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Research Article

Rice Yield Improvement by Sugarcane Filter Cake Fertilizer Application in the Protected Dyke

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This study was carried out to evaluate the fertility of rice soil and the effect of inorganic fertilizers combined with sugarcane filter cakes on rice yield in a protected dike area in Cho Moi district, An Giang province. The experiment consists of 4 treatments, and the dose of fertilizer in each treatment is (1) controlled according to the farmers' dosage (224 kg N + 148 kg P_2O_5 ha^{-1}), (2) fertilize according to farmers + 6 tons/ha of cow manure composted with straw, (3) fertilizer according to farmers + 6 tons/ha of cow manure composted 15 cm deep, and (4) fertilize according to farmers + 2 tons/ha of organic fertilizer with sugarcane filter cakes. By analyzing the nutrient content of soil samples, it was found that inorganic fertilizers in combination with sugarcane residues improved soil fertility as reduced soil acidity and electrical conductivity, and increased organic matter, total nitrogen content, and exchangeable K. In addition, exchange and enriched exchangeable Mg achieved the highest rice yield, a statistically significant difference compared with organic fertilizer treatment with straw compost and inorganic fertilizer. However, the content of total P, available P, exchangeable Na, and Ca have not improved significantly. Therefore, applying inorganic fertilizers combined with sugarcane filter cakes is an excellent measure to help improve the supply of nutrients from the soil and increase rice yield in the dike land.

1. Introduction

The historic flood in 2000 [1] forced the Mekong Delta to have coping strategies. Many provinces upstream of floods have built a system of dikes to help farmers harvest rice before the floods. However, the concept that the embankment covers two solid crops (including winter-spring and summer-autumn rice) and then releases the flood initially has been abused. After building the closed dike, the localities have increased the area of 3rd crop of rice to run. According to Vo Thi et al. [2], when dyke covers to produce three-rice crops continuously for many years may have some impact on soil fertility. The amount of fertilizer increased, but the yield did not improve. A loss of natural flood sediments has been suggested as part of the reason why fertilizer inputs have increased within the dike area [3]. These sediments were primarily seen as important sources of nutrients, notably potassium [4], which were essential for rice growth. In addition, traditional farming techniques did not effectively improve soil fertility.

According to Minh et al. [5], beside steel slag fertilizer's effectiveness in neutralizing acid soil properties and improving rice yield and production, sugarcane was one of Vietnam's most important industrial crops and covers a total of 127,000 hectares of plantation area [6]. In 2020-2021, Vietnam produced 0.763 million tons of sugar (accounting for 0.34% of total world sugar production). A current sugarcane production of 7.498 million tons was being used mainly for sugar production for direct consumption, ethanol production, bioelectricity, and fertilization. Sugarcane filter cake and ash account for about 3% of the total crushed cane weight, equivalent to about 0.4 million tonnes of filter cake

Table 1: Fertilizer dosage of different treatments in the Cho Moi district.

No.	Experiment	Fertilizer dosage (kg/ha)
1	NT1	224 N + 148 P_2O_5 (following to farmer dose)
2	NT2	224 N + 148 P_2O_5 + fertilizer 6 tons ha^{-1} cow manure + straw compost
3	NT3	224 N + 148 P_2O_5 + fertilize 6 tons ha^{-1} cow manure + compost 15 cm deep
4	NT4	224 N + 148 P_2O_5 + fertilizer 2 tons ha^{-1} compost of sugarcane filter cakes

and ash [7]. Sugarcane filter cake has played as a rich source of nutrients for the growth of soil microorganisms and its addition to the soil has been shown to significantly impact their populations [8]. In addition, it affected the soil composition in terms of the rates of C, N, and P mineralization [9]. With the increased cost of synthetic fertilizers and the need to recycle large quantities of organic residues sustainably, there was increasing interest in using this resource for agriculture. The sugarcane filter cake was a recognized low-cost material and was considered to be able to improve soil fertility and plant productivity [10]. Therefore, the study aimed to evaluate the influence of sugarcane filter cakes on changing some soil chemical properties and enhancing rice yield in the protected dike area in Cho Moi district, An Giang province, Vietnam.

2. Materials and Methods

2.1. Materials. The rice variety used in the experiment is OM 6976, a new purebred rice variety selected by the Mekong Delta Rice Institute, Vietnam. The growth duration ranged from 100 to 105 days. The seed distribution was 22 kg/1,000 m^2.

Sugarcane filter cakes fertilizer containing a total of main elements including 23% C, 2.5% N, 3% P_2O_5, 1% K_2O, 0.05% CaO, 0.4% MgO, 2.5% humic acid, and 0.001% Zn.

Cow manure was composted according to local farmers' practices.

2.2. Research Methods

2.2.1. Experimental Setup Method. The test area of the study was conducted in Cho Moi district, An Giang province, Vietnam. The experimental design was a randomized complete block design evaluated in three replications in two seasons of year (summer-autumn and autumn-winter 2017). Each planting area was 25 m^2 (5 m × 5 m), and there were four treatments (NT1, NT2, NT3, and NT4) in the experiment.

The dosage of fertilizer in each treatment is presented in Table 1.

2.2.2. Methods of Sampling and Analysis

(1) Soil Sampling and Analysis. Soil samples were taken at the 0–20 cm layer before tilling and after harvesting at the experimental site. Each experimental plot took three samples. Each sample was from 1–1.5 kg of soil and mixed to get 1–1.5 kg. Then, the mixed soil samples of each treatment lot were taken at 1 kg. For physicochemical analysis, the soil samples were air-dried and passed through 2 mm and 0.5 mm sieves. The soil physicochemical properties analyzed was included

(2) Before Tilling. Soil samples were collected to analyze soil (pH), electrical conductivity (EC), organic carbon (OC), total nitrogen (N%) and total phosphorus (P%), available phosphorus (mg P_2O_5/kg), exchangeable cations such as potassium (K^+), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), aluminum (Al^{3+}), and soil texture. Postharvest: soil properties analyzed similarly to before tillage.

(3) Collected Agronomic Criteria. The total panicle/m^2 number; the total seeds number/panicle; the filled and unfilled grains/panicle ratio; an average of 1,000 grains weight, at a standard moisture content of 14% were calculated, in which

theoretical yield (ton/ha) = panicles number/m^2 ∗ filled grains number/panicle ∗ 1,000 grains weight ∗ 10^{-4}

(4) Actual Yield. Each treatment plot collected 05 points diagonally according to the experimental method in Vietnam, 3 m^2 each. Grains were cleaned, weighed, and measured immediately, reducing to a standard moisture content of 14%.

2.2.3. Analytical Methods. The following analytical methods were used as follows:

- Soil pH (pH_{H2O}) and electrical conductivity (EC): determined after water extraction (ratio 1 : 2.5)
- Soil pH (pH_{KCl}): extracted with KCl solution (ratio 1 : 2.5)
- Exchangeable aluminum (Al^{3+}) (meq/100 g): extracted with 1 N KCl, titrated with 1 N NaOH, complexed with NaF, and titrated with 0.01 N H_2SO_4
- Exchangeable cations are calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) (meq/100 g): extracted with $BaCl_2$ and measured on an atomic absorber
- Soil texture: based on the Robinson method according to the principles of Stocke's law and determining the grain level based on the USDA/Soil taxonomy triangle
- Available phosphorus (mg P_2O_5/kg): bray 2 method
- Total nitrogen (N%): digested with concentrated H_2SO_4-$CuSO_4$-Se and distilled Kjeldahl
- Total (P): digested with concentrated H_2SO_4-$HClO_4$, showing the color of phosphomolybdate colorimetric color on the spectrophotometer

Table 2: Some physicochemical parameters of rice-growing soils.

No.	Target/unit	Content/ value
1	pH_{H2O} (1 : 2.5)	5.87
2	pH_{KCl} (1 : 2.5)	4.8
3	EC 1 : 2.5 (mS/cm)	0.6
4	Organic carbon (%C)	2.0
5	Total N (%N)	0.175
6	Total P (%P_2O_5)	0.088
7	Available P (mg P/kg)	17.89
8	Exchangeable K (meq/100 g)	0.116
9	Exchangeable Na (meq/100 g)	0.167
10	Exchangeable Ca (meq/100 g)	12.5
11	Exchangeable Mg (meq/100 g)	4.81
12	Exchangeable Al (meq/100 g)	ND
13	Soil texture (%)	
	Sand	2.76
	Silt	41.57
	Clay	55.68

Note: ND, not detected.

2.3. Data Processing Methods. Microsoft Excel software used data for analyzing the linear regression (GLM-general linear msodel). Besides, the SPSS software was used for Duncan's test at a 5% significance differences level.

3. Results and Discussion

3.1. Soil Properties of the Experimental Site. The soil properties in Table 2 show that the topsoil layer has a low pH of 5.87. It is the typical pH range of the alluvial nonacid soil group in the Mekong Delta [11]. The surface layer's organic carbon content is low (2.0% C) [12] and average total N content (0.175%). The content of total phosphorus is low (0.088%) and available P (17.89 mg P/kg) [13]. This parameter is very volatile depending on the organic quality and the phosphate fertilization process for crop cultivation. The content of easily digestible potassium in the soil is very low (0.116 meq/100 g) [14]. The exchangeable Ca content is relatively high in the surface layer. The exchangeable Mg content was quite good (4.81 meq/100 g). The Na content <1 cmol (+)/kg indicates that the soil is not affected by salinity in the surface layer. The exchangeable Al content was not detected, typical of the alluvial soil group without the acidity. The texture of the surface layer is clay-silt clay (55.68% clay, 41.58% silt, and 2.76% sand, respectively), a characteristic silty clay texture of alluvial soil. In general, this is a group of soils with favorable physicochemical and nutritional properties for rice plant growth due to the characteristics of alluvial soil, good nutrition, relatively normal pH, and silty clay soil texture.

3.2. The Efficiency of Sugarcane Filter Cakes in Improving Yield Composition and Yield of Rice

3.2.1. Rice Yield and Yield Components. The rice yield and yield components were compared with the farmer's treatment of inorganic fertilizer combined with organic fertilizer with sugarcane filter cakes (NT4), and the treatment using only inorganic fertilizer according to the farmer (NT1), inorganic fertilizers mixed with the cow manure composted with straw applied on top or buried 15 cm deep (NT2, NT3). The results presented in Table 3 show no significant difference in the rice yield components of treatments in the summer-autumn crop. It led to no significant difference between theoretical and actual yield. However, yield components changed in the autumn-winter season, despite the number of panicles/m^2 (ranging from 335 panicles to 386 panicles) and the average 1,000-grain weight (27.3–27.8 g) not significantly different between treatments. Still, there was a significant difference in the seeds number/panicle and the percentage of filled seeds, specifically the combined inorganic fertilizer treatment. The sugarcane filter cake fertilizer had the highest average seeds number/panicle (112 seeds/panicle), significantly different from the treatment with only inorganic fertilizer (90.3 seeds/panicle) and the treatment with fertilizer. The cow manure composted with straw (80.3–84.1 seeds/panicle). The percentage of filled seeds also had a statistically significant difference between treatments. The average rate of filled seeds of the treatment with the sugarcane filter cake fertilizer was 89.0%, while the percentage of filled seeds was the highest. This rate for the treatment with only inorganic fertilizer was 86.8%, and the treatment with cow manure for composting was 86.7–87.2%. This result may be because the treatment of inorganic fertilizer combined with the sugarcane filter cake fertilizer has high N content and enough nutrients provided to the rice. Therefore, it leads to a higher seed number/panicle than other treatments. At the same time, K^+ high in sugarcane filter cakes also increases the percentage of filled grain for rice. As a result, the average value was higher than 8.82 tons/ha in the treatment with sugarcane filter cake fertilizer in terms of the theoretical yield. Still, there was no statistically significant difference between the other treatments (7.09–7.88 tons/ha).

3.2.2. Actual Yield. The results presented in Figure 1 show that the sugarcane filter cake application in the summer-autumn crop did not show an effect. The yield was 4.92 tons/ha, the lowest and not significantly different from the fertilizer alone: inorganic fertilizers or compost cow manure. Inorganic fertilizer application combined with sugarcane residue fertilizer in the next autumn-winter crop, rice yield increased to 5.65 tons/ha, the highest, significantly different from inorganic fertilizer (4.67 tons/ha) ha) and inorganic fertilizers combined with cow manure composted with straw (4.87–4.94 tons/ha). The analytical results are also consistent with Vo Thi et al. [15] study. The experiment was carried out using organic fertilizer with sugarcane filter cakes on rice from the sixth crop with 10 tons/ha in the year. The first organic fertilizer crop has not shown effectiveness, and the yield is 4.33 tons/ha, not significantly different from inorganic fertilizer only. After applying sugarcane filter cakes organic fertilizer to the second and third crops, the rice yield increased to nearly 6 tons/ha. It differs significantly from the batch without sugarcane filter cakes (4.8 tons/ha). The results on other crops, such as vegetables and fruit trees, by

Table 3: Rice yield and yield components of different treatments in the Cho Moi district.

Treatments	Summer collection						Autumn-winter season					
	Effective panicle/m^2 (panicle)	Number of seeds/panicle (seeds)	Percentage of filled seeds (%)	Weight of 1000 seeds (g)	Theoretical yield (ton/ha)	Actual yield (ton/ha)	Effective panicle/m^2 (panicle)	Number of seeds/panicle (seeds)	Percentage of filled seeds (%)	Weight of 1000 seeds (g)	Theoretical yield (ton/ha)	Actual yield (ton/ha)
NT1	457a	70a	79.6a	25.5a	6.39a	5.04a	371a	90.3ab	86.7b	27.5a	7.88a	4.67b
NT2	479a	63a	84.7a	25.5a	6.40a	5.23a	386a	84.1b	86.7b	27.3a	7.68a	4.94ab
NT3	528a	68.6a	74.3a	25.8a	6.84a	4.95a	362a	80.3b	87.2b	27.8a	7.09a	4.87ab
NT4	454a	71.6a	79.9a	25.3a	6.44a	4.92a	335a	112a	89a	27.5a	8.82a	5.65a
CV (%)	15.4	22.2	6.85	3.32	8.24	10.2	11.5	11.8	0.79	0.88	12.5	8.85
F	ns	ns	ns	ns	ns	ns	ns	*	*	ns	ns	*

Note. NT1: fertilize according to farmers (224 kg N + 148 kg P_2O_5) ha^{-1}. NT2: fertilize according to farmers +6 tons ha^{-1} cow manure with straw. NT3: fertilize according to farmers +6 tons ha^{-1} cow manure composted with straw buried 15 cm deep. NT4: fertilize according to farmers +2 tons ha^{-1} sugarcane filter cakes.

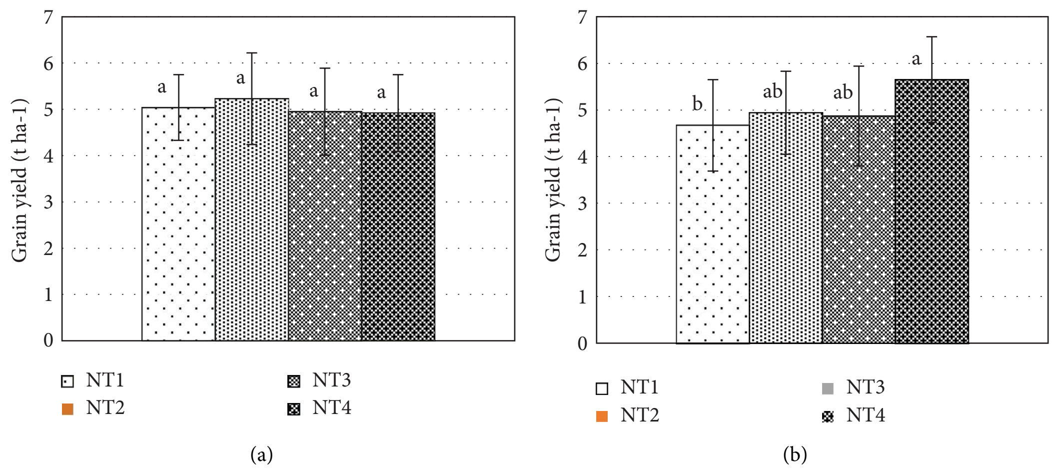

Figure 1: Sugarcane filter cakes fertilization on rice yield at different treatments and cropping season. (a) Summer-autumn; (b) autumn-winter. Note: a, b mean significant differences according to the treatment ($p < 0.05$); ns: no meaningful difference. The standard deviation in the vertical bar and columns with the same letter are not significantly different at 5%.

Table 4: Some chemical properties of rice soil before and after the experiment in the Cho Moi district.

Experiment/criteria		pH_{H2O} 1 : 2.5	EC 1 : 2.5 (mS/cm)	OC (%)	N (%)	Total P (%P_2O_5)	Avai P (mgP/kg)	K^+	Na^+	Ca^+	Mg^+
									meq/100 g		
Beginning		**5.87**	**0.6**	**2.00**	**0.175**	**0.088**	**17.89**	**0.116**	**0.167**	**12.5**	**4.81**
After experiment	NT1	5.23	0.396	2.72	0.196	0.143	42.9	0.13	0.21	8.27	3.95
	NT2	5.10	0.336	2.55	0.168	0.12	36.8	0.11	0.249	7.83	4.15
	NT3	5.07	0.416	2.69	0.182	0.12	31.7	0.13	0.291	8.19	4.32
	NT4	5.64	0.474	2.95	0.21	0.139	39.1	0.17	0.285	7.86	4.67

Note. NT1: fertilize according to farmers (224 kg N + 148 kg P_2O_5) ha^{-1}. NT2: fertilize according to farmers +6 tons ha^{-1} cow manure composted with straw. NT3: fertilize according to farmers +6 tons ha^{-1} cow manure composted with straw buried 15 cm deep. NT4: fertilize according to farmers +2 tons ha^{-1} sugarcane filter cakes. The bold data is emphasized for data at the beginning of the experiment only, it does not mean and show the significance.

applying organic fertilizer with sugarcane residue combined with balanced inorganic fertilizers, help improve crop yield significantly different from organic fertilizers [16, 17].

Organic fertilizer application of sugarcane filter cakes in rice cultivation helps significantly increase rice yield on 3-crop rice fields and helps restore soil fertility gradually. Increasing the soil's organic matter content is the primary role in improving soil fertility due to the beneficial effect of organic matter on soil's physiochemical and biological properties [18]. Thus, a significant increase in rice yield results from improved soil quality.

Based on these results, it is recommended that three-rice crop cultivation is necessary to apply organic fertilizers. It helps to improve soil characteristics, increase soil fertility, and increase rice yield. According to a study by Zhang et al. [19], applying inorganic and organic fertilizers in rice soil for a long time significantly increased organic content and mineralized N in the soil. In addition, degradable organic compounds in compost help improve soil nitrogen mineralization [20].

3.3. The Effectiveness of Sugarcane Filter Cakes in Improving Soil Fertility. Table 4 shows the changes in soil properties of different treatments before and after the experiment, which can be explained in the following.

3.3.1. Soil pH. Soil pH is an essential soil assessment criterion because it is directly related to plant growth, microbial activity, and chemical and biological reactions. In addition, soil pH affects the nutrients' solubility, availability, and effectiveness of fertilizers. Applying inorganic fertilizers combined with sugarcane filter cakes fertilizer with 2 tons/ha soil pH reached 5.64. It tended to increase compared to the treatments with only inorganic fertilizers (5.23) and the treatments with only inorganic fertilizers (5.23). Furthermore, inorganic fertilizer combined with cow manure composted straw (5.10). This result shows that applying organic fertilizer with sugarcane filter cakes (with 0.05% CaO content), with an amount of fertilizer of about 2 tons/ha, to the soil improves the soil's pH. The analysis results are also consistent with the study of Anh Thy et al. [21]. Applying sugarcane filter cakes improves soil pH (pH = 4.6), significantly different from only inorganic fertilizers (pH = 3.4) compared with other organic fertilizers.

3.3.2. Organic Matter Content in the Soil. Organic matter affects soil properties by providing nutrients and improving soil's physical, chemical, and biological properties. The organic C content in all treatments increased compared to the beginning of the cropping season. In which, the treatment of inorganic fertilizer combined with organic fertilizer of sugarcane filter cakes reached the organic C content value of 2.95% and tended to increase more than the treatment with only inorganic fertilizer (2.72%), and the treatment with inorganic fertilizer combined with the cow manure compost (2.69%). This result may be because organic fertilizer with sugarcane filter cakes is rich in C (23%), which helps accumulate more organic matter in the soil than other forms of fertilizer. It is also consistent with Vo Thi et al. [16]. This study evaluated the effect of sugarcane filter cakes, and wild anemone green manure improves soil quality for orchard cultivation. It was found that applying 10 tons/ha of organic fertilizer with sugarcane residue significantly increased the organic matter content compared to using only inorganic fertilizers and wild anemone green manure. Reference [21] study on the rambutan garden soil showed that sugarcane filter cakes improve and maintain soil organic matter content at a rich level, better than other forms of organic fertilizers. However, the organic fertilizer application in a short time (2 crops) tended to increase. However, it was still insignificant compared to the organic C content at the beginning of the season (2%). Therefore, increasing the organic matter in the soil by applying organic fertilizers helps to improve soil fertility. Organic matter plays an essential role in soil physicochemical and biological processes through its beneficial influence on the soil structure, water holding capacity, cation exchange capacity, forming complexes with metal ions, and helping increase soil microbial activity [22–24]. This result is also consistent with previous studies that need to apply organic fertilizers for a long time to improve soil biological, physical, chemical, and fertility properties [16, 17, 25].

3.3.3. Total Nitrogen. Total soil nitrogen content in all treatments tended to improve compared to the soil at the beginning of the crop. However, the treatment of inorganic fertilizer combined with organic fertilizer of sugarcane filter cakes increased total N content (0.21%), higher than the farmer's treatment, despite having a higher amount of inorganic nitrogen applied than the treatments (0.196%). The treatment of inorganic fertilizer combined with cow manure compost (0.182%) is possibly due to higher N-rich sugarcane bagasse (2.5%) than other fertilizers. Applying 2 tons/ha of fertilizer to sugarcane filter cakes improves the total N content in the soil. The analytical results are also consistent with Ho Van Thiet et al. [26] study on rambutan garden soil. After six months of application, the sugarcane filter cakes organic fertilizer helps increase the degradable organic N content. Soil is 30 mg/kg, significantly different from only fertilizing biogas, vermicompost (22–25 mg/kg), and inorganic fertilizer (16 mg/kg). Research by Vo Thi et al. [27] and Duong Minh et al. [17] showed that adding organic fertilizer increases the content of total and available N in the soil.

3.3.4. The Content of Total and Available P in the Soil. After two crops of inorganic fertilizer and inorganic combined with organic fertilizer, the content of total and available P in the soil improved significantly, the increasing trend in all treatments (from 0.12 to 1.143% P_2O_5 and from 31.7 to 42.9 mg P/kg) compared with before tilling (0.088% P_2O_5 and 17.89 mg P/kg). This result may be due to the inorganic P content applied at a high dose in the farmer's treatment and the high P content in the sugarcane filter cake (3% P), which was also supplied to the soil when the sugarcane filter cake was decomposed.

3.3.5. The Content of Cation Exchange in the Soil. The analysis showed that K^+ in the soil tended to increase in all treatments compared to the beginning of the crop. Inorganic fertilizer application, according to farmers, combined with organic fertilizer with sugarcane filter cakes, tended to increase K^+ exchange content (0.167 meq/100 g) compared with the treatment of only inorganic fertilizer (0.116 meq/100 g) and fertilizer application. Inorganic fertilizer combined with cow manure compost (0.131 meq/100 g). The analytical results are also consistent with the research on rambutan by Duong Minh et al. [17]. In sugarcane filter cakes, fertilizer applied at 25 kg/plant in combination with inorganic fertilizers improves the exchangeable soil potassium (0.55 cmol/kg soil), significantly higher than just inorganic fertilizers. Thus, compared with only using inorganic fertilizers like farmers with high amounts of N and P and no K application to reduce costs, fertilizers in cultivation K exchanged in the treatment with sugarcane filter cakes fertilizer was improved very effectively. The exchangeable Mg^{2+} in the soil has not improved compared to the beginning of the cropping season. However, the treatment with organic fertilizer applied sugarcane filter cakes tended to increase (4.67 meq/100 g) compared with the treatment that only applied inorganic fertilizer. Organic fertilizer (3.95 meq/100 g) and inorganic fertilizer treatment combined with the cow manure compost (4.32 meq/100 g). The results are obtained due to the high content of this element in sugarcane filter cakes [17]. Other research results also noted that compost after decomposition would provide Mg elements to the soil [28].

4. Conclusions and Recommendations

The effectiveness of inorganic fertilizers combined with sugarcane filter cake fertilizer improves soil pH, EC, organic matter, and total N content. In addition, it increases exchangeable K^+ and Mg^{2+} compared with only inorganic fertilizers and combined with a composted cow manure straw. It then increased rice yield to 5.7 tons/ha in the second crop (autumn-winter). However, the content of total P, available P, exchangeable Na, and Ca has not been improved.

Based on these results, it is recommended that three-rice crop cultivation in the protected dyke is necessary to apply organic fertilizers to enhance soil fertility and increase rice yield. Furthermore, it is necessary to conduct experiments for a longer time to see the effect of sugarcane filter cake organic fertilizer in improving the physicochemical fertility of the soil.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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