BIO Web of Conferences **69**, 02002 (2023)
2nd ICAFE 2023
https://doi.org/10.1051/bioconf/20236902002

Fertilization and Amelioration Method to Increase Rice Productivity in Tidal Swamp Land Type C on The Border of West Kalimantan-Malaysia

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Abstract. Tidal swamp land is an important resource in providing rice in the border area of Sambas Regency, West Kalimantan-Malaysia. However, rice production capacity in tidal swamp land is still low. Applying appropriate and balanced fertilizers tailored to the unique nutrient requirements and salinity levels of tidal swamp soil can support optimal paddy growth and productivity. Therefore, this study was conducted to determine the combination of fertilization and amelioration application on the growth and productivity of rice in tidal swamp land with a type C overflow. The study tested the treatment of amelioration (without lime/A_0; $CaCO_3$/A_1; and (Ca, Mg)$(CO_3)_2$)/A_2) and fertilization dose (based on farmer and recommendation) in Tebas Sungai Village, Tebas District, Sambas Regency, West Kalimantan. The treatment was arranged in a split-plot design consisted of amelioration methods as main plot while fertilization dose as suplot. The results showed that plant growth, yield components, and productivity were influenced by lime source and fertilizer dose. The highest productivity (5.62 tons ha^{-1}) was obtained from the plot treated with $CaCO_3$ and fertilized according to the recommendation.
Keywords: Calcium Carbonate, Dolomite, Land Management, Soil Liming, Sub-Optimal Land

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1 Introduction

The border area is a frontier area or veranda of a country, so development in that area needs to be prioritized by the government. It is not only to increase the income and welfare of the border community but also to increase the security from foreign intervention, intrusion of radical concepts, and prevent from becoming an entry point for negative things like drugs. Agricultural development in border areas aims to increase the income and welfare of farmers through the development of potential local commodities, increasing the productivity of the population, and promoting the domestic strategic commodity-based economy. By developing rice cultivation with fertilization technology and soil improvement, it is hoped that productivity, production, and production continuity can be increased, thereby increasing the value of commodities and supporting the region's capacity to provide rice. In line with sustainable development goals (SDGs) that promote sustainable use of ecosystem and poverty allevation. Rice has become a strategic and economic commodity in the border area of Sambas Regency, West Kalimantan-Malaysia, because, in addition to meeting local needs, it has a great potential to become an export commodity to neighboring countries. The development of rice cultivation in the tidal swamp land at the border has faced low productivity due to the low quality of the land and farmers' knowledge of rice cultivation [1].

Tidal swamp land has been reported by several researchers to have low fertility levels [2], characterized by low pH, low levels of N, P, and base element, while the levels of toxic elements such as Al [3] and Fe were relatively high [4]. Another issue is the threat of pyrite oxidation if the water layer is below the pyrite layer [5]. The success of rice cultivation development in tidal swamp land is supported by land management related to fertilization and soil improvement [6]. Fertilization and soil improvement are essential to manipulate the plant growth environment conditions to grow better and produce higher yields. Low rice productivity is closely related to the fertilizers applied. Proper fertilization has not considered by the type of fertilizer but by quantity and balance [7]. Fertilization methods should be adjusted to the soil fertility level. Fertilization by farmers is often not only limited to the type of fertilizer used but also with insufficient dosage. Therefore, increasing rice productivity needs to be supported by appropriate fertilization methods based on the plant's needs and the amount available in the soil [8].

The limited availability of nutrients in the soil in tidal swamp areas can be improved by the application of ameliorants. Amelioration is an action of applying materials such as lime into soil to elevate its chemical properties, microbial activity, and soil physics so that rice plants can grow better and be more productive [9]. Therefore, this research aims to determine fertilization and amelioration methods that can improve the growth and increase the productivity of rice plants cultivated in tidal swamp areas with type C overflow.

2 Materials dan method

The research was conducted in Tebas Sungai Village, Tebas District, Sambas Regency, West Kalimantan from February to June 2019. This activity was preceded by land identification and soil characterization, including land typology, pyrite depth, and collecting information on existing land management practices by farmers, such as fertilization methods, amelioration, rice varieties cultivated, and rice productivity.

2.1 Land/soil characterization

Land typology was determined based on the level of water availability in the rice fields during the single tide or maximum tide, and small double tide during the rainy season. If water enters the rice fields during both single and small double tides, the swamp land is categorized as type A overflow land. If water only enters the rice fields during a single tide, it is categorized as type B overflow land. If water does not enter the rice fields during both small double and single tides, but the groundwater level is <50 cm, it is categorized as type C overflow land. Meanwhile, if tidal water does not enter the rice fields and the groundwater level is ≥50 cm, it is categorized as type D tidal swamp land [10].

Soil chemical properties, including soil pH, soil organic carbon, total nitrogen, available phosphorus, and exchangeable calcium, magnesium, potassium, and sodium, were assessed through various analytical methods. The pH of the soil was determined using a pH meter. Soil organic carbon content was analyzed using the Walkley-Black method. Total nitrogen was measured using the Kjeldahl method. Available phosphorus was determined using the Bray II-Olsen method. Furthermore, exchangeable calcium, magnesium, potassium, and sodium were extracted using NH4OAc 1.0 N solution. Soil samples were collected from five different locations, each taken at a depth of 0-20 cm from the soil surface. Five soil samples were combined as a composite sample for laboratory analysis. The pyrite depth were also measured during the soil sampling. The results of the soil chemical analysis were then inputted into the Decision Support System (DSS), a computer application program, to determine recommendations for fertilization and amelioration methods.

2.2 Field experiment

The treatment in this study included fertilization and amelioration treatments. Fertilization methods consisted of farmer practice (MP) and recommended practice (MR), while amelioration included without ameliorant (A0), 1,000 kg CaCO3 ha-1 (A1), and 1,000 kg (Ca,Mg)CO3 ha-1 (A2). The main plot was occupied by the amelioration treatments, while the subplots were occupied by the fertilization treatments. Biotara was applied as one of the recommendation fertilizer due to it contains beneficial microorganism such as Trichoderma sp., Bacillus sp., and Azospirillum sp.

Table 1. Percentage of survival rate of Chrysanthemum varieties, 1 and 3 wap (weeks after planting).

Treatment	Biotara (kg ha^{-1})	Lime (kg ha^{-1})	Organic fertilizer (kg ha^{-1})	Urea (kg ha^{-1})	NPK (kg ha^{-1})	SP-36 (kg ha^{-1})	KCl (kg ha^{-1})
Recommended practice	25	1.000	1.000	200	300	50	50
According to farmer practice	-	300	-	50	125	50	25

The Inpari-32 rice seeds were soaked for 2 days, then drained. The seeds were then evenly spread in planting boxes measuring 18 cm x 56 cm with a seed density of 100-125g box^{-1}. Land preparation was carried out after the application of lime, biotara, and organic fertilizer. Prior to land preparation, the soil was flooded with water up to ± 5.0 cm for 2 days. The soil was then plowed using a hand tractor to a depth of ± 20 cm, then incubated for 2 days, and flooded with water for 2 days. Land preparation was done to muddy the soil and level it. Next, the soil was left for 2 days and was ready for planting. The Inpari-32 rice seedlings, 15 days, were planted in 10 m x 10 m plots using the Jarwo 4:1 planting system with a spacing of 25 x 12.5 x 50 cm, meaning that the distance between rows (4 rows) was 25 cm, the distance between plants was 12.5 cm, and the distance between margin plants was 50 cm.

The types of fertilizers used included urea, NPK compound fertilizer, agricultural lime, dolomite, and biofertilizer (Biotara) and organic fertilizer from cow manure (Table 1). The dosage of each fertilizer was determined based on the analysis of soil chemical properties using the DSS method. The ameliorants were applied two weeks before planting, along with biotara and organic fertilizer. The Urea, SP-36, KCl, and half of the NPK dosage were given at 7-10 days after transplanting (DAT), and the remaining NPK fertilizer was given at 35-42 DAT.

Plant height and tiller numbers were observed at two different time points: 30 and 60 days after transplanting (DAT). Additionally, measurements were taken for tiller numbers per hill, panicle length, number of filled grains per panicle, 1000-grain weight, and yield. To gather data, five random plants were selected diagonally from the center of the plot. For each selected plant, plant height, tiller number, panicle length, number of filled grains per panicle, and 1000-grain weight were measured. Plant height was determined by measuring the distance from the soil surface to the tallest part of the plant. Tiller numbers were counted by considering all the tillers present on each plant. Panicle length was measured using a ruler to assess its size. To determine the number of filled grains per panicle, a sample of panicles was taken, and any unfilled grains were separated and excluded from the count, resulting in the number of filled grains per panicle. The 1000-grain weight was determined by weighing 250 filled grains, then converted to 1000-grain weight in grams. Rice yield was obtained from a 4 x 4 m plot (four rows of Jarwo 4:1 from right to left and 32 rice plants from front to back).

2.3 Statistical analysis

All statiscal analysis were performed by GenStat 11 Edition. The effect of the treatments was determined by analysis of variance (ANOVA) and if there were significant differences, the Duncan's multiple range test (DMRT) was performed according to the significant level 5%.

3 Results and discussion

Tebas District is one of the 19 districts in Sambas Regency. This district is a rice production center in Sambas Regency that covers 30% of rice production in Sambas Regency. Tebas Sungai Village is one of the 21 villages in Tebas District and is a leading village in rice production in the district. The average rice productivity in West Kalimantan 2 tons ha^{-1} [11]. Based on interviews with farmers, it is known that the commonly grown rice varieties are Inpari-32 and Cilosari.

3.1 Land characteristics

Based on discussions with several farmers and observations in the field regarding the highest water level during the rainy season, it was concluded that the research location was classified as a tidal swamp area with type C flooding [10]. According to farmers, the highest water level during a single high tide in the rainy season was 10-20 cm from the surface of the paddy field. This information was supported by the former high water mark in the tertiary channel which shows approximately the same value.

The measurement results of the depth of pyrite at five observation points showed variations in depth ranging from 55-92 cm. This depth is still considered safe for the use of agricultural tools and machinery in soil cultivation. What needs to be considered in soil cultivation is that the water level from the surface of the soil does not exceed 55 cm or a maximum of 40 cm to avoid pyrite oxidation which triggers soil acidification [12]

3.2 Soil characteristics

The results of soil chemical analysis in the research location showed that the soil was acidic, had low levels of organic C, total N, available P, and exchangeable (Ca, K, and Na) ions (Table 2). However, the exchangeable Mg content was categorized as high. These results are consistent with previous studies (13). Generally, soils in tidal swamp areas are deficient in major elements that determine rice productivity improvement.

After harvest, farmers usually do not return rice straw to the field but utilize it as feed supplement for cattle or other livestock. This condition causes a continuous decrease in organic C content. Additionally, the habit of farmers to prepare land by burning not only contributes to the decrease in organic C but also reduces the total N content in the soil. Therefore, soil health in terms of organic matter should be improved by utilizing rice straw and cow dung in the village.

Based on the soil chemical analysis results in Table 2, to improve soil support for rice growth and productivity in the area, it is necessary to apply lime, fertilize with N, P, and K, and use organic and biotara fertilizers as shown in Table 1.

Table 2. Soil characteristics in the study site.

No.	Parameter		Value	Criteria
1.	pH H_2O		4.59	Acid
2.	Organic C (%)		1.88	Low
3.	Total N (%)		0.16	Low
4.	Available P (μg g^{-1})		8.7	Low
6.	Exchangeable (cmol(+) kg^{-1})	Ca	2.30	Low
7.		Mg	2.80	High
8.		K	0.11	Low
9.		Na	0.22	Low

3.3 Plant growth

The results of the analysis of variance showed that the tested treatments had a significant effect on plant height and the number of tillers at 30 and 60 DAT. Plants fertilized using the farmer's method were shorter and produced fewer tillers (Table 3.). This was due to the fact that the type and dosage of fertilizer used by the farmers were insufficient, despite the fact that soil analysis showed low availability of N, P, K, and organic C (Table 2). Therefore, the addition of these nutrients had a significant effect on plant height and tillers formation [14,15].

Since the availability of organic C in the soil was low, the addition of organic fertilizers, or even biotara, was able to improve the ability of plants to grow taller and produce more tillers. The availability of organic fertilizers such as cow manure at the research site is important for soil health and productivity of rice. In addition, organic fertilizers also improve the activity of microorganisms, thereby increasing nutrient availability and plant productivity [16].

The plot of land that was not ameliorated showed lower plant growth. This can be understood because the soil in the research location is deficient in Ca, so the application of ameliorants containing Ca resulted in better plant growth.

Table 3. Effect of fertilization and amelioration methods on plant height and tillers number of Inpari-32 rice variety at 30 and 60 DAT on tidal swamp land of C flood type.

Treatment	Plant height (cm)		Tillers number	
	30 DAT	60 DAT	30 DAT	60 DAT
A_0MP	51.7 a	83.7 a	6.7 a	13.6 a
A_0MR	60.8 b	92.8 ab	8.5 a	14.7 a
A_1MP	65.9 bc	103.8 bc	10.7 ab	19.5 bc
A_1MR	74.6 d	112.3 d	13.8 b	25.6 d
A_2MP	60.2 b	94.5 b	8.4 a	16.7 ab
A_2MR	68.3 c	102.1 c	10.2 ab	20.7 c
Average	63.6	98.2	9.7	18.5

Note: The values within columns sharing the same letter are not statistically different based on the DMRT at a significance level of 5%.

Table 3 also shows that the rice paddies that were ameliorated with dolomite had lower growth and less ability to form tillers compared to those ameliorated with $CaCO_3$. This was due to the location's soil being deficient in Ca, but having a relatively high availability of Mg. The application of dolomite resulted in a lower amount of Ca contributed to the soil compared to using $CaCO_3$. The Ca component in $CaCO_3$ is 40%, while in (Ca, Mg) $(CO_3)_2$ it is only around 21.70%. This difference caused rice plants that were ameliorated with $CaCO_3$ to grow better [17].

3.4 Rice yield and productivity

The three yield components that affect rice productivity were panicle length, number of filled grains per panicle, and 1,000-grain weight [18,19]. Table 4 informed that these three yield components of Inpari-32 rice variety grown in tidal swamp land type C were influenced by fertilization and amelioration methods.

Table 4. Effect of fertilization and amelioration methods on panicle length, number of filled grains per panicle, and 1,000-grain weight of Inpari-32 rice variety in tidal swamp land type C.

Treatment	Length of panicle (cm)	Number of filled grain per panicle	Weight of 1.000 grain
A_0MP	19.6 a	58.4 a	18.3 a
A_0MR	21.2 ab	69.2 b	20.7 ab
A_1MP	23.2 bc	73.5 bc	24.2 c
A_1MR	27.3 d	90.4 d	27.4 d
A_2MP	21.8 ab	69.7 b	22.4 bc
A_2MR	24.0 c	74.1 bc	24.6 c
Average	23.0	72.6	22.9

Note: The values within columns sharing the same letter are not statistically different based on the DMRT at a significance level of 5%.

The fertilization method affected the yield components. Yield components of rice plants fertilized with recommended fertilization method produced longer panicles, more filled grains per panicle, and heavier 1,000-grain weight (Table 4). Fertilizing plants with necessary elements in a balanced amount leads to the growth of rice plants and the formation of longer panicles, more filled grains, and heavier grains. Fertilization with P and organic rice straw increases rice productivity in tidal swamp land [20].

The differences in yield components of rice plants resulted in different rice productivity. High rice productivity was supported by longer panicles, more filled grains per panicle, and heavier 1,000-grain weight (Table 4).

Table 5. Effect of fertilization method and amelioration on the productivity of Inpari-32 rice variety in tidal swamp land type C (ton/ha).

Amelioration method	Fertilization method		Average
	Farmer practice	Recommended practice	
Without amelioration	3.25 a	3.61 a	3.43 x
$CaCO_3$	4.73 c	5.62 c	5.18 z
$(Ca, Mg)(CO_3)_2$	4.15 b	4.78 b	4.47 y
Average	4.04 p	5.20 q	-

Note: The values within columns and rows sharing the same letter are not statistically different based on the DMRT at a significance level of 5%.

The results of this study showed that the highest productivity (5.62 tons ha^{-1}) was obtained from plots fertilized based on recommendation and ameliorated with $CaCO_3$ (Table 5). This can be understood because the necessary nutrients and their quantities were met by the combination of the fertilization and amelioration methods. Appropriate fertilization and amelioration methods must consider the amount and composition of nutrients, and the source of ameliorants [17]. Fertilization based on recommendation was able to increase productivity by 1.16 tons ha^{-1}. This figure was certainly significant for improving farmers' income. Table 5 also shows that plots ameliorated with $CaCO_3$ increased productivity by 1.75 tons ha^{-1}, while the use of dolomite only increased productivity by 1.04 tons ha^{-1}.

4 Conclusions

The growth of plants, yield components, and productivity of Inpari-32 rice variety cultivated in tidal swampland type C were influenced by fertilization methods and amelioration methods. The growth of plants, yield components, and productivity of rice fertilized based on recommendation method were better than those of the farmers' method, and the use of CaCO3 ameliorant was better than (Ca, Mg)(CO3)2. The highest productivity (5.62 tons ha) was obtained from the plot that was ameliorated with CaCO3 and fertilized based on the recommendation method.

The efficacy of the treatment in this study needs to be tested for different seasons. In addition, research is needed to substitute biotara with organic fertilizer from cow manure available in the research location. It is also necessary to determine whether the use of recommended fertilization methods increases soil fertility.

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