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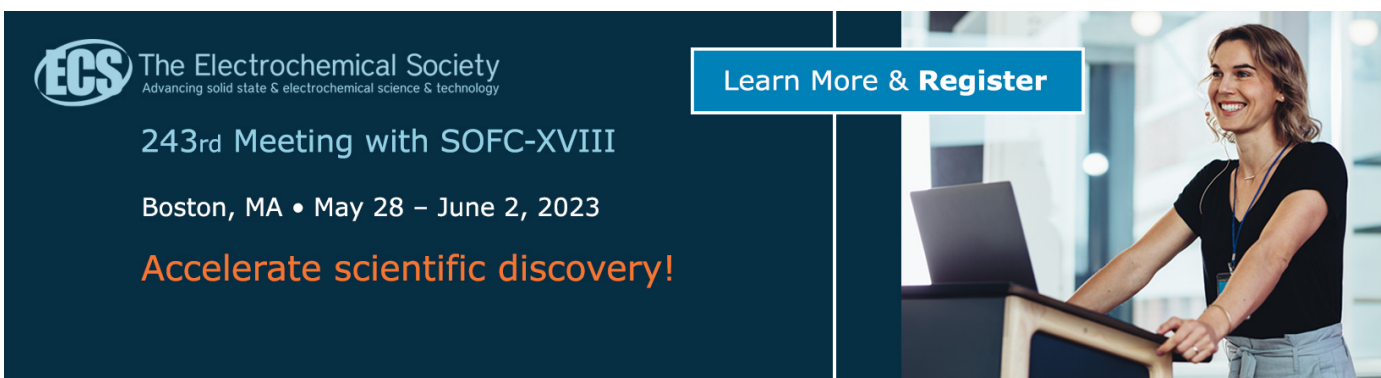
Assessing the production of the new superior rice varieties in tidal swampland in Bulungan Regency, North Kalimantan

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Assessing the production of the new superior rice varieties in tidal swampland in Bulungan Regency, North Kalimantan

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Abstract. The productivity of swampland in North Kalimantan, is still low and can be improved through appropriate cultivation technology. The study aims to increase swampland productivity in Tanjung Buka, Tanjung Palas Tengah Sub-District, Bulungan Regency through new superior varieties of rice. The introduction of new superior varieties of swamp rice (inbrida swamp rice-Inpara), namely Inpara-2, 4, 8, Inpari-30, Inpari-32, and local variety as a comparison, with the legowo row planting system (Jarwo) 2:1. The fertilizer dosage was 50 kg NPK ha⁻¹, 100 Urea kg ha⁻¹ and 1,000 kg dolomite ha⁻¹. Plant growth, yield components and economic data were observed and calculated. Plant growth and yield components parameter were analyzed with Analysis of Variant (ANOVA), and followed with the Duncan Multiple Range Test (DMRT). Break-even point value and the BCR ratio were calculated for economic analysis. The result showed that the highest rice productivity was Inpara-2 and Inpari-32, and the lowest productivity was local variety. The research results showed that Inpara-2, 4, 8, Inpari-30, and Inpari-32 with the legowo row planting system (Jarwo) 2:1 had BCR >1, whereas if using of local variety BCR <1. Therefore, the recommended varieties to developed in this study area are Inpari-32 and Inpara-2.

1. Introduction

Swamplands have an increasingly important role in agricultural development. However, their management has not yet been optimal [1–3]. The constraints to agricultural development in the swamp are the biophysical of land (water regime), the physicochemical characteristics, and the socio-economic conditions. The tidal swampland has less favourable properties, including acid to very acid, the content of N, P, and K are low to very low, levels of Al, Fe, Mn, H₂S, and high and toxic organic acids. Rice productivity tidal swamp low that is <3 t ha⁻¹ Milled Dry Grain (MDG) and with a cropping pattern once a year or Cropping Index (CI) 100 [4]. With improved water management, soil, and crop management, tidal swamp rice productivity can be increased 5.0 to 6.3 t ha⁻¹ MDG with the cropping index twice a year (CI 200).

The potential for swamps in East Kalimantan Province (including North Kalimantan) reaches 783,153 ha, consisting of 404,500 ha of tidal swamps and 259,537 ha swamps-scattered in 13 districts, and only 25,142 ha have been cleared and used for rice fields, and plantations 36,348 ha [5].

Tidal swamps are generally acidic, have low nutrient content, and high iron (Fe) content, which causes toxicity. Iron toxicity and soil nutrient imbalance are the main problems, causing rice productivity in tidal swamps to be relatively low (1 to 2 t ha⁻¹). Iron toxicity can be treated by tolerant varieties of rice, ameliorations, and fertilizing to improve nutrient balance in the soil.



Superior rice varieties are an effort to increase productivity [6]. Several varieties of lowland rice and swamp rice have been produced by the Indonesian Agency for Agricultural Research and Development, including Inbrida Swamp Rice (Inpara), Inbrida Irrigation Rice (Inpari), and Inbrida Gogo Rice (Inpago). Some of the new varieties (VUB/*Varietas Unggul Baru, in Bahasa Indonesia*) of rice are tolerant soaking, drought-tolerant, iron toxicity tolerant, pest and disease resistant, and have high productivity. The research objective was to increase the land productivity of tidal swamps through the use of new high yielding varieties and cropping systems by the specific conditions of the region.

2. Methodology

The research was conducted on tidal swamps area in Tanjung Buka, Tanjung Palas Tengah Sub-District, Bulungan Regency on MT I-2018. The materials used are rice seeds of new high yielding varieties (VUB) Inpara-2, Inpara-4, Inpara-8, Inpari-30, Inpari-32, and local varieties; agricultural lime; Urea fertilizer; NPK fertilizer; pesticides (insecticides and fungicides); and other supporting tools.

The study used a simple randomized block design (RBD) and six treatments, namely the new superior variety (VUB) rice, i.e.: Inpara-2 (V1), Inpara-4 (V2), Inpara-8 (V3), Inpari-30 (V4), Inpari-32 (V5), and local varieties (V6), where each variety treatment was repeated three times. The rice planting system is Jajar Legowo (Jarwo) 2:1, with a spacing (50x25) x 12.5 cm. The dosages for each treatment of varieties were dolomite lime 1,000 kg ha⁻¹, Urea 100 kg ha⁻¹, NPK 200 kg ha⁻¹, and KCl 50 kg ha⁻¹. Urea was used as a base fertilizer at a dose of 50 kg ha⁻¹, NPK 200 kg ha⁻¹, and KCl 50 kg ha⁻¹. The first supplementary fertilizer was given when the plants are 25 days after planting (DAP). The dosage is according to the Leaf Color Chart (LCC) tool, which is 75 to 100 kg Urea ha⁻¹, and the second supplementary fertilizer is at the age of 40 DAP with a dose of 50 kg Urea ha⁻¹, and 50 kg NPK ha⁻¹.

Plant parameters observed were growth components (plant height, number of productive tillers), yield components (harvest age, number of filled grains, empty grain per panicle, weight or weight of 1,000 grains, and productivity (moisture content 14%). Analyzed growth data, yield components, and productivity using the Analysis of Variant (ANOVA), and further testing with the Duncan Multiple Range Test (DMRT) [7]. BCR (Benefit Cost Ratio) analysis is conducted to determine whether or not rice farming is feasible in the study location. If BCR <1 the farming is not feasible, and if BCR ≥1 farming is feasible.

3. Results and discussion

3.1. Location characteristics

The agricultural development area in Tanjung Buka, Tanjung Palas Tengah Sub-District, Bulungan Regency, has podsolc soil types of red-yellow (greyish brown, red-yellow) and laterite, with soil acidity (pH) ranging from 3.5 to 6.5. This region has a wet tropical climate with temperatures ranging from 22° to 33°C.

Tanjung Palas Tengah sub-district based on its agroecosystem as follows: (a) rainfed lowland rice and potential tidal swamp area of 10,000 ha, and functional 2,428 ha, highest productivity 4.0 t ha⁻¹, (b) dry land rice, potential 600 ha, functional 150 ha and the highest productivity 2.5 t ha⁻¹, (c) paddy around the coast, potential 135 ha, functional 45 ha with productivity 3 t ha⁻¹.

Based on the type of overflow, the swamps in the study area are types A and B. Tidal swamp based on the type of flood, divided into types A, B, C, and D. Type A swamps are always inundated by tides, both during the rainy season and dry. The land of overflow type B only overflows with the high tide during the rainy season. Whereas land type C overflow was not overflowing with the tide, but it was influenced by groundwater level with a depth of <50 cm, and land type overflow D was like type C with groundwater depth >50 cm.

3.2. Soil physical and chemical properties

The results of the composite soil analysis in the study area showed that the pH of the swampland was slightly acidic, high organic matter content, high N, medium P, high K, medium CEC, low Ca, and high Fe content. Data from the analysis of soil physical and chemical properties in Tanjung Buka are in table 1.

Constraints of the biophysical and chemical tidal swamp for agricultural development: (1) standing water at high tide and low tide, (2) high soil acidity due to the solubility of aluminum (Al^{3+}), ferric iron (Fe^{3+}), and high sulphate (SO_4^{2-}) content, (3) low soil fertility, and (4) iron toxicity caused by high concentrations of dissolved iron in the soil (200 to 500 ppm). Iron toxicity can reduce rice production by 30 to 100%. Iron toxicity in swamps is caused by a high of Fe^{2+} concentrations in the soil solution because it is in reductive conditions. This condition is caused by poor drainage, low Eh values, deficiency of K, Ca, Mg, P, Zn, Mn, and low soil oxygen. Iron toxicity in the tidal swamp can be controlled through proper water management, amelioration, fertilization, the timing of planting, and the use of tolerant rice varieties [8,9].

Table 1. Results of soil analysis in Tanjung Buka, Bulungan Regency.

No	Description	Value	Unit	Criteria
1.	pH H ₂ O	4.92	-	slightly acidic
	pH KCl	3.28	-	neutral
2.	Water content	7.74	%	
3.	C-Organic	12.84	%	high
4.	N-Total	0.50	%	moderate-high
5.	P ₂ O ₅ available	37.29	ppm	moderate
6.	P ₂ O ₅ potential	39.29	mg 100 g ⁻¹	moderate
7.	K ₂ O potential	2.76	mg 100 g ⁻¹	high
8.	CEC	21.25	cmol ₍₊₎ kg ⁻¹	moderate
9.	Cation			
	- Ca	2.68	cmol ₍₊₎ kg ⁻¹	low
	- Mg	2.50	cmol ₍₊₎ kg ⁻¹	high
	- K	0.94	cmol ₍₊₎ kg ⁻¹	high
	- Na	0.33	cmol ₍₊₎ kg ⁻¹	moderate
	- <i>Exch-Al</i> ³⁺	0.08	cmol ₍₊₎ kg ⁻¹	low
	- <i>Exch-H</i> ⁺	0.27	cmol ₍₊₎ kg ⁻¹	low
10.	Texture			
	- Sand	4.4	%	
	- Silt	54	%	
	- Clay	42	%	
11.	Heavy metal			
	- Ag	0.00	ppm	
	- Cd	0.00	ppm	
12.	Micronutrient			
	- Cu	0.00	ppm	
	- Zn	42.04	ppm	
	- Fe	10,205	ppm	high
13.	Macronutrient			
	- Na	0.05	%	very low
	- Mg	0.08	%	very low
	- Ca	1.30	%	very low
	- K	0.17	%	moderate
14.	Density	0.91	g cm ⁻³	

Source: primary data.

3.3. New superior varieties of rice

Growth and yield components of new superior varieties of rice were significantly different between varieties. They were not significantly different to plant height, the number of productive tillers, and harvest age (table 2). Data on the average percentage of empty grain, weight or weight of 1,000 grains, and productivity are in table 3. The phenotype and genotype diversity values of rice are found in plant height, number of productive tillers, number of filled grains per panicle, and the number of empty grains per panicle [10]. These characters are generally controlled more by rice genetic factors than environmental factors.

Table 2. Average plant height, number of productive tillers, and age of harvest.

No	Varieties	Plant height (cm)	Productive tillers (seeds per clump)	Harvest age (day)
1	V1 (Inpara-2)	100.00 b	13.30 b	120 b
2	V2 (Inpara-4)	95.00 c	12.50 b	124 b
3	V (Inpara-8)	105.00 b	15.20 a	114 b
4	V4 (Inpari-30)	99.60 c	15.30 a	112 b
5	V5 (Inpari-32)	95.50 c	16.20 a	119 b
6	V6 (Local)	130.10 a	11.10 c	155 a
	CV	2.30%	3.27%	3.63%

Note : Values followed by the same letter in each column are not significantly different ($p < 0.05$).

The height of the rice plants tested ranged from 95.00 cm to 106.00 cm. The lowest measurement result for the new high yielding variety Inpara-4 was 95 cm, and the highest was Inpara-8. The difference in plant height between these varieties is caused, among others, by the influence of plant genetic factors and environmental factors. Genetic aspects of rice varieties will affect plant height, while external factors (climate, soil) and internal factors (rate of photosynthesis, respiration, enzyme activity) will affect plant growth [11].

The highest number of productive tillers was Inpari-32, namely 16.20 stems per hill, not significantly different from the productive tillers of Inpara-2, Inpara-4, Inpara-8, and Inpari-30 varieties. The lowest productive tillers per hill were local rice varieties, namely 11.10 stems per hill. The number of productive tillers, apart from being influenced by plant genetic factors and the environment. Fertilization factors are one of the determinants of the number of tillers. The fertilizer that plays a role in determining the number of tillers is nitrogen fertilizer because nitrogen has a function to improve vegetative plant growth [12–14].

The harvest age for new high-yielding rice varieties ranges from 112 to 124 days after sowing (DAS). The Inpari-30 had the fastest harvest age at 112 DAS, while the local variety had along age, namely 155 DAS. The harvesting ages of Inpara 2, 4 and 8 and Inpari 30, Inpari 32 were not significantly different between new varieties, but substantially different from local variety rice.

The percentage of unhulled rice of several varieties tested ranged from 24.00 to 27.15 percent. Inpari-32 has the lowest average of empty unhulled rice, namely 24.00 percent, and Inpari-30 is 26.10 percent, and local variety is 27.15 percent. The amount of empty unhulled rice will affect rice productivity. The percentage of empty unhulled rice is influenced by genetic factor, environmental and pests-diseases.

Table 3. The average percentage of empty unhulled rice, 1,000 grain weight, and productivity.

No	Varieties	Grain percentage empty (%)	Weight of 1,000 grains (g)	Productivity (t ha ⁻¹)
1	V1 (Inpara-2)	25.15 a	21.80 b	4.75 c
2	V2 (Inpara-4)	26.00 a	20.50 b	4.10 b
3	V (Inpara-8)	24.60 b	19.50 b	3.60 a
4	V4 (Inpari-30)	26.10 a	20.10 b	4.00 b
5	V5 (Inpari-32)	24.00 b	23.50 a	5.75 a
6	V6 (Local)	27.15 a	18.10 c	2.60 d
	CV	3.28%	4.00%	4.19%

Note : Values followed by the same letter in each column are not significantly different ($p < 0.05$).

The lowest weight or weight of 1,000 grains of new superior rice varieties was Inpara-8, namely 19.50 g and the highest was Inpari-32, which was 23.50 g, while the local variety had the lowest 1,000 grain weight, which was 18.10 g. The weight of 1,000 grains between superior varieties and the local variety was significantly different. The weight of 1,000 grains is one of the components that affect rice productivity.

The rice productivity of the varieties tested ranged from 2.6 to 5.75 t ha⁻¹ harvest dry grain (DDG). Inpara-2 rice productivity is 4.75 t ha⁻¹, Inpara-4 productivity is 4.1 t ha⁻¹, Inpara-8 productivity is 3.60 t ha⁻¹, Inpari-30 productivity is 4.00 t ha⁻¹, Inpari-32 productivity is 5.75 t ha⁻¹, and the lowest productivity is local rice, namely 2.6 t ha⁻¹. The results of previous studies indicated that the productivity of rice in which the productivity was tested was below the yield potential [15–17].

IAARD has found several new high yielding varieties of swamp rice (Inpara) that are tolerant to iron toxicity, as in table 4. Data descriptions of swamp rice show that varieties that are tolerant to iron toxicity include Inpara-2, Inpara-8 [18–19]. The results of adaptation tests for Inpara varieties in swamps show that several Inpara varieties are tolerant of iron toxicity (Fe content 325 ppm) and have high productivity [8,19,20].

Table 4. Description of Inpara and Inpari rice from the IAARD [18,19].

Varieties and years are released	Age (day)	Height (cm)	Productivity potential (t ha ⁻¹)	Tolerance to stress	
				Abiotic	Biotic
Inpara-2	128	103	6.1	Fe and Al	planthopper, bacterial leaf blight (BLB), blast
Inpara-4	135	94	7.6	soaking	planthopper, bacterial leaf blight (BLB)
Inpara-8	115	107	6.0	Fe	bacterial leaf blight (BLB), blast
Inpari-30	111	101	9.6	-	-
Inpari-32	120	97	8.53	-	bacterial leaf blight (BLB), blast

Farmer is considered in choosing varieties that are resistant to iron toxicity to be cultivated in tidal swamps [22–23]. Each rice variety can absorb different nutrients and has a different tolerance for iron toxicity so that not all great yielding varieties can adapt well to tidal swamps. Rice plants have a mechanism to overcome the high Fe²⁺ ions in soil solution [24–25], namely by (a) holding down Fe²⁺ ions on the root surface, by oxidizing Fe²⁺ to Fe³⁺, so that the root surface looks rusty red; (b) Fe²⁺ is absorbed by roots, and distributed to disposal sites, such as old leaves or less active tissue; (c) the plant tolerates high levels of Fe²⁺ in leaf cells.

3.4. Farming analysis

The results analysis of rice farming on tidal swamps in Tanjung Buka, show that of the six VUB rice tested, those with BCR >1 were Inpara-2, 4, Inpara-30, and 32, while the local varieties BCR <1. Based on the description of the new superior varieties of rice, it can be seen that the productivity of the tested rice is not following the yield potential. However, with the conditions of swampy land in Bulungan Regency, the productivity of rice is higher than the productivity of local rice varieties. Farming analysis of several rice varieties tested in Tanjung Buka in table 5.

Table 5. Analysis of rice farming on tidal swamps in Tanjung Buka.

Description of varieties	Rice varieties					
	V1 Inpara-2	V2 Inpara-4	V3 Inpara-8	V4 Inpara-30	V5 Inpara-32	V6 Local
Productivity (t ha ⁻¹ HDG)	4,100	4,750	4,000	3,900	5,750	2,600
Production cost (xIDR 1,000)	7,750	7,750	7,750	7,750	7,750	7,750
Income (xIDR 1,000)	16,400	19,000	16,000	15,600	23,000	10,400
Benefit (xIDR 1,000)	8,650	11,250	8,250	7,850	15,250	2,650
B/C ratio	1.12	1.45	1.06	1.01	1.97	0.34

Notes: HDG= harvest dry grain,
Price of HDG= IDR 4,000 kg⁻¹.

4. Conclusions

The productivity of swampland can be improved through appropriate cultivation technology. Increasing the productivity of tidal swamps can be done through the use of new superior varieties (VUB) of rice. The productivity of VUB rice tested on tidal swamps in Tanjung Buka, Bulungan Regency, ranges from 2.60 to 5.75 t ha⁻¹. The results of farming analysis through the use of new superior varieties of rice and applying the legowo row 2:1 planting system, it can be seen that of the 6 VUB rice that has BCR >1, namely the Inpara-2, Inpara-4, Inpara-8, Inpara-30, Inpara-32 varieties; while locality varieties BCR <1. Therefore, the recommended varieties for development in tidal swamps in Tanjung Buka, Bulungan Regency are Inpara-32 and Inpara-2.

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