The performance of grain yield and variability of ten high yielding varieties of rice at tidal swampland

M Saleh* and I Khairullah
Indonesian Swampland Agricultural Research Institute, Jl. Kebun Karet, Loktabat Utara, Banjarbaru, South Kalimantan 70712, Indonesia

*E-mail: saleh_duransyah@yahoo.co.id

Abstract. Rice is the main food crop for Indonesians; hence, increasing population leads to expanding demand for this commodity. This research was carried out over potential acid sulfate soils of tidal swamplands in Matang Danau village, Sambas regency, West Kalimantan during 2018 Dry Season. The aim of the research was to evaluate grain yields and the variability of ten rice varieties. The study employed completely randomized block design with three replications. Ten rice varieties, namely Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 6, Inpara 8, Inpara 9, Margasari, Inpari 32 and Cillosari (as control) were investigated. The results showed that all varieties performed good phenotypic acceptability (score 3), without symptoms of Fe toxicity. Yielded grain ranged from 2.44 to 5.39 tons/ha in dry milled grain. The highest yield was shown by Inpari 32 (5.33 t/ha) and Inpara 1 (5.39 t/ha), suggesting that these varieties suit acid sulfate soils as an alternative to existing Cilosari cultivar.

1. Introduction
Rice endures as the main food crop in Indonesia. With increasing number of inhabitants, rice demand remains high. Meanwhile, productive lands for rice production have gradually been limited, as a consequence of land use conversion to non-agricultural purposes, such as industry, housing and other man-made structures.

Future agricultural development may expand to swamplands; the abundant resource in Indonesia. Indonesian swampland is about 34.12 M ha or roughly 17.92% of the total Indonesian land mass (191.19 M ha). It is distributed in Sumatera (12.93 M ha), Kalimantan (10.02 M ha), Papua (9.87 M ha), Sulawesi (1.05 M ha), Maluku (0.16 M ha) and Java (0.09 M ha) [1]. Based on land typology, swamplands are divided into freshwater (lebak) and tidal swamplands.

Tidal swampland is extensive and spreads over major islands. The largest is in Sumatera with 3.02 M ha, followed by Kalimantan with 2.99 M ha and Papua with 2.43 M ha. In Sulawesi, tidal swampland covers about 0.32 M ha, while in Java and Maluku possess 0.09 M and 0.07 M ha respectively [1].

Acid sulfate soils, a type of tidal swamplands, cover 4.37 M ha of potential acid sulphate soil and 2.37 M ha of actual acid sulphate soils [2]. Acid sulfate soils are likely to be developed as rice fields, due to availability of land and cultivation technologies. However, productivity level of tidal swamplands is generally low, because of physico-chemical issues such as pyrite (FeS₂) layer.

Iron toxicity refers to a physiological disorder of lowland plant nutrients associated with excessively dissolved Fe [3], salinity, P deficiency, low bases [4], multiple nutrient stress...
and low pH [5] and plant physiological conditions [6]. Rice growth and yields in acid sulfate soils are strongly affected by iron toxicity. Yield reduction due to iron toxicity ranges from 30 to 100%, depending on the tolerance of variety [7].

Research on the adaptability of rice cultivars have been conducted over acid sulfate soils. According to Khairullah et al. [8], high yielding varieties like Margasari, Mendawak, Inpara 1, 2, 3, 6, 7, 8, and 9 increased yield up to 31%, compared with Margasari in tidal swampland. Research serially published by Kusrini et al. [9] and Kusrini et al. [10] reported that Inpara 1 dan Inpara 4 could be used as alternatives in tidal swampland with type C overflow. Soil acidity in Barambai swampland was very acidic (pH 3.99) and contained high iron (181.89 ppm) in actual acid sulfate soils. Averaged yield of Inpara variety was only 1.99 t/ha, lower than its potential about 5.0 to 7.0 t/ha [11]. Koesrini et al. [9] showed that the adaptability varied among tested varieties. High yield, well adapted Inpara 3, 4, 6, 8, and 9 produced around 3.475-4.299 t/ha, or about 38.5 to 71.3% higher than Margasari and 51.4 to 87.2% higher than Mekongga. Furthermore, Inpara-1 variety produced the highest yield of 6.6 t/ha, while other varieties produced between 3.98 to 5.90 t/ha. Grain yield in rainy planting season was 89.4% higher than the one over dry season [12].

This study aimed to examine the performance, production and diversity of ten rice varieties in acid sulfate soils of tidal swampland.

2. Methodology
The trial was carried out in Matang Danau Village, Sambas Regency, Indonesia, in dry season 2018. The research was arranged in completely randomized block design, with three replications. Each plot size was 30 m x 3 m. As a treatment, ten HYV's of rice were used, namely Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 6, Inpara 8, Inpara 9, Margasari, Inpari 32 and Cilosari.

Soil was mechanically prepared using a hand tractor until it was ready for planting. Dolomite 1 t ha\(^{-1}\) at two weeks was applied before transplanting. We used fertilizers at a rate of 90 kg ha\(^{-1}\) N, 60 P\(_2\)O\(_5\) kg ha\(^{-1}\), 60 kg K\(_2\)O ha\(^{-1}\). Phosphor and potassium fertilizers applied at a similar time once plants were at their seven days after transplanting (DAT). Meanwhile, N was given twice, i.e. when at 7 and 30 DAT; half of the amount of N fertilizer each application. Replacement of dead plants was done by embroidering them on age 21 DAT using spare seedlings. Pest and disease attacks were controlled according to the intensity by using recommended insecticides, pesticides or fungicides. Controlled weeding was carried out at 21 and 49 DAT by removing weeds. Harvesting was carried out when the rice at its ripening stage: dry and droopy panicles, straw grains and unbreakable grain contents, yellow upper leaves and dry lower parts.

Planting was carried out with a 2:1 row legowo system, with plant spacing of 25 x 25 cm and 1-2 plants per hill. Observations were made on growth score and plant height in vegetative and generative phases, number of tillers and number of panicles/hills, grain yield when harvested (dry harvest), and yield after processing/drying (milled grain). Heritability, in a broad sense, was estimated by using variance component [13].

Table 1. Analysis of variance and expected mean square of Randomized Block Design

| Source of variance | DF | Mean Square | F   | EMS |
|-------------------|----|-------------|-----|-----|
| Replication (r)   | r-1| M1          | M1/M3 | -   |
| Genotype (g)      | g-1| M2          | M2/M3 | \(\sigma^2 e + r (\sigma^2 g)\) |
| Error             | (r-1)(g-1) | M3 | - | \(\sigma^2 e\) |
| Total             | Rg-1|             |     |     |

Phenotype variance, genetic variance can be calculated based on:
\[2g = (M2-M3)/r, 2e = M3, 2f = 2g + 2e, \text{Heritability (H)} = 2g / 2f\]
\[M2 = \text{mean square of genotype, } M3 = \text{mean square of error.}\]
Genetic variability is estimated based on genetic variance and standard deviation of genetic variance (Anderson and Ban Croff in Wahdah et al. [13]).

3. Results and Discussion

Observations on growth scores, total tillers and plant heights are shown in Table 1. All varieties showed good growth (score 3), where plants grew normally, leaves were green and there were no visible symptoms of plant toxicity.

Total number of tillers in the vegetative phase showed significant differences among tested varieties, where Inpara 4 yielded the highest number of tillers. Plant height also indicated significant differences between cultivars. Tallest plants observed during the vegetative phase were Inpara 8 and 9 cultivars, which were 104.78 and 105.82 cm, respectively. This indicated that there was no linear relationship between the number of tillers and plant height in the vegetative phase.

Table 2. Growth scores, number of tillers and plant height in the vegetative phase of ten HYV’s of rice cultivars

| Varieties | Vegetative growth score | Number of tillers at vegetative phase | Plant height at vegetative phase |
|-----------|-------------------------|--------------------------------------|---------------------------------|
| Inpara 1  | 3 a                     | 23.61 a                              | 95.67 cd                        |
| Inpara 2  | 3 a                     | 29.27 b                              | 90.17 bc                        |
| Inpara 3  | 3 a                     | 20.84 a                              | 100.93 de                       |
| Inpara 4  | 3 a                     | 34.90 c                              | 69.67 a                         |
| Inpara 6  | 3 a                     | 20.07 a                              | 92.50 bcd                       |
| Inpara 8  | 3 a                     | 20.10 a                              | 104.78 e                        |
| Inpara 9  | 3 a                     | 22.78 a                              | 105.82 e                        |
| Margasari | 3 a                     | 32.52 bc                             | 98.87 de                        |
| Inpari 32 | 3 a                     | 26.13 a                              | 86.43 b                         |
| Cilosari  | 3 a                     | 24.01 a                              | 97.87 cde                       |
| Average   | 3                       | 25.74                                | 89.79                           |

1 = very good, 3 = good, 5 = intermediate, 7= poor

In the generative phase, observations were made on growth scores, numbers of productive tillers and plant height (Table 3). Growth score in this phase was classified as good (score 3), where plants normally grew and leaves were green. There were no visible signs of plant toxicity.

Number of productive tillers represents the amount of tillers capable of producing panicles. Analysis of variance on this variable showed differences between tested varieties. The highest number of tillers was shown by the Inpara 2 and Inpara 4 varieties.

According to IRRI [14], the number of productive tillers is classified as very low (< 5), low (5 – 9), medium (10 – 19), high (20 – 25) and very high ( > 25). Based on aforementioned categories, Inpara 1, Inpara 6, Inpara 8, Inpara 9, Margasari, Inpari 32 and Cilosari were categorized as highly productive tillers. Meanwhile, Inpara 2 and Inpara 4 cultivars were classified as very high.

As indicated in Table 3, Margasari variety shows the highest plant height. This variety is a cross-bred between a tidal swampland variety and a superior cultivar. According to IRRI [14], classification for plant height is low (< 110 cm), medium (110 – 130 cm) and high (> 130 cm). Based on this grouping, all studied varieties were classified as low.
Table 3. Score of growth in the generative phase, the number of productive tillers and plant height in the generative phase of ten high yielding varieties of rice

| Varieties | Generative growth score | Productive tiller number phase | Plant height at generative phase |
|-----------|-------------------------|--------------------------------|---------------------------------|
| Inpara 1  | 3 a                     | 21.73 bcd                      | 103.43 d                        |
| Inpara 2  | 3 a                     | 26.33 e                        | 97.80 bc                        |
| Inpara 3  | 3 a                     | 13.20 a                        | 101.53 cd                       |
| Inpara 4  | 3 a                     | 26.20 e                        | 94.53 b                         |
| Inpara 6  | 3 a                     | 20.13 bc                       | 101.87 d                        |
| Inpara 8  | 3 a                     | 23.87 de                       | 104.93 d                        |
| Inpara 9  | 3 a                     | 23.67 cde                      | 105.40 d                        |
| Margasari | 3 a                     | 21.20 bed                      | 119.00 e                        |
| Inpari 32 | 3 a                     | 21.93 bcd                      | 86.33 a                         |
| Cilosari  | 3 a                     | 23.00 cde                      | 103.83 d                        |
| **Average** | **3**                   | **21.25**                      | **103.87**                      |

Yield, in terms of harvested dry grain (GKP) and dry milled grain (GKG), exhibited significant differences between assessed varieties Table 4). This research found that GKP ranged from 3.31 to 6.45 t/ha. Two varieties capable of producing above 5.0 tons/ha were Inpari 32 (5.92 t/ha) and Inpara 1 (6.45 t/ha). We noted that Inpari 32 was a high yielding variety due to its resistance to bacterial leaf blight, which has been often found in Indonesian rice fields. Inpari 32 suits for tidal swamps with low stress levels, but not entirely adaptive to higher levels. In this research area, fortunately, stress level was considerably low to moderate to allow Inpari 32 adapts.

Table 4. Yield of harvested dry unhulled rice and milled dry unhulled rice ten HYV’ of rice

| Varieties | Harvested Dry Grain (t/ha) | Milled Dry Grain (t/ha) | Grain Yield Potential (t/ha) |
|-----------|-----------------------------|-------------------------|-----------------------------|
| Inpara 1  | 6.45 e                      | 5.39 d                  | 6.47                        |
| Inpara 2  | 4.64 c                      | 4.00 c                  | 6.08                        |
| Inpara 3  | 4.11 b                      | 3.31 b                  | 5.61                        |
| Inpara 4  | 4.59 bc                     | 3.80 c                  | 7.60                        |
| Inpara 6  | 4.43 bc                     | 3.79 c                  | 7.20                        |
| Inpara 8  | 4.43 bc                     | 3.84 c                  | 6.00                        |
| Inpara 9  | 3.31 a                      | 3.09 b                  | 5.60                        |
| Margasari | 3.31 a                      | 2.44 a                  | 4.00                        |
| Inpari 32 | 5.92 d                      | 5.33 d                  | 8.53                        |
| Cilosari  | 4.37 bc                     | 3.79 c                  | 6.50                        |
| **Average** | **4.84**                   | **4.06**                | **6.36**                    |

Water contents in dry and ready-to-mill grain ranged from 10.2 to 12.9 percent. Grain yields observed after drying and ready-to-mill grain (GKG) were between 2.44 and 5.39 t/ha of milled grain. Two varieties produced above 5.0 t/ha, i.e. Inpari 32 (5.33 t/ha) and Inpara 1 (5.39 t/ha). Compared to their potential genetic, yield disparity of Inpara 1 (16.7%) was smaller than the one by Inpari 32 (37.5%) (Table 5). This research indicated that high-yielding irrigated rice varieties ill-suited than high-yielding swamp rice over swamps.
Table 5. Environmental variance, genotype variant, phenotypic variant, heritability and heritability criteria of ten HYV’s

| Characters                        | Environmental variance | Genotypic variance | Phenotypic variance | Herritability | Criteria |
|-----------------------------------|------------------------|--------------------|---------------------|---------------|----------|
| Plant height at vegetative phase  | 24.81                  | 104.06             | 128.87              | 0.807         | High     |
| Tiller number at vegetative phase | 6.87                   | 25.14              | 32.013              | 0.785         | High     |
| Plant height at generative phase  | 5.09                   | 68.70              | 73.79               | 0.931         | High     |
| Productive tiller number          | 11.71                  | 11.13              | 22.84               | 0.487         | Moderate |
| Harvested dry grain               | 0.09                   | 0.95               | 1.043               | 0.910         | High     |
| Milled dry grain                  | 0.06                   | 0.80               | 0.866               | 0.923         | High     |

The role of environmental variances, genotype variants, phenotype variants, heritability estimates and criteria is presented in table 4. Plant characters can be categorized as having high, medium and low heritability values, if the values are H > 50%, 20 < H < 50% and H < 20% [15, 16]. Heritability predictive value was generally high, although number of productive tillers was classified as moderate.

Moderate to high heritability plant characters indicated that the environment did not affect the appearance of a character [16]. In such conditions, the selection can be done in the early generations [13]. Selection over characters with low heritability values, as a result of their genetically-inconsistent phenotypic performance, can be done for later generations [13].

Wahdah et al. [13] suggested that if environmental influences more than genetic on the appearance of a plant character, selection in population would not bring genetic changes, and can minimize genetic progress. Genetic standard deviation and the criteria for genetic diversity of observed characters are presented in Table 6.

Table 6. Coefficient of diversity, genotypic variants and value of 2 x genotypic variants and criteria for genetic diversity of ten HYV’s of rice

| Characters                        | Genotypic Variance | Deviation standard of genitic | Value 2 X standard deviation of genetic | Criteria of genetic variance |
|-----------------------------------|--------------------|-------------------------------|----------------------------------------|-----------------------------|
| Plant height at vegetative phase  | 104.06             | 51.90                         | 103.90                                 | Broad                       |
| Tiller number at vegetative phase | 25.14              | 11.66                         | 23.32                                  | Broad                       |
| Plant height at generative phase  | 68.70              | 29.87                         | 55.74                                  | Broad                       |
| Productive tiller number          | 11.13              | 6.47                          | 12.935                                 | Narrow                      |
| Harvested dry grain               | 0.95               | 0.415                         | 0.831                                  | Broad                       |
| Milled dry grain                  | 0.80               | 1.105                         | 2.21                                   | Narrow                      |

A character is considered to have wide variability if the value of its genetic variance is greater than twice of genetic standard deviation [13]. Among ten varieties being tested, the character of vegetative plant height, number of vegetative tillers, and generative plant height showed wide genetic variability or diversity. Character of the number of productive tillers and the yield of dry milled grain was relatively alike. Plant characters with wide genetic variation are usually rooted from different genetic sources; hence, there is a room for selection [13].
4. Conclusion
Achieved grain yield ranged from 2.44 to 5.39 t/ha of milled grain, the highests were shown by Inpari 32 (5.33 t/ha) and Inpara 1 (5.39 t/ha). Heritability predictive value was generally high, except for the character of productive tillers number, which was classified as moderate. Wide genetic diversity was indicated by characters of vegetative plant height, numbers of vegetative tillers, generative plant height and yields of harvested dry grain.

References
[1] Ritung S, Wahyunto, Nugroho K, Sukarman, Hikmatullah, Suparto and Tafakresnanto C 2018 Teknologi Inovatif Pertanian, (Bogor: IAARD Press)
[2] Widjaja-Adhi I P G, Suriadikarta D A, Sutriadi M T, Subiksa I G M and Suastika I W 2000 Sumberdaya lahan Indonesia dan pengelolaannya, ed Adimihardja, et al. (Bogor: Pusat Penelitian Tanah dan Agroklimat) pp 127-64
[3] Tanaka A and Yoshida S 1966 Nutritional Disorders of the Rice Plant in Asia. (Los Banos: The International Rice Research Institute) p 51
[4] Ikehashi H and Ponnampерума F N 1978 Soils and Rice, (Los Banos: The International Rice Research Institute) pp 801-23
[5] Benckiser G, Santiago S, Neue H U, Watanabe I and Ottow J C G 1984 Effect of fertilization on exudation, dehydrogenase activity, iron-reducing populations and Fe++ formation in the rhizosphere of rice (Oryza sativa L.) in relation to iron toxicity Plant Soil 79 305-16
[6] Ottow J C G, Prade K, Bertenbreiter W and Jack V A 1991 Proc. of Int. Symp. on Rice Production on Acid Soils of the Tropics, ed P Deturck, et al. (Sri Langka: Institute of Fundamental Studies)
[7] Virmani S S 1977 Genetic evaluation and utilization adverse soil: Varietal tolerance of rice to iron toxicity in Liberia. In: The International Rice Research Institute, (Manila: The International Rice Research Institute) pp 4-5
[8] Khairullah I, Saleh M, Alwi M and Masganti 2021 Increasing productivity of rice through iron toxicity control in acid sulfate soils of tidal swampland. In: IOP Conference Series: Earth and Environmental Science: IOP) p 012151
[9] Koesrini, Saleh M and Nurzakiah S 2017 Adaptabilitas varietas inpara di lahan rawa pasang surut tipe luapan air B pada musim kemarau Jurnal Agronomi Indonesia 45 117-23
[10] Koesrini, Saleh M and Thamrin M 2018 Adaptasi agronomi padi unggul varietas Inpara pada lahan rawa pasang surut Jurnal Penelitian Pertanian Tanaman Pangan 2 77-84
[11] Balai Besar Penelitian Padi 2016 Deskripsi varietas Inbrida Padi Rawa (INPARA). In: https://pppadi.litbang.pertanian.go.id
[12] Susanto G W A 2004 Variasi genetik karakter kuantitatif galur galur kedelai F5. In: Prosiding Lokakarya Perhimpunan Ilmu Pemuliaan Indonesia VII, ed A Kasno, et al. (Malang: PERIPI dan Balitkabi)
[13] Wahidah R, Baihaki A, Setiawuraidja R and Suryatmana G 1996 Variabilitas dan heritabilitas laju akumulasi bahan kering pada biji kedelai Zuriat 7 92–8
[14] IRRI 1996 Standard Evaluation System for Rice (Manila-Philippines: International Rice Research Institute)
[15] Me Whirter K S 1979 Plant breeding, ed R Knight (Brisbane: Australian Vice)
[16] Jhonharnas 1999 Performance of 13 sweet potato genotypes in Sumanik, West Sumatra (Indonesia) Zuriat 10 66-72