting seasons on tidal type C, Inpara 1 had the highest yield at 6.6 t $ha^{-1}$, while Inpara 4 yielded the lowest at 4.96 t $ha^{-1}$. Conversely, on tidal swamp land in South Kalimantan of tidal type B, Inpara 4 achieved the highest yield at 4.3 t $ha^{-1}$, whereas Inpara 1 yielded the lowest at 2.54 t $ha^{-1}$ [8]. The yield potential of Inpara 1 is 6.47 t $ha^{-1}$, while Inpara 4 is 7.6 t $ha^{-1}$. Inpara 1 is resistant to Fe and Al toxicity, while Inpara 4 is tolerant to submergence for up to 14 days during the vegetative stage [16].

**Table 3**. Rice yield during the DS 2018 and RS 2018/19 in Matang Danau Village, Paloh Sub district, Sambas Regency, West Kalimantan Province

| Variety | Rice yield (t $ha^{-1}$) | | average (t $ha^{-1}$) | Yield potential (t $ha^{-1}$) | PHTP (%) |
|---|---|---|---|---|---|
| | DS 2018 | RS 2018/19 | | | |
| Inpara 1 | 5.39 a | 7.80 bc | 6.60 | 6.47 | 102.0 |
| Inpara 2 | 4.00 ab | 7.44 cd | 5.72 | 6.08 | 94.1 |
| Inpara 3 | 3.31 ab | 7.30 cd | 5.31 | 5.60 | 94.8 |
| Inpara 4 | 3.47 ab | 6.45 e | 4.96 | 7.60 | 65.2 |
| Inpara 6 | 3.79 ab | 6.53 e | 5.16 | 6.00 | 86.0 |
| Inpara 8 | 3.84 ab | 7.44 cd | 5.64 | 6.00 | 94.0 |
| Inpara 9 | 3.09 ab | 7.25 d | 5.17 | 5.60 | 92.3 |
| Inpari 32 | 5.33 a | 6.33 e | 5.83 | 8.53 | 68.3 |
| Margasari | 2.44 b | 5.52 f | 3.98 | 4.50 | 88.4 |
| Cilosari | 3.79 ab | 8.00 ab | 5.90 | 6.50 | 90.8 |
| Average | 3.85 | 7.01 | 5.43 | 5.69 | 87.6 |

Note: Numbers in the same column followed by the same letter are not significantly different at the 5% level according to DMRT. PHPT = comparison of the average yield to the yield potential

Except for Inpara 4 and Margasari, the average yield of the ten tested rice varieties exceeded 5.0 tons per hectare. [15] reported that Inpara 3 produced a yield of 5.3 t $ha^{-1}$ in tidal type C acid sulphate soil of Sanggau Regency, West Kalimantan. In addition to its strong adaptability, the firm texture of its rice is preferred by local consumers. In West Kalimantan, the average yield of Inpara 3 was 5.43 t $ha^{-1}$, while in South Kalimantan, it was 3.09 t $ha^{-1}$ [8]. This yield difference is primarily due to variations in soil fertility. In the tidal swamp areas of West Kalimantan, the soil pH reached 5.3 with an iron content of 150 ppm, whereas in South Kalimantan, the soil pH measured 4.62 with an iron content of 439 ppm. Notably, iron toxicity symptoms were not observed in rice plants in West Kalimantan, facilitating more optimal plant growth and yields approaching their potential. Conversely, testing in South Kalimantan exhibited symptoms of iron toxicity.

Iron toxicity is one of the main problems often encountered in tidal swamp areas and can reduce land productivity and rice crop yields by 30-60% [17, 18]. Consequently, the productivity of high-yield rice in these areas remains relatively low, typically averaging 3-4 ton $ha^{-1}$ [19], well below its potential yield of 5-7.6 t $ha^{-1}$ [16].

Potential yield represents the maximum yield achievable by a variety under optimal climate conditions for plant growth, without any environmental constraints [15]. In the tidal swamp areas of West Kalimantan, the average potential harvest index (PHTP) reaches 87.6%, indicating a high potential yield. In contrast, the PHTP in tidal swamp areas of South Kalimantan was 50.7% for tidal type B [8] and 33.1% for tidal type C [9]. These variations in PHTP highlight the maximum production capacity of a variety in a specific location under particular environmental conditions.

Based on the changes in yield between the DS and the RS (PH1), rice crops produce higher yields during the RS than in the DS. The average yield of the ten varieties was 3.85 ton $ha^{-1}$ in the DS and 7.01 ton $ha^{-1}$ in the RS, indicating an increase in yield across all varieties. Inpara showed the highest yield increase at 134.6%, while Inpari 32 had the smallest gain at 18.8%. In Matang Danau Village and other parts of West Kalimantan, rice cultivation predominantly occurs during the RS, with limited planting during the DS in certain areas (Table 3). By contrast, in South Kalimantan, the DS was the primary growing season, with 90% of cultivation using local rice varieties. Moreover, rice yields during the DS generally surpass those in the RS.

The yield performance of all varieties exceeds that of Margasari, as indicated by the PH 2 value. The highest yield increase was obtained by Inpara 1, with a 65.8% increase, while Inpara 4 had the lowest increase at 24.6%. Margasari is a variety derived from crossing local varieties Siam Unus and Cisokan. Its harvesting age aligns closely with Cisokan, around 120-125 days, while its yield and firm rice flavor resemble Siam Unus [19].

**Table 4**. Comparison of the changes in yield between the DS and the RS (PH 1), with Margasari as a reference (PH 2), and Cilosari (PH 3) during the DS of 2018 and the RS of 2018/19 in Matang Danau Village, Paloh District, Sambas Regency, West Kalimantan Province

| Variety | PH 1 (%) | PH 2 (%) | PH 3 (%) |
|---|---|---|---|
| Inpara 1 | 44.7 | 65.8 | 11.9 |
| Inpara 2 | 86.0 | 43.7 | -3.1 |
| Inpara 3 | 120.5 | 33.4 | -10.0 |
| Inpara 4 | 85.9 | 24.6 | -15.9 |
| Inpara 6 | 72.3 | 29.6 | -12.5 |
| Inpara 8 | 93.8 | 41.7 | -4.4 |
| Inpara 9 | 134.6 | 29.9 | -12.3 |
| Inpari 32 | 18.8 | 46.5 | -1.2 |
| Margasari | 126.2 | - | - |
| Cilosari | 111.1 | - | - |
| Rataan | 89.4 | 39.4 | -5.9 |

Note: PH 1 represents the increase in yield during the RS compared to the DS, PH 2 signifies the yield increase of each variety compared to Margasari, and PH 3 indicates the yield increase of each variety compared to Cilosari.

According to the PH 3 value, only Inpara 1 exhibits a positive yield increase, while all other varieties exhibit declines. This suggests that, based on the average yield of both planting seasons, only Inpara 1 yields higher than Cilosari. With appropriate cultivation technology management, Cilosari can yield up to 3.79 ton $ha^{-1}$ of yield in the DS and 8.00 ton $ha^{-1}$ in the RS. However, with farmer management alone, the yield was only 2.35 ton $ha^{-1}$. Research has shown that, by applying appropriate cultivation technologies, selecting adaptive varieties, and implementing proper harvest and post-harvest management, rice yields in tidal swamp areas can reach 4-5 t $ha^{-1}$ [20]. Therefore, Cilosari remains a recommended variety for cultivation in Matang Danau Village, provided it is managed with careful cultivation techniques and supported by a reliable seed source. Each area requires

location-specific varieties because not all varieties exhibit good adaptation in all locations [21].

Based on this research, the Inpara 1 emerges as a promising alternative for rice cultivation in Matang Danau Village. Incorporating high-yield varieties into rotation strategies can effectively interrupt the life cycles of pests and plant diseases, thereby diminishing the intensity of pest attacks.

## 4 Conclusion

The evaluation of the ten rice varieties indicates that the Inpara 1 produced the highest yield at 6.6 ton $ha^{-1}$, while the other varieties yielded between 3.98 and 5.90 t $ha^{-1}$. In comparison to the reference varieties Margasari and Cilosari, the Inpara 1 exhibited the most significant yield increase. Furthermore, the yield during the rainy season (RS) was 89.4% higher than that during the dry season (DS). Future research should focus on the relationship between the number or capacity of water pumps and water availability for rice plants, particularly those cultivated during the DS.

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