The adaptability of rice varieties on tidal swampland in South Kalimantan

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Abstract. Swampland was marginal land with considerable potential for rice farming. The key solution to overcome swampland constraints is nutrient, water, and plant management as well as the use of adaptive rice varieties. Inpara (Inbred swamp rice) is a variety released for adaptation to swampland. This research aimed to evaluate the adaptability of Inpara varieties in tidal swampland. The research was conducted at potential acid sulphate soil (Karang Bunga village, Barito Kuala regency) and actual acid sulphate soil (Barambai Kolam Kanan village, Barito Kuala regency). Randomized block design with three replications was applied to examine rice varieties. Data were collected and analyzed by variance analysis, if it is significant it will be tested with DMRT test. The result showed that there was a variation yield and adaptation (Fe score) among varieties tested. Some of the superior adaptive rice varieties were Inpara 1, Inpara 3, Inpara 4, Inpara 6, and Inpara 9 in tidal swampland. The average yield in potential acid sulphate soil was 37.9% higher than that of actual acid sulphate soil. The implication of this research was the variety of Inpara 1, Inpara 3, Inpara 4, Inpara 6, and Inpara 9 can be used as substitute varieties in the tidal swampland.

1. Introduction

Swamplands are marginal lands with considerable potentials for agricultural development, especially rice cultivation. The total area of swampland in Indonesia is estimated about 20.14 million ha of tidal swampland and 13.30 million ha of swampland [1] and about 33.93 million ha according to [2]. The main constraints in tidal swampland are soil and water acidity, macro per micronutrient deficiency, ferrum (Fe), aluminum (Al), and sulfate (SO₄) toxicity [3], while the main constraints in swampland are drought and waterlogging [4]. The constraints of marginal land are more than that of dry land, irrigated land, and rainfed land. These constraints caused low rice productivity on swampland.

Increasing rice productivity in a swampland is by improving water, nutrient, and crop management as well as the use of adaptive rice varieties. The combination of these technology components can increase rice yield on swampland as reported by [5] on water management, [6] on nutrient management, [7] on crop management, and [8] on adaptable varieties.

Local rice variety was the adaptable variety on tidal swampland and dominate almost 90% of rice cultivation during the dry season in the swampland of South Kalimantan. The cropping index for tidal swampland is generally still 1, by planting Local rice varieties. This Local rice is preferred to be planted because of its adaptation to waterlogged conditions, soil acidity, and rice texture. However, Local rice has long-lived plants (8-10 months), and its productivity is low (2.0-2.5 t ha⁻¹). Several Local rice varieties existing in South Kalimantan, are Siam Mayang, Siam Unus, Siam Kupang, Siam Karang Dukuh, and several other cultivars with various names [9]. To increase the cropping index (CI) from CI
1 (Local rice) to CI 2 (Local rice- new rice varieties) in tidal swampland, it can be done through the use of new adaptive variety and early maturity variety on the second crop.

High yielding variety is one of the component technologies that is easy for farmers to adopt. Inpara or Inbred rice swampland is a variety released by the Indonesian Agency for Agricultural Research and Development (IAARD) for adaptation in swampland and earlier harvesting (115 to 135 days after sowing, DAS). Nowadays, IAARD has released 10 Inpara varieties with various characteristics, including plant morphology, grain shape, rice texture, rice color, pest resistance, and their adaptation to swampland [10].

To determine its adaptability in tidal swampland, it is necessary to evaluate its adaptation. This research aimed to evaluate the adaptability of Inpara varieties on potential acid sulphate soil (PASS) and actual acid sulphate soil (AASS) in South Kalimantan.

2. Materials and methods

The field research was conducted at two types of tidal swampland, i.e. potential acid sulphate soil (Karang Bunga village, Mandastana district, Barito Kuala regency) and actual acid sulphate soil (Barambai Kolam Kanan village, Barambai district, Barito Kuala regency) on the dry season of 2016. Randomized block design with three replications was applied to examine nine Inpara varieties (Inpara 1, 2, 3, 4, 5, 6, 7, 8, and 9) and check varieties used were Margasari and Ciherang (PASS) and Margasari and Lokal (AASS).

2.1. Materials

The rice seed used were Inpara 1 to 9, Margasari, and Ciherang from Indonesian Center for Rice Research (ICRR) and Indonesian Swampland Agricultural Research Institute (ISARI) and Local variety from farmer’s rice field. The input production used were dolomite lime, N, NPK fertilizer, herbicides, and pesticides.

2.2. Methods

Land preparation was done mechanically using a tractor. Amelioration using dolomite 1 t ha⁻¹ was applied during tillage. Planting area is based on treatment design, every plot has a size of 4 m x 10 m, plant spacing “legowo 2:1” (25-40) cm x 12.5 cm. The seedling used a wet system with the seedling age of 25 day after sowing (DAS). Based fertilizer with a dosage of 60 kg N + 37.5 kg P + 37.5 kg K per hectare at 7 days after planting (DAP). The second and third fertilization were at 30 and 60 DAP with a dosage of 22.5 kg N + 22.5 kg P + 22.5 kg K per ha. Intensive plant management was done to obtain optimum growth and yield. Harvest has been done when 90% of panicles are filled.

Parameters tested: (1) Physical (texture) and chemical properties of soil (pH, Organic C, total N, Phosphorus, Exch. Ca, Exch. Mg, Exch. K, Exch. Na, CEC, and Fe²⁺), (2) Iron toxicity score, (3) Plant growth (plant height, number of tillers), (4) Grain yield ha⁻¹, (5) Harvesting time (DAP). IRRI classification crop tolerance to Fe toxicity in six groups, i.e. score 0= growth and tillering nearly normal with no spot or discoloration, score 1= Growth and tillering nearly normal; reddish-brown spots or orange discoloration on tips of older leaves, score 3= Growth and tillering nearly normal; older leaves reddish-brown, purple or orange-yellow, score 5= Growth and tillering retarded; many leaves discolored, score 7= Growth and tillering ceases; most leaves discolored or dead, score 9= Almost all plants dead or dying [11].

3. Results and discussion

3.1. Chemical properties

The research was conducted in PASS (Karang Bunga village) and AASS (Barambai Kolam Kanan village). The soil of the study sites classified as Sulfaquent (type B) and Sulfaquett (type C) based on [12]. The limiting factors for the two types of tidal swampland are soil acidity, low base saturation, and Fe concentration (table 1). Sahrawat in [13] reported that iron toxicity is an important growth-limiting
factor in Ultisol, Sulfaquent soil, acidic Oxisol, and some Histosol. The Fe concentration is very high in both locations and has the potential of Fe toxicity. Sahrawat et al. in [14] stated that Fe concentration exceeds 100 ppm at pH 3.7 or exceeds 300 ppm at pH 5 caused Fe toxicity. The most significant differences between those types are soil acidity, nutrient status, and acid saturation (Al³⁺ and H⁺).

High soil acidity can inhibit the absorption of nutrients by plants. Therefore soil acidity must be reduced, and one of them is with lime application. Liming can change the soil’s acidity to nearly neutral levels and increase the availability of nutrients for plants [15,16], especially Ca and Mg. Liming can also improve soil structure, because of the high concentration of Ca that can increases the ionic strength in the soil solution, which further increases the flocculation of clay minerals, resulting in stable aggregate formation [17].

In this study, dolomite lime is used at a dose of 1 t ha⁻¹. After completion of the harvesting, it is known that the applied lime resulted in increased soil pH and decreased the concentrations of Fe. The increase in soil pH in PASS was 0.28 units (4.62 to 4.90) and in AASS was 0.35 units (3.99 to 4.34), respectively. While, the decrease in the Fe concentration (mg kg⁻¹) in PASS and AASS was 270.49 (439.56 to 169.07) and 37.89 (181.89 to 144.00), respectively (table 1). Fe toxicity had a negative effect on plant growth and production. Liming increased yield significantly on rice production [18], on corn production [19], and soybean production [20]. Potential acid sulphate soil has better and more suitable developed as agricultural land [2].

**Table 1.** Soil analysis at PASS (Karang Bunga village) and AASS (Barambai Kolam Kanan village), Barito Kuala regency, South Kalimantan, dry season of 2016.

| Chemical properties       | Methods                          | Tidal swampland          |
|---------------------------|---------------------------------|--------------------------|
|                           |                                 | PASS | AASS |
| Initial soil analysis     |                                 |      |      |
| pH H₂O (1:2:5)            | Water extract, Electrode Glass  | 4.62 (acid) | 3.99 (very acid) |
| Organic C (%)             | Walkley and Black               | 5.73 (very high) | 3.71 (high) |
| Total N (%)               | Kjeldahl                        | 0.46 (medium) | 0.38 (medium) |
| Phosphorus (mg kg⁻¹ P)    | Bray 1, Spectrofotometer        | 10.83 (medium) | 13.76 (high) |
| Exch. Ca (cmol(+) kg⁻¹)   | NH₄Oac 1N pH 7, AAS             | 1.49 (very low) | 0.36 (very low) |
| Exch. Mg (cmol(+) kg⁻¹)   | NH₄Oac 1N pH 7, AAS             | 1.22 (medium) | 0.89 (low) |
| Exch. K (cmol(+) kg⁻¹)    | NH₄Oac 1N pH 7, AAS             | 0.15 (low) | 0.25 (low) |
| Exch Na (cmol(+) kg⁻¹)    | NH₄Oac 1N pH 7, AAS             | 0.39 (low) | 0.41 (medium) |
| CEC (cmol(+) kg⁻¹)        | NH₄Oac 1N pH 7, Destillation    | 53.40 (very high) | 51.8 (very high) |
| Fe²⁺ (mg kg⁻¹)            | NH₄Oac 1N pH 4.8, AAS           | 439.56 (very high) | 181.89 (high) |
| Base saturation (%)       | Pipette                         | 6.09 (very low) | 3.69 (very low) |
| Texture                   |                                 | Clay | Silty clay |
| Sand (%)                  |                                 | 3.23 | 5.47 |
| Ash (%)                   |                                 | 26.02 | 43.44 |
| Clay (%)                  |                                 | 70.76 | 51.09 |
| Analysis after harvest    |                                 |      |      |
| pH (1:2:5)                | Water extract, Electrode Glass  | 4.90 | 4.34 |
| Fe²⁺ (mg kg⁻¹)            | NH₄Oac 1N pH 4.8, AAS           | 169.07 (high) | 144.00 (high) |

**3.2. Plant growth and yield**

Iron toxicity is a physiology symptom on a plant caused by excessively dissolved iron and as a limiting factor in tidal swampland. The score of Fe toxicity on the vegetative and generative phase showed that rice plant growth had no significant difference in both phase-in PASS. All Inpara varieties showed no symptoms with a score of 0. All varieties tested showed plant growth and tillering nearly normal. Iron
toxicity symptoms began to appear on both phases in AASS. There was a variation score among varieties tested. The lowest score was showed by Inpara 1 and Inpara 9 (score 0) in the vegetative phase and Inpara 4 and Inpara 9 (score 1) in the generative phase (table 2). Bronzing is the common symptom that appears on Fe toxicity [11] and its value varies depending on variety, Fe toxicity intensity, phase of plant growth, nutrient status [21].

Inpara 1 and Inpara 9 showed no Fe toxicity symptoms, otherwise Inpara 4 and 9 showed growth and tillering nearly normal, reddish-brown spots or orange discoloration on tips of older leaves [11]. Inpara 1 derived from crossing between Batang Ombilin/IR9884-54-3 and Inpara 9 derived from crossing between Mesir/IR60080-23 [10]. Inpara 4 is introduced from IRRI and this variety is derived from the Swarna Sub-1 line (IR05F101) which is tolerant of 14 days immersion in the vegetative phase [22].

The highest score of Fe toxicity showed by Inpara 3, Inpara 5, and Inpara 8 with a score of 3.7 in AASS. Those varieties showed the symptoms growth and tillering nearly normal, older leaves of reddish-brown, purple or orange-yellow colour. Inpara 5 variety is not recommended to be planted in tidal swampland, because it is not resistant to Fe toxicity and susceptible to blast disease [23]. Ferrum toxicity resulted in alterations of biochemical and physiological processes of rice plants and consequently their vegetative, generative, and rice yield. Decreasing yield caused by Fe toxicity varied between 30 to 60% as reported by [24] and 30 to 100% [22] depending on the variety tolerance, the intensity of toxicity, and soil fertility.

### Table 2. Fe toxicity scoring on plant growth on PASS (Karang Bunga village) and on AASS (Barambai Kolam Kanan village), Barito Kuala Regency, South Kalimantan, dry season of 2016.

| Varieties | Vegetative phase | Generative phase |
|-----------|------------------|------------------|
|           | PASS  | AASS  | PASS  | AASS  |
| Inpara 1  | 0.0 ns | 0.0 e | 2.3 ns | 2.3 abc |
| Inpara 2  | 0.0 ns | 1.3 cde | 2.0 ns | 3.0 ab |
| Inpara 3  | 0.0 ns | 2.3 bcd | 1.0 ns | 3.7 a |
| Inpara 4  | 0.0 ns | 0.7 de | 1.7 ns | 1.0 c |
| Inpara 5  | 0.0 ns | 2.3 bcd | 2.3 ns | 3.7 a |
| Inpara 6  | 0.0 ns | 6.3 a | 1.0 ns | 2.3 abc |
| Inpara 7  | 0.0 ns | 3.0 bc | 1.0 ns | 3.0 ab |
| Inpara 8  | 0.3 ns | 1.7 e | 1.0 ns | 3.7 ab |
| Inpara 9  | 0.0 ns | 0.0 e | 1.0 ns | 1.0 c |
| Margasari | 0.0 ns | 1.0 cde | 1.0 ns | 1.7 bc |
| Ciherang  | 0.0 ns | - | 1.7 ns | - |
| Lokal     | - | 3.7 b | - | 1.7 bc |
| Means     | 0.1  | 2.3  | 1.5  | 2.6  |

Note: the same number in the same column showed that there were no differences according to DMRT test 5%

Plant growth is influenced by environmental conditions, nutrient availability, variety tolerance, diseases, and weather condition. High iron toxicity will affect plant growth, especially on roots, causing absorption and translocation of nutrient distraction and the abnormal formation of plant organs and tissues. Ferrum toxicity symptoms are called bronzing which caused old leaves to be reddish-brown, thus affecting the photosynthesis process and plant growth, ie. plant height, the number of tillers per panicles, and rice yield. The concentration of Fe 300 to 1,500 ppm can be caused by Fe toxicity [25]. In these experiments the Fe concentration after liming 169.07 ppm in PASS and 144.00 ppm in AASS, so it is still bellowed the critical limit (table 1).

Variant analysis result of plant height showed that there were differences among Inpara varieties tested on three-phases of the observation. The mean plant height in PASS is higher than that of AASS. The average plant height in the vegetative, generative, and harvest phases in PASS were higher 20.8%, 19.6%, and 9.5% compared to the same parameters in AASS. It's related to soil fertility on both types (table 1).
The highest plant height among Inpara varieties tested is shown by Inpara 9 in both types, i.e. 115.6 cm in PASS and 105.5 cm in AASS (table 3). Inpara 9 variety is derived from crossing between Mesir/IR60080-23. The check variety, Margasari, was a variety derived from crossing between Local varieties Siam Unus and high yielding variety Cisokan. The result of crosses between Local variety (8-10 months) and Cisokan variety (4 months) produced Margasari variety with a harvesting time of 4 month and rice texture similar to Local variety [10]. The weakness of Margasari variety is easily fallen. Its plant morphology is similar to Local variety which is slightly scattered with less strong stems. At high N fertilization, Margasari variety collapses easily [23]. Based on [11], the plant height of Inpara and Cihernang varieties was categorized low (<110 cm), while that of Margasari variety is categorized moderate (110-130 cm).

Table 3. Plant height on several rice varieties on PASS (Karang Bunga village) and on AASS (Barambai Kolam Kanan village), Barito Kuala Regency, South Kalimantan, dry season of 2016.

| Varieties       | Vegetative phase | Generative phase | Harvesting time |
|-----------------|------------------|-----------------|-----------------|
|                 | PASS | AASS | PASS | AASS | PASS | AASS |
| Inpara 1        | 52.3 b | 54.9 abc | 94.0 b | 86.9 bc | 95.6 d | 96.1 de |
| Inpara 2        | 56.5 b | 39.9 e | 97.9 b | 72.8 d | 99.2 c | 97.3 cde |
| Inpara 3        | 62.0 ab | 48.3 b-e | 94.0 b | 80.7 cd | 101.8 c | 92.3 ef |
| Inpara 4        | 44.1 c | 31.3 f | 74.9 c | 57.5 e | 94.4 d | 85.7 fg |
| Inpara 5        | 48.7 bc | 50.5 bcd | 88.6 bc | 85.4 bc | 90.1 e | 85.8 fg |
| Inpara 6        | 58.9 ab | 47.4 cde | 101.1 ac | 87.6 bc | 102.0 c | 75.4 h |
| Inpara 7        | 54.5 b | 43.2 de | 97.2 b | 84.4 bc | 97.0 d | 84.8 g |
| Inpara 8        | 60.8 ab | 47.5 cde | 107.6 ab | 82.0 cd | 115.3 b | 102.0 cd |
| Inpara 9        | 66.8 a | 57.4 ab | 115.8 a | 95.6 ab | 115.6 b | 105.5 c |
| Margasari       | 57.9 ab | 46.1 cde | 117.3 a | 93.7 ab | 125.9 a | 121.4 b |
| Cihernang       | 59.3 | | 98.0 b | | 101.3 | |
| Lokal           | - | 60.9 a | - | 104.7 | - | 142.9 a |
| Means           | 56.1 | 48.1 | 98.4 | 84.6 | 102.9 | 91.4 |

Note: the same number in the same column showed that there were no differences according to DMRT test 5%.

Ferrum toxicity not only affects plant height but also affects the formation of tillering. Ota and Yamada in [13] reported there are two types of bronzing, namely, type 1 and type 2. Type 1 occurs 1 to 2 weeks after planting (WAP) with symptoms the leaves turning to be brown or reddish-brown and type 2 occurs 1 to 2 months after planting (MAP) with symptoms of inhibition of tiller formation and panicles.

Variant analysis result of the number of tillers on vegetative and generative phase and the number of panicles on harvesting time showed that there were differences among Inpara varieties tested in tidal swampland. The mean number of tiller and number of panicles in type B overflow were higher than that of in type C overflow. The average number of tiller in the vegetative and generative and the number of panicles on harvesting time in PASS were higher 32.5%, 29.5%, and 34.4% compared to the same parameter in AASS (table 4). It's related to soil fertility on both types (table 1). [26] reported that Fe toxicity caused root damage, i.e short, few, and dark brown root. Its nutrient absorption is disturbed so that it affects plant height and number of tillers. Based on [11], the number of tiller of Inpara tested is categorized medium with 10 to 19 tillers per plant. The highest number of tillers and panicles is shown by Inpara 4 and 5.

The number of the tiller varieties tested on the vegetative phase in PASS was the same as that of Margasari and Cihernang varieties, while in AASS the number of tiller of Inpara 1 and Inpara 5 was higher than Margasari and Local varieties. The number of tiller of the varieties tested on the generative phase in PASS there was only Inpara 8 variety that showed the lower than both check varieties, while in AASS the number of tiller of Inpara 4 was higher than both check varieties. The highest number of panicles was shown by Inpara 5, but the filling of panicles was not optimal. It's related to the susceptibility of Inpara 5 to Fe toxicity [23].
Table 4. Number of tiller and panicles of several rice varieties on PASS (Karang Bunga village) and on AASS (Barambai Kolam Kanan village) Barito Kuala Regency, South Kalimantan, dry season of 2016.

| Varieties | Number of tillers on vegetative phase | Number of tillers on generative phase | Number of panicles on harvesting time |
|-----------|--------------------------------------|--------------------------------------|--------------------------------------|
|           | PASS       | AASS       | PASS       | AASS       | PASS       | AASS       |
| Inpara 1  | 17.1 ab    | 18.7 a     | 13.0 bc    | 10.4 c     | 11.6 bc    | 9.1 bc     |
| Inpara 2  | 16.8 ab    | 11.8 b     | 12.9 bc    | 11.9 bc    | 11.8 bc    | 9.1 bc     |
| Inpara 3  | 14.5 ab    | 9.6 c      | 11.7 bc    | 8.7 de     | 11.3 bc    | 7.8 cd     |
| Inpara 4  | 18.1 ab    | 13.2 b     | 15.9 ab    | 14.0 a     | 14.2 ab    | 11.8 a     |
| Inpara 5  | 17.2 ab    | 19.1 a     | 16.5 a     | 11.9 ab    | 15.4 a     | 11.1 a     |
| Inpara 6  | 13.3 b     | 8.4 c      | 12.2 bc    | 8.2 e      | 10.9 bc    | 7.2 c      |
| Inpara 7  | 16.9 ab    | 9.9 e      | 13.9 b     | 10.0 cd    | 12.6 bc    | 10.5 ab    |
| Inpara 8  | 14.2 ab    | 9.2 c      | 11.1 c     | 8.7 de     | 10.1 c     | 7.3 cd     |
| Inpara 9  | 16.3 ab    | 9.8 c      | 13.4 bc    | 10.1 cd    | 14.0 ab    | 7.9 cd     |
| Margasari | 19.0 a     | 12.8 b     | 15.1 ab    | 11.1 bc    | 13.3 ab    | 11.2 a     |
| Ciherrang | 15.9 ab    | -          | 12.6 bc    | -          | 10.6 bc    | -          |
| Lokal     | -          | 12.8 b     | -          | 12.4 ab    | -          | 10.7 ab    |
| Means     | 16.3       | 12.2       | 13.4       | 10.7       | 12.4       | 9.4        |

Note: the same number in the same column showed that there were no differences according to DMRT test 5%.

Yield performance is an important parameter to determine the superiority of variety. The yield is also the resultant of the genetic and environmental factors for plant growth. The variant analysis result of yield showed that there were no differences in yield between Inpara varieties in PASS. All varieties have the same yield with check varieties of Margasari and Ciherrang varieties and among varieties tested with range of 2.34 to 4.3 t ha\(^{-1}\). In AASS, there were no differences with check varieties of Margasari and Ciherrang, while among varieties were different. Inpara 3, Inpara 5, and Inpara 8 yield were lower than Inpara 4 yield respectively.

The yield average of varieties tested was lower than that of a varietal description. This condition is due to the sub-optimal of environmental conditions (high soil acidity and low nutrient availability). Liming application with dosage of 1 t ha\(^{-1}\) and inorganic fertilization 50 kg Urea + 550 kg NPK per hectare is still not enough to support optimal plant growth. The dosage of fertilizer used was recommended dosage based on the Decision Support System (DSS) rice fertilization program and in this condition the dose is still not optimal.

Based on the average yield, Inpara 4, Inpara 6, Inpara 3, Inpara 1 and Inpara 9 varieties showed yield more than 2.5 t ha\(^{-1}\). [23] reported that Inpara 1 and Inpara 6 varieties have a good adaptation in swampy land yielding up to 2.118 t ha\(^{-1}\) and 2.275 t ha\(^{-1}\) with an increased yield of 1.9% and 9.5% higher than Ciherrang variety. Inpara 5 variety is not adaptive in swampy land. Inpara 4 is an introduced variety by IRRI which has an upright type, medium grain shape, rice taste 'pera', average yield of 4.7 t ha\(^{-1}\) with a potential yield of 7.6 t ha\(^{-1}\). This variety has tolerance for 14 days of immersion in the vegetative phase and it is recommended to be planted in tidal swampland, swampy land, and flood-prone rice field.

Inpara 6 is the result of crossing IR64/IRBB21/IR51672 has an upright type, medium grain shape, rice taste 'pera', average yield of 4.7 t ha\(^{-1}\) with a potential yield of 6.0 t ha\(^{-1}\). This variety is tolerant of Fe toxicity and recommended to be cultivated in PASS and swampy land. Inpara 3 is the result of crossing IR69256/IR43524-55-1-3-2 has an upright type, slender grain shape, rice taste 'pera', average yield of 4.6 t ha\(^{-1}\) with a potential yield of 5.6 t ha\(^{-1}\). This variety tolerant to Fe and Al toxicity and recommended to cultivated in tidal swampland, swampy land, and irrigated rice field. Inpara 1 is the result of crossing Batang Ombilin/IR9884-54-3 has an upright type, medium grain shape, rice taste 'pera', average yield of 5.0 t ha\(^{-1}\) with a potential yield of 6.47 t ha\(^{-1}\). This variety is tolerant of Fe and Al toxicity and recommended to be cultivated in tidal swampland and swampy land. Inpara 9 is the
result of crossing Mesir/IR6008023 has an upright type, slender grain shape, rice taste ‘pera’, average yield of 4.2 t ha\(^{-1}\) with a potential yield of 5.6 t ha\(^{-1}\). This variety is tolerant of Fe toxicity and recommended to be cultivated in tidal swampland, shallow and medium freshwater swampy land [10].

The average yield in PASS was 37.9% higher than that of AASS (table 5). Soil acidity, nutrient deficiency, and iron toxicity were the main constraints in both typologies (table 1). There were significant different types of overflow between those typologies. The type of water overflow in the PASS is type B which is affected by spring tides, while in the AASS is type C which is no influence of the tide. The washing process for toxins such as Fe, SO\(_4\) and other organic acids in type B is smoother than in type C. Water sources in type B come from the flow of river water and rainwater, while in type C the main source of water comes from rainwater. This difference in water management is thought to be the cause of the large yield gap between the two land typologies. [3] also stated that the soil fertility in PASS is higher than that of AASS.

**Table 5.** The yield of several rice varieties on PASS (Karang Bunga village) and on AAS (Barambai Kolam Kanan village), Barito Kuala Regency, South Kalimantan, dry season of 2016.

| Varieties | Yield of rice varieties (t ha\(^{-1}\)) | Yield mean\(^1\) (t ha\(^{-1}\)) | Yield differences\(^2\) (t ha\(^{-1}\)) | Yield decreasing\(^3\) (%) |
|-----------|----------------------------------------|-------------------------------|-----------------------------------------|--------------------------|
|           | PASS                                   | AASS                          |                                         |                          |
| Inpara 1  | 2.54 ns                                 | 2.53 ab                       | 2.54 (4)                                | 0.01                     | 0.39                     |
| Inpara 2  | 2.73 ns                                 | 2.12 abc                      | 2.43 (7)                                | 0.61                     | 22.34                    |
| Inpara 3  | 3.70 ns                                 | 1.43 c                        | 2.57 (3)                                | 2.27                     | 61.35                    |
| Inpara 4  | 4.30 ns                                 | 2.82 a                        | 3.56 (1)                                | 1.48                     | 34.42                    |
| Inpara 5  | 2.34 ns                                 | 1.26 c                        | 1.80 (10)                               | 1.08                     | 46.15                    |
| Inpara 6  | 3.83 ns                                 | 2.18 abc                      | 3.01 (2)                                | 1.65                     | 43.08                    |
| Inpara 7  | 2.40 ns                                 | 2.15 abc                      | 2.28 (9)                                | 0.25                     | 10.42                    |
| Inpara 8  | 3.60 ns                                 | 1.33 c                        | 2.47 (6)                                | 2.27                     | 63.06                    |
| Inpara 9  | 3.48 ns                                 | 1.52 bc                       | 2.50 (5)                                | 1.96                     | 56.32                    |
| Margasari | 2.51 ns                                 | 2.15 abc                      | 2.33 (8)                                | 0.36                     | 14.34                    |
| Ciharang  | 3.37 ns                                 | -                             | -                                        | -                        | -                        |
| Lokal     | -                                      | 2.13 abc                      | -                                        | -                        | -                        |
| Means     | 3.09                                    | 1.97                          | 2.55                                    | 1.19                     | 37.9                     |

Note: the same number in the same column showed that there were no differences according to DMRT test.

\(^1\) Yields on PASS = the yield on AASS; \(^2\) yield differences per yield AASS.

The yield varietal of varieties tested in the two typologies was low, i.e. 3.09 t ha\(^{-1}\) in PASS and 1.97 t ha\(^{-1}\) in AASS, whereas based on the description of potential crops, the yield of Inpara variety could reach 4.5 to 7.6 t ha\(^{-1}\) (table 6). The average yield achieved in PASS and AASS typologies was 0.51% and 0.33% compared to the yield potential in the variety description. The average yield achieved in PASS typology higher than that of AASS typologie. The yield achieved by Inpara 5 variety was the lowest among varieties tested on both typologies. Inpara 5 variety was not resistant of iron toxicity, so it was not recommended to be planted in tidal swampland.

Harvesting time in both typologies was earlier than that of in the varietal description. The plant harvested 7 to 8 days earlier than the varietal description (table 7). The harvesting time was very much influenced by genetics factors, so that it didn’t change much even though environmental condition change.
Table 6. Differences of yield in both typologies compared with potential yield on varietal descriptions.

| Varieties | Yield of rice varieties (t ha⁻¹) | Yield potential on varietal descriptions (t ha⁻¹) | Yield of PASS/YPVD | Yield of AASS/YPVD |
|-----------|---------------------------------|-----------------------------------------------|-------------------|------------------|
|           | PASS                            | AASS                                         |                   |                  |
| Inpara 1  | 2.54                            | 2.53                                         | 6.47              | 0.39             | 0.39             |
| Inpara 2  | 2.73                            | 2.12                                         | 6.08              | 0.45             | 0.35             |
| Inpara 3  | 3.70                            | 1.43                                         | 5.60              | 0.66             | 0.26             |
| Inpara 4  | 4.30                            | 2.82                                         | 7.60              | 0.57             | 0.37             |
| Inpara 5  | 2.34                            | 1.26                                         | 7.20              | 0.33             | 0.18             |
| Inpara 6  | 3.83                            | 2.18                                         | 6.00              | 0.64             | 0.36             |
| Inpara 7  | 2.40                            | 2.15                                         | 5.10              | 0.47             | 0.42             |
| Inpara 8  | 3.60                            | 1.33                                         | 6.00              | 0.60             | 0.22             |
| Inpara 9  | 3.48                            | 1.52                                         | 5.60              | 0.62             | 0.27             |
| Margasari | 2.51                            | 2.15                                         | 4.50              | 0.56             | 0.48             |
| Ciherang  | 3.37                            | -                                            | 6.15              | 0.55             | -                |
| Lokal     | -                               | 2.13                                         | -                 | -                |                  |
| Means     | 3.09                            | 1.97                                         | 6.02              | 0.51             | 0.33             |

Note: ¹YPVD = Yield potential on varietal descriptions

Table 7. Different harvesting time in both typologies compared with harvesting time on varietal descriptions.

| Varieties | Harvesting time of rice varieties | Harvesting time on varietal descriptions (DAS) | Harvesting time of PASS/HTVD | Harvesting time of AASS/HTVD |
|-----------|----------------------------------|-----------------------------------------------|-------------------------------|-------------------------------|
|           | PASS                             | AASS                                         |                               |                               |
| Inpara 1  | 113                              | 105                                          | 131                           | 0.86                          | 0.80                          |
| Inpara 2  | 113                              | 116                                          | 128                           | 0.88                          | 0.90                          |
| Inpara 3  | 113                              | 116                                          | 127                           | 0.89                          | 0.91                          |
| Inpara 4  | 121                              | 127                                          | 135                           | 0.90                          | 0.94                          |
| Inpara 5  | 108                              | 94                                           | 115                           | 0.93                          | 0.81                          |
| Inpara 6  | 108                              | 100                                          | 117                           | 0.92                          | 0.85                          |
| Inpara 7  | 108                              | 116                                          | 114                           | 0.94                          | 1.01                          |
| Inpara 8  | 113                              | 116                                          | 115                           | 0.98                          | 1.01                          |
| Inpara 9  | 113                              | 116                                          | 114                           | 0.99                          | 1.01                          |
| Margasari | 113                              | 116                                          | 120                           | 0.94                          | 0.97                          |
| Ciherang  | 108                              | -                                            | 120                           | 0.90                          | -                             |
| Lokal     | -                                | 223                                          | 223                           | 1.00                          |                               |
| Means     | 111.9                            | 122.3                                        | 121.5                         | 0.92                          | 0.93                          |

Note: ¹HTVD = Harvesting time on varietal descriptions

4. Conclusions

Inpara or Inbred rice swampland is a variety released by the Indonesian Agency for Agricultural Research and Development (IAARD) for adaptation in swampland. These varieties have a variation of adaptation in tidal swampland. The yield average of varieties tested was lower than that of a varietal description. This condition is due to the sub-optimal of environmental conditions (high soil acidity and low nutrient availability). Some of the superior adaptive rice varieties in tidal swampland are Inpara 1, Inpara 3, Inpara 4, Inpara 6, and Inpara 9. The average yield in PASS was 37.9% higher than that of AASS.
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