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Research Article

Improvement of Glutinous Corn and Watermelon Yield by Lime and Microbial Organic Fertilizers

Le Vinh Thuc[1] and Vo Quang Minh[2]

[1]*College of Agriculture, Can Tho University, Cantho 90000, Vietnam*
[2]*College of Environment and Natural Resources, Can Tho University, Cantho 90000, Vietnam*

Correspondence should be addressed to Vo Quang Minh; vqminh@ctu.edu.vn

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Background. The characteristics of acid soil, often low pH and high toxicity, affect the growth and yield of plants. *Aims*. This study evaluates the effects of supplemented lime and microbial organic fertilizer on glutinous corn (*Zea mays*) and watermelon (*Citrullus lanatus*) yield, yield components, and economic efficiency on acid-sulfate soils. *Materials and Methods*. Two experiments were carried out in Phung Hiep District, Hau Giang Province, as a typical acid-sulfate soil area. The randomized complete block with four treatments and three replicates was designed for the experiment, in which supplemented fertilizers were 800 kg of lime/ha; 2,000 kg of microbial organic fertilizer/ha; and 800 kg of lime in combination with 2,000 kg of microbial organic fertilizer/ha, and treatment as farmer dose (FFT), without lime and microbial organic fertilizer. *Results*. As a result, using lime combined with microbial organic fertilizer increased the yield compared to using only lime or microbial organic fertilizer. Besides, the incomes increased to 12.0% and 13.8%, respectively, compared to farmer recommendations. *Conclusion*. To improve the yield of glutinous corn or watermelon and income on acid-sulfate soils, lime should be applied at 800 kg combined with 2,000 kg of microbial organic fertilizer/ha.

1. Introduction

The conversion to growing crops on inefficient rice land has brought significant economic benefits to farmers[1]. In Phung Hiep District, Hau Giang Province, farmers have converted to these models; glutinous corn (*Zea mays*) and watermelon (*Citrullus lanatus*) are the two crops preferred by the farmers due to their high income compared with rice monoculture [2]. However, the study area's soil is located in the low-lying acid soil basin of the Hau River [3]. Normally, acid-sulfate soils are unsuitable for crop production [4, 5]. Phosphorus availability for the plant in acid-sulfate soil was low due to the significant fixation by Al and Fe [6]. Still, aluminum in acid-sulfate soil solution was chelated by organic matter [7] while lime was raised soil pH to precipitate aluminum as inert aluminum hydroxides, thereby reducing its toxicity [8]. In the Phung Hiep District, farmers apply very high amounts of chemical fertilizers when planting corn and watermelon, especially nitrogen fertilizers. Using high nitrogen fertilizer inefficiently leads to environmental pollution [9]. Therefore, reducing the number of chemical fertilizers applied to crops is necessary. Liming is a common agronomic practice worldwide to manage acid-sulfate soils for crop production [4]. Research results of Dang et al. [10] showed that applying 2 tons of lime/ha improved the yield of pomelo trees on acid soil in Hau Giang compared to the treatment without lime. The study of Farhana et al. [11] showed using 2 to 8.0 ton ha^{-1} of ground magnesium limestone combined with 0.25 ton ha^{-1} of JITU; sugar cane-based bioorganic fertilizer helps to increase soil pH and reduce toxicity Fe^{2+} and Al^{3+} in acid-sulfate soil. Therefore, the study is carried out to evaluate the influence of lime and microbial organic fertilizers on glutinous corn and watermelon's growth, yield, and economic efficiency on acid soils in Phung Hiep district, Hau Giang province.

2. Material and Methods

2.1. Experiment Materials. The study was carried out from January to June 2019 in Phung Hiep District, Hau Giang Province, Vietnam. The MX10 glutinous corn variety has a growth period of 62–65 days and is resistant to leaf spots and rust. The kernel has extraordinarily high uniformity, and the rate of kernel type 1 is over 95%. The kernel is slightly plump; the seeds are milky white, eaten fresh (cooked), delicious, soft, flexible, sweet, and fragrant. Watermelon variety TN522 has a growth period of 55–60 days, good resistance to pests and diseases, large, thick, hard leaves, round fruit, and bright color. Lime powder used in the experiment is $CaCO_3$ with ≥64.73% CaO. Microbial, organic fertilizer is in powder form containing 23% organic, *Azotobacter* spp.: 1×10^6 CFU/g, and *Lactobacillus* spp.: 1×10^6 CFU/g, 1% N, 0.5% P_2O_5, 0.5% K_2O, 3% humic acid, 25% moisture, and black color. The experimental soil properties for glutinous corn and watermelon experiments are described in Table 1.

2.2. Study Methods

2.2.1. Experimental Layout. The experiment was designed in a completely randomized block with four treatments: the chemical fertilizer base, lime 800 kg/ha (lime treatment), microbial organic fertilizer 2,000 kg/ha (microbial organic fertilizer treatment), lime 800 kg/ha and microbial organic fertilizer 2,000 kg/ha (lime and microbial organic fertilizer treatment), and fertilizing according to farmers using control treatments, without lime and microbial organic fertilizers (FFT treatment) (as a control treatment) with three replicates (Figure 1). Each replicate was a plot with an area of 50 m^2.

2.2.2. Cultivation Techniques. Glutinous corn is planted at a distance of 0.25 m from the plant and 0.75 m from the row (250 plants/plot). Watermelon is grown 0.4 m from the plant and 3.0 m from the row (40 vines/plot). The experiment on glutinous corn was carried out up to 63 days after sowing (DAS) and on a watermelon until 55 DAS. The chemical fertilizers applied to the treatments are presented in Table 2.

2.2.3. Monitoring Parameters. The plant height and diameter of glutinous corn were collected by measuring from the soil surface to the apex of the spike in centimeters, and the diameter of the plant was measured at 5 cm above the ground at 20 DAS and harvest [12]. The number of leaves was counted per plant at 20 DAS and harvest. Kernel length (cm) was measured from the left stalk to the tip of the kernel at harvest time. Kernel diameter (cm) was measured in the middle of the kernel at harvest time. The yield of glutinous corn was calculated from the total number of commercial kernels (the kernel was not affected by disease or injured by insects) per 25 m^2 and converted into hectares.

The vine length of the watermelon was recorded with tape from the base to the growing tip of the plant. The number of leaves/plants was determined by direct counting. The fruit length of the watermelon was measured as the distance in centimeters between the fruit's tendril attachment point and the blossom end. In contrast, the fruit width was recorded by measuring the largest diameter of the cross-sectioned sampled fruits [13]. Fruit rind thickness was measured by cutting the cross-section of the fruit and recording the thickness in centimeters using a calliper meter. The watermelon yield was calculated according to fruit yield per 25 m^2 and converted into tons/ha. The Brix index of watermelon fruit flesh was measured by a refractometer (Atago MASTER-53M) at the fruit's beginning, middle, and end (average value) at harvest time.

Net profit = revenue − expenses [14]. The cost of raw materials (inorganic fertilizers, lime, microbial organic fertilizers, plant protection drugs), labor, and product sales were calculated according to 2019 prices.

2.3. Data Analysis. The data were analyzed using one-way analysis of variance (ANOVA) with the SPSS software package version 13.0. All the mean values were analyzed using ANOVA, and a comparison among the means for determining significant differences was performed using Duncan's multiple range test at $p < 0.05$.

3. Results and Discussion

3.1. Effect on the Growth of Glutinous Corn and Watermelon. Figure 2 shows that the height and diameter of the stem of glutinous corn at 20 DAS and the harvest between the four treatments were significantly different ($p < 0.05$). However, the treatment of adding lime and microbial organic fertilizers had a higher plant height. The difference was not statistically significant between the treatment of microbial organic fertilizer and fertilizer application by farmers. Plant height and diameter at the time of harvest in the treatments of individual microbial organic fertilizer application, combined application of lime and microbial organic fertilizer, and fertilizer application by the farmer were statistically significant ($p < 0.05$) with only lime application. The number of leaves between treatments was not statistically significant at 20 DAS and harvest.

Figure 3 indicates that at the time of 20 DAS and harvesting, there was a statistically significant difference between the treatments ($p < 0.05$). The combination of lime and microbial organic fertilizer had a more considerable length of the stem than that of only lime or microbial organic fertilizer. The diameter of the watermelon stem in the farmer's fertilizer treatment and the addition of lime and microbial organic fertilizer at 20 DAS were not different. The stem diameter between the four treatments was not statistically significant at the harvest time. The number of watermelon leaves in the treatment with lime addition and microbial organic fertilizer at the time of harvest was significantly different ($p < 0.05$) from the other treatments. In general, adding lime in combination with microbial organic fertilizers increased the length of the stem and the number of watermelon leaves.

The plant growth indexes of glutinous corn and watermelon were significantly different in the treatments, which might be explained by the fact that the Phung Hiep

Table 1: Soil properties of the experiment site at the beginning season.

Crops	pH	EC (mS cm^{-1})	CEC (cmol kg^{-1})	OM (%C)	AvaiP (mg kg^{-1})	Texture (%) Clay	Silt	Sand	Bacteria dissolve phosphorus (CFU g^{-1})	Bacteria nitrogen fixation (CFU g^{-1})
Glutinous corn	4.53	0.54	21.45	5.62	7.34	74.4	24.5	1.1	2.46×10^5	1.82×10^5
Watermelon	4.48	0.56	20.57	5.54	7.02	74.2	24.6	1.2	2.54×10^5	1.69×10^5

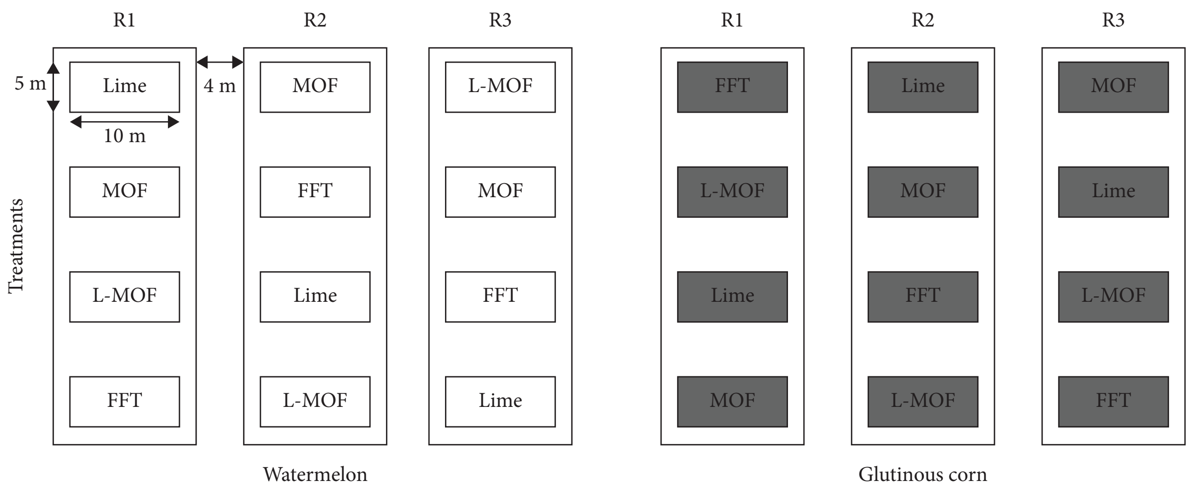

Figure 1: Experimental field layout. R: replication; MOF: microbial organic fertilizer; L-MOF: lime and microbial organic fertilizer treatment; FFT: fertilizer following farmer dose treatment.

Table 2: Amount (kg/ha) and percentage (%) of applied fertilizer at different treatments for glutinous corn and watermelon.

Crops		Glutinous corn					Watermelon				
Treatments	Types of fertilizers	N	P_2O_5	K_2O	Lime	MOF	N	P_2O_5	K_2O	Lime	MOF
Lime; MOF; L-MOF	DAS	100	80	60	800	2.000	223	200	175	800	2.000
	0	—	—	—	100	—	—	—	—	100	—
	10	30	50	20	—	100	30	50	20	—	100
	20	30	50	40	—	—	30	50	40	—	—
	40	40	—	40	—	—	40	—	40	—	—
FFT	DAS	123	110	70	0	0	257	190	205	0	0
	10	20	40	20	—	—	20	40	20	—	—
	18	20	40	30	—	—	20	40	30	—	—
	35	30	20	30	—	—	30	20	30	—	—
	45	30	—	20	—	—	30	—	20	—	—

Note: MOF: microbial organic fertilizer; L-MOF: lime and microbial organic fertilizer; FFT: fertilizer following farmer dose treatment; DAS: day after sowing.

soil is classified as low acid soil in the Hau river [15], with a low pH and high toxicity of iron (Fe^{2+}) and aluminum (Al^{3+}) [16]. Therefore, liming in combination with microbial organic fertilizers improves soil pH [17] and enhances microbial activity, leading to increased nitrogen and phosphorus availability in the soil [18], improving plant growth more than just lime.

3.2. Yield Components of Glutinous Corn and Watermelon

3.2.1. Yield Components of Glutinous Corn. The length and width of kernel and the number of seeds/row between the four treatments were statistically significant ($p < 0.05$) (Figure 4(a)). The treatment with supplemental lime and microbial organic fertilizer gave a greater kernel length than those with only lime or microbial organic fertilizer. This treatment also gave larger kernel width than the treatment with only lime. The number of seeds/rows added with lime and microbial organic fertilizer was not statistically significant with the farmer's fertilizer treatment, but the difference ($p < 0.05$) was more effective than that of the treatments only by fertilizing with lime or microbial organic fertilizers. The reason for no statistical significance between the treatment of microbial organic fertilizer and fertilizer application by farmers might be due to the number of leaf stability of the variety under nutrient-supplied conditions [19]. The number of rows/kernel of the four treatments was not statistically significant, consistent with

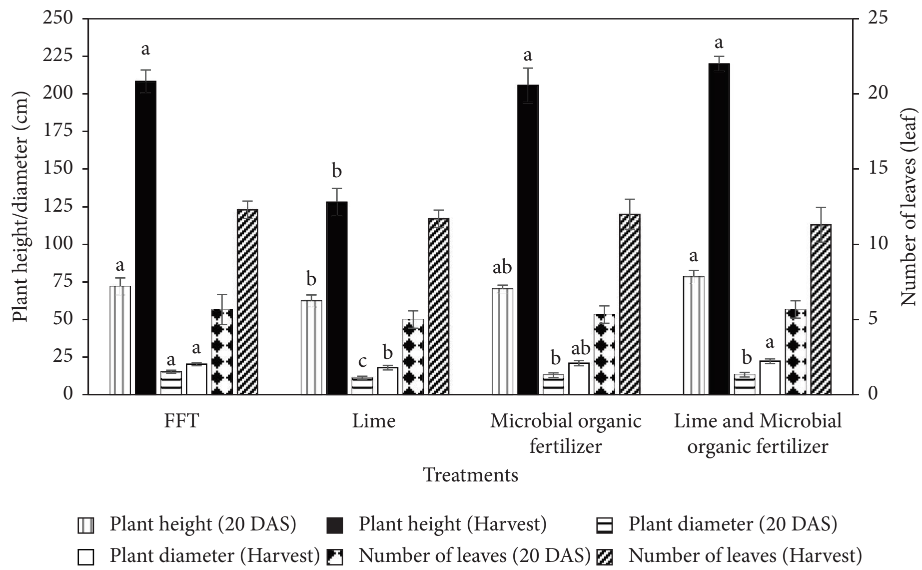

Figure 2: Plant height, plant diameter, and number of leaves of glutinous corn at 20 days after sowing and harvest time.

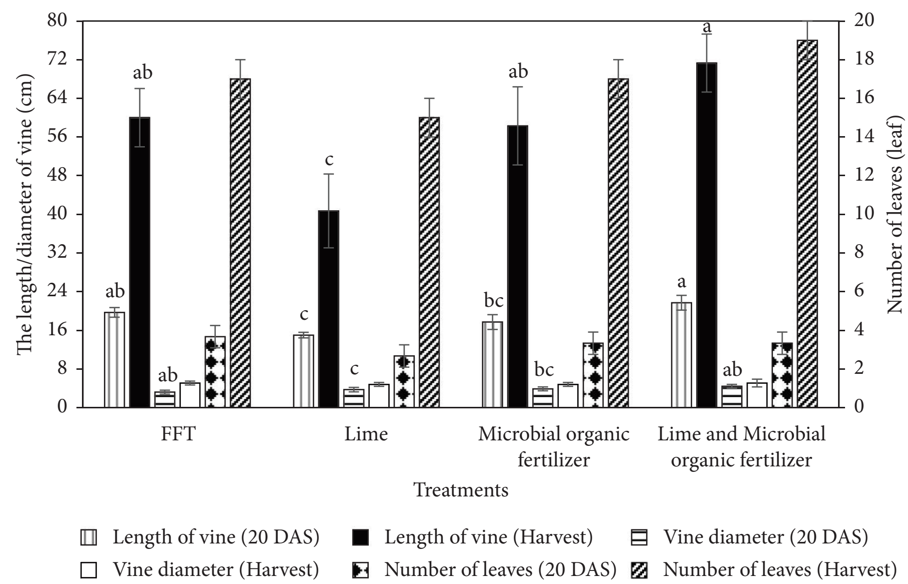

Figure 3: Vine length, vine diameter, and number of leaves of watermelon at 20 days after sowing and harvest time.

Assefa et al. [20], which showed that the glutinous hybrid corn lines had 11 to 13 rows on the kernel.

3.2.2. The Height, Width, and Brix Index of Watermelon Fruit. The height, width, and Brix of the watermelon fruits of the four treatments are statistically significant ($p < 0.05$) (Figure 4(b)). However, according to farmers, the two treatments of liming with a combination of microbial organic fertilizers and fertilizer application had higher height, width, and Brix index, which were statistically significantly different from those only supplemented with lime. The fruit peel thickness of the four treatments was not statistically significant. The addition of lime, combined with microbial organic fertilizers, increased the length of the vine and the number of watermelon leaves. The three treatments, supplemented with microbial organic fertilizer, limed with microbial organic fertilizer, and fertilized according to farmers with different heights, widths, and Brix indexes, were not statistically significant (Figure 4(b)). However, according to farmers, the two treatments of liming with a combination of microbial organic fertilizers and fertilizer application had higher length, width, and Brix, which were statistically significantly different from those only supplemented with lime.

3.2.3. Yield and Percentage Yield Increment Compared to FFT in the Experimental Treatments. Figure 5(a) indicates that the treatment of fertilizers with the addition of lime combined with microbial organic fertilizers gave a corn yield of 9.12 tons ha^{-1}, achieving the highest, statistically significant

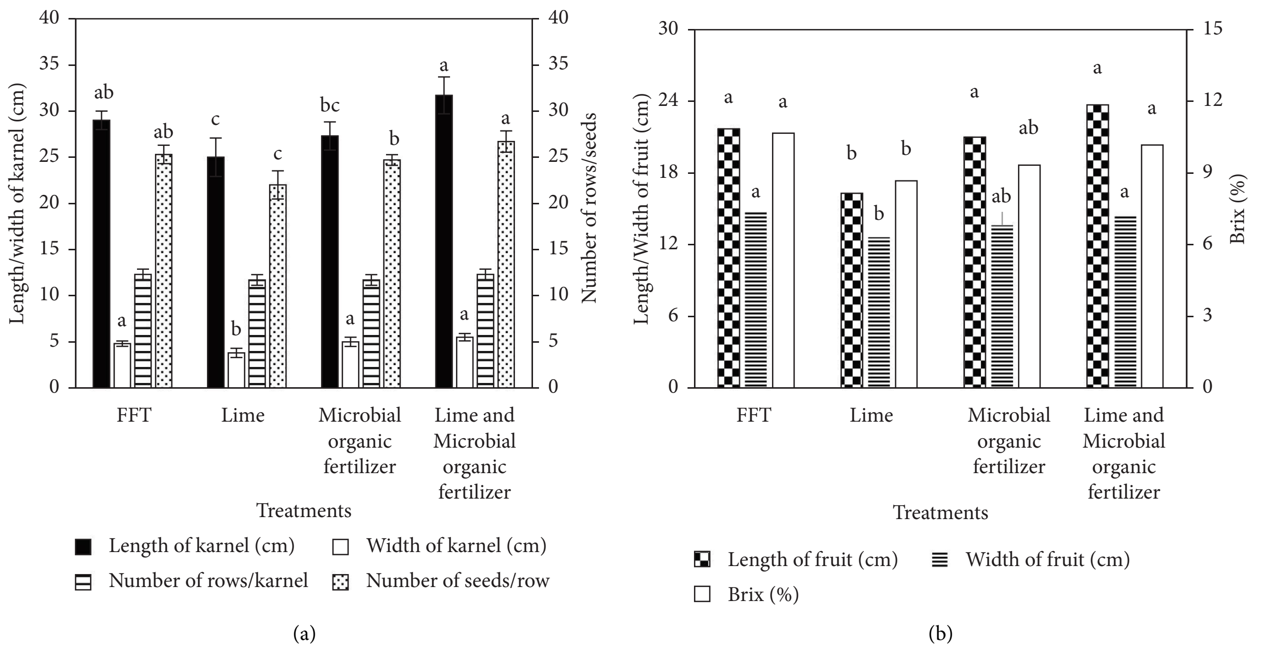

Figure 4: Length and width of kernel, number of row/kernel, and number of seeds/kernel of glutinous corn (a); length, width, and Brix index of fruit of watermelon (b).

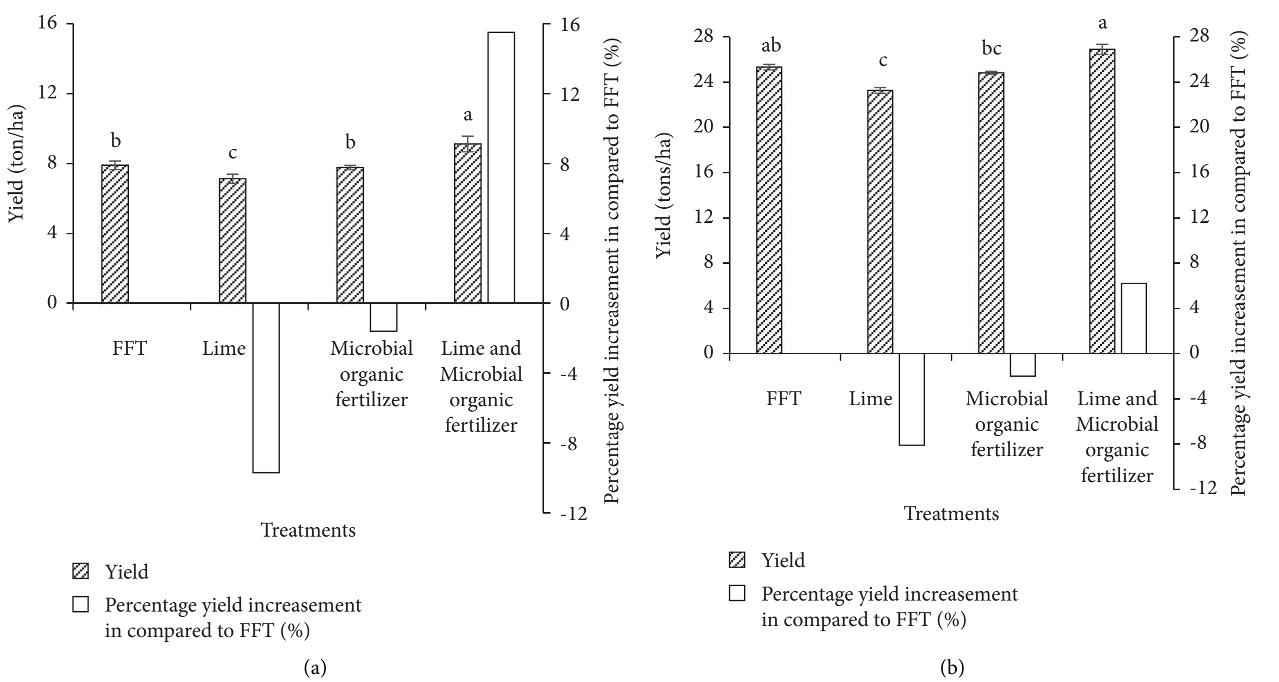

Figure 5: Yield and percentage yield increment compared to FFT in the experimental treatments: (a) glutinous corn and (b) watermelon.

difference ($p < 0.05$) compared with the other treatments. According to farmers, the yield increase rate compared to the fertilizer treatment was 15.5%. On the contrary, the treatment with only supplemental lime gave the lowest yield, with 7.13 tons ha^{-1}. In the farmer-based fertilization (FFT) treatment, the corn yield was 7.9 tons ha-1 and was not different from that in the treatment with only microbial organic fertilizer (7.77 tons ha^{-1}). Research results of Thuy [21] also show that the percentage of commercial corn was improved when nitrogen fertilizer (160 N·kg/ha) was combined with the addition of organic fertilizer (10 tons manure/ha) and lime (400 kg lime/ha).

The results in Figure 5(b) show that the length, width, and Brix of the watermelon fruit of the four treatments are statistically significant ($p < 0.05$). In the treatment of adding lime in combination with microbial organic fertilizer, the yield of watermelon (26.9 tons ha^{-1}) was not statistically significant compared with the farmer's fertilizer treatment (25.3 tons ha^{-1}). However, the treatment of adding lime in combination with microbial organic fertilizer for watermelon yield was significantly different ($p < 0.05$) from that of only adding lime (23.27 tons/ha) or microbial organic fertilizer (24.83 tons/ha). According to Hue and Mai [22], the combined application of lime and microbial organic fertilizers on soil with a low pH (4.4) helped reduce Mn in the soil and increase soil pH (5.7), thereby increasing growth and watermelon yield.

The results recorded on glutinous corn and watermelon in the liming treatment both gave lower yields than the FFT treatment (Figures 5(a) and 5(b)). According to Farhana et al. [11], adding lime alone will not help acid-sulfate soils become more fertile. However, in the treatment with only microbial organic fertilizer, the yield of glutinous corn or watermelon was not different from the FFT treatment but significantly higher than the lime treatment, because the application of microbial organic fertilizer helped to supply N, P_2O_5 and K_2O, and soil organic matter. In addition, microbial organic fertilizer also has nitrogen-fixing and phosphorus-dissolving bacteria to help plants effectively use N and P_2O_5 to achieve high yields. The results recorded on maize (glutinous corn) and watermelon in the liming treatment both gave lower yields than in the FFT treatment. According to Farhana et al. [11], adding lime alone will not help acid-sulfate soils become more fertile. However, in the treatment with only microbial organic fertilizer, the yield of glutinous corn or watermelon was not different from the FFT treatment but significantly higher than the lime treatment because the application of microbial organic fertilizer helped to supply N, P_2O_5 and K_2O, and soil organic matter. In addition, microbial organic fertilizer also has nitrogen-fixing and phosphorus-dissolving bacteria to help plants effectively use N and P_2O_5 to achieve high yields.

3.3. Economic Efficiency of Glutinous Corn and Watermelon. In the experiment on glutinous corn, the treatment with lime and microbial organic fertilizer gave a higher net profit (3,045,698 VND/ha). It achieved a higher net profit rate (12%) than the treatment fertilizer, according to farmers. Similarly, in the watermelon experiment, the net profit was also higher (5,184,783 VND/ha), and the net profit ratio was higher (13.8%). Although adding lime in combination with microbial organic fertilizers increases the cost of fertilizers (lime and microbial organic fertilizer) and pesticides, compared to fertilizers, according to farmers; however, a high yield should give a high net profit.

4. Conclusion

We fertilized glutinous corn with formula 100 N-80 P_2O_5-60 K_2O (kg/ha) and watermelon at 223 N-200 P_2O_5-175 K_2O (kg/ha) with the addition of lime (800 kg/ha) combined with microbial organic fertilizer (2,000 kg/ha) to increase the height of corn plants, stem diameter, and corn yield compared with the addition of lime alone. Stem length, number of leaves, fruit length, fruit width, Brix degree, and watermelon yield improved when adding lime combined with microbial organic fertilizers compared with just adding lime. Adding lime in combination with microbial organic fertilizers increases the yield of glutinous corn and watermelon, leading to an increase in net profit as 12.0% and 13.8%, respectively, compared to fertilizing according to farmers for glutinous corn with formula 123 N-110 P_2O_5-70 K_2O (kg/ha) and watermelon with formula 257 N-190 P_2O_5-205 K_2O (kg/ha).

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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