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Research Article
Effects of Combined Application of Organic and Chemical Fertilizers on Yield and Production Cost of Huai Bong 60 Cassava

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Abstract
Background and Objective: Cassava is a root crop of significant economic importance. To reduce the use of chemical fertilizer and support better cassava quality and soil health, combining compost with a smaller amount of chemical fertilizer can be a good option. This method may give more yield than using only chemical fertilizer. This study evaluates the effects of the combined application of organic and chemical fertilizers on the yield and production cost of Huai Bong 60 cassava. **Materials and Methods:** The five treatments used were (T1) Negative control, (T2) Chemical fertilizer according to the soil test results for cassava production as 218.75 kg/ha of chemical fertilizer 46-0-0 and 168.75 kg/ha of chemical fertilizer 0-0-60, (T3) 6.25 ton/ha of organic fertilizer+25% of the chemical fertilizer based on the soil test results as 51.56 kg/ha of chemical fertilizer 46-0-0 and 42.19 kg/ha of chemical fertilizer 0-0-60, (T4) 6.25 ton/ha of organic fertilizer +50% of the chemical fertilizer based on the soil test results as 109.38 kg/ha of chemical fertilizer 46-0-0 and 84.38 kg/ha of chemical fertilizer 0-0-60, (T5) 6.25 ton/ha of organic fertilizer+100% of the chemical fertilizer based on the soil test results as 218.75 kg/ha of chemical fertilizer 46-0-0 and 168.75 kg/ha of chemical fertilizer 0-0-60 for observation and experimental purposes. Data were analyzed using ANOVA and LSD ($p<0.05$) in PSPP. **Results:** The fresh root yield in treatments T2 to T5 showed similar results. These treatments gave yields between 21,692.25 and 23,676.38 kg/ha. In contrast, the control group (T1) had the lowest yield at 17,276.06 kg/ha. However, the highest fertilizer cost was in treatment T5, which used both organic and chemical fertilizers based on soil analysis. The T4, T2 and T3 had lower fertilizer costs, respectively. **Conclusion:** Applying 6.25 ton/ha of organic fertilizer together with 25% of the recommended chemical fertilizer (T3) gave a cassava yield close to using full chemical fertilizer. This practice helped lower chemical fertilizer costs by 75% and gave the best net profit of about 1,350.58 USD/ha.

Key words: Cassava yield, organic fertilizer, chemical fertilizer reduction, soil health, cost efficiency, sustainable development

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important plant crop for people in Asia[1]. It can get sick from various diseases. These diseases can make the plant weak and reduce the amount of food (roots) it produces[2-4]. Cassava is widely used as a base ingredient in the food, animal feed and bioethanol industries[3]. Lopburi province in Thailand is one of the major areas for cassava cultivation[5]. It helps them have enough food, find jobs and earn money. Lopburi soil has a lot of rocks and contains low amounts of plant nutrients. Cassava can grow well even in poor soil and tough weather, so it is a useful crop in this region[6]. Most farmers in Thailand grow cassava using chemical fertilizers. There is not much information about using both organic and chemical fertilizers together. Over time, the soil becomes less healthy and cassava yields go down[7,8]. Cassava takes a lot of nutrients from the soil when the roots are harvested. It uses the most potassium (K), nitrogen (N), calcium (Ca), magnesium (Mg) and phosphorus (P)[9]. If farmers do not use fertilizers, the soil will lose its nutrients. Many cassava-growing areas have shown low yields because of this. In tropical regions, this problem is worse because heavy rain washes away the topsoil and nutrients. Organic materials are sometimes used instead of chemical fertilizers, but they often do not have enough nutrients for growing cassava on a large scale. Using both organic and chemical fertilizers can help. It makes the nutrients more available to plants and reduces nutrient loss[10]. It also helps protect the environment by reducing the problems caused by using only chemical fertilizers. At the same time, it improves the soil by supporting good microbes that help plants grow[11]. So, it is important to find the right way to use both organic and chemical fertilizers for growing cassava in Lopburi soil. In this study, organic fertilizer was used to help reduce the amount of chemical fertilizer, improve cassava quality and yield and give farmers a better chance to have a farming system that lasts a long time. The objective of this study was to evaluate the effects of combining organic and chemical fertilizers on the yield and production cost of Huai Bong 60 cassava. The goal was to determine the most effective fertilizer combination for optimizing crop performance and economic returns.

MATERIALS AND METHODS

Planting material preparation: Cassava planting materials were prepared in 2024 at the farm in Koh Rang Sub-District, Chai Badan District, Lopburi Province, Thailand. The soil in the area was sandy clayey soil, with a pH of 5.92. The soil contained 0.04% total nitrogen, 44.57 mg/kg of available phosphorus, 36.87 mg/kg of exchangeable potassium and 0.56% organic matter. During the 9 month cassava growing period, the average maximum and minimum temperatures were 45 and 23°C, respectively. The cassava variety used was Huai Bong 60. Stems were cut into 30 cm pieces to be used for planting. These stem pieces were planted in an upright position, with a spacing of 1.2 m between rows and 1.5 m between plants.

Soil characteristics before the experiment: The preliminary soil property analysis before the experiment as shown in Table 1. This indicated that the soil in the experimental field had low fertility based on the organic matter content in which was only 0.56%. This corresponds with the low level of available nitrogen in the soil. However, the amount of available phosphorus was found to be high. These soil analysis results were used to calculate the chemical fertilizer application rate for cassava. Since the level of available phosphorus was already high, no phosphorus fertilizer was applied in any treatment. Instead, nitrogen was applied using urea fertilizer (46-0-0) and potassium was applied in the form of potassium chloride (0-0-60).

In the fertilizer management for growing Huay Bong cassava variety, PGPB-III biofertilizer produced by the Department of Agriculture Thailand, was used for soaking cassava stem cuttings for 15 min before planting. This method served as an indirect plant disease control replacing the conventional soaking of cuttings in chemical pesticides. This represents an additional benefit of integrated fertilizer management for cassava production. In treatments 3, 4 and 5, organic fertilizer in the form of cattle manure was applied at a rate of 6.25 ton/ha in which was combined with chemical fertilizer based on soil analysis at the rates of 25, 50 and 100%, respectively, as shown in Table 2.

Field experiment: A field experiment took place at the farm in Koh Rang Sub-District, Chaibadan Distric, Lopburi Province, Thailand, from April, 2024 to January, 2025. The soil was sandy clayey soil with a pH of 5.92, which is mildly acidic and suitable for general plant nutrient absorption. The total nitrogen content was low at 0.04%, but the levels of available phosphorus (44.57 mg/kg), exchangeable potassium (36.87 mg/kg), calcium (481.47 mg/kg) and magnesium (118.92 mg/kg), were considered high while organic matter was low at 0.56%. The soil had a high electrical conductivity (2.01 ds/cm), which could not affect plant growth. During the crop growing season, the average maximum temperature was 45°C and the minimum was 23°C. The experiment used a Randomized Complete Block

Table 1: Soil properties before the experiment

Parameter	Value	Interpretation
pH	5.92	Moderately acidic
EC (dS/m)	2.01	Non-saline
OM (%)	0.56	Low
Available N (%)	0.04	Very low
Available P (mg/kg)	44.57	High
Exchangeable K (mg/kg)	36.87	Low
Exchangeable Ca (mg/kg)	481.47	High
Exchangeable Mg (mg/kg)	118.92	Medium

Table 2: Different types of fertilizer to support cassava growth

		Chemical fertilizer (kg/ha)		
Treatment	Fertilizer application	46-0-0	18-46-0	0-0-60
T1	Negative control	0	0	0
T2	Chemical fertilizer according to the soil test results for cassava production	218.75	0	168.75
T3	6.25 ton/ha of organic fertilizer+25% of the chemical fertilizer based on the soil test results	51.56	0	42.19
T4	6.25 ton/ha of organic fertilizer+50% of the chemical fertilizer based on the soil test results	109.38	0	84.38
T5	6.25 ton/ha of organic fertilizer+100% of the chemical fertilizer based on the soil test results	218.75	0	168.75

*All treatments involved soaking the planting materials in PGPB biofertilizer solution for 15 min before planting, without using any pesticides or fungicides, **Organic fertilizer was applied when the cassava plants were 2 months old after planting and ***Chemical fertilizer was applied twice: The first time when the cassava plants were 2 months after planting and the second time when they were 4 months after planting

Design (RCBD) with four replications. There were five treatments, shown in Table 1. The fertilizers were applied three time, once during early growth for organic fertilizer and again 2 and 4 months after planting for chemical fertilizer. Before planting, cassava stems were soaked in Plant Growth-Promoting Rhizobacteria III (PGPR-III) biofertilizers solution of Department of Agriculture, Thailand (10 g in 1 L of water) for 15 min for all treatments. The stakes, cut to 30 cm long, were planted upright at 1.2×1.5 m spacing. Weeds were managed using a pre-emergence herbicide mixture of S-metolachlor (175 mL in 80 L of water) and flumioxazin (10 g in 80 L of water), followed by hand weeding 1 month after planting. Germination rates were recorded 30 days after planting and cassava growth was observed at 3, 6 and 9 months.

Total starch content of cassava storage roots: The total starch content in cassava roots was estimated by checking the specific gravity of the storage roots, using a starch percentage scale designed for cassava[12].

Statistical analysis: The data from each treatment were analyzed using One-way Analysis of Variance (ANOVA). All statistical tests were performed with the PSPP software. To compare the treatments, the Least Significant Difference (LSD) method was used at the 0.05 level of significance to determine if there were any meaningful differences between them.

RESULTS AND DISCUSSION

Growth of Huay Bong 60 cassava at 3, 6, 9 months after planting: Plant height of Huay Bong 60 cassava at 3, 6 and 9 months after planting showed that plant height at 3 months did not differ significantly among treatments, as shown in Table 3. However, significant differences were observed at 6 and 9 months. This indicates that the early stages of cassava growth may not be strongly affected by fertilizer, which could be due to the plant's ability to utilize nutrients from the soil without much external input[13].

At 6 months, the highest plant was found in treatment T5, which received organic fertilizer combined with 100% chemical fertilizer based on soil analysis. This was not significantly different from treatments T2 to T4, indicating that chemical fertilizer application influenced plant height as shown in Table 3. This supports the idea that chemical fertilizers could significantly influence cassava growth[7]. The impact of chemical fertilizer on plant height at 6 months was consistent with findings by Bilong *et al.*[14] who found that a balanced application of organic and chemical fertilizers enhanced cassava growth.

At 9 months, the plant heights among treatments were significantly different. The highest plant height was found in treatment T2 in which was received only chemical fertilizer according to soil analysis, followed by treatments that received both organic and chemical fertilizers in varying rates (T3-T5). The control treatment had the lowest plant height as shown in Table 3. This indicated that organic fertilizers provided long-term benefits to soil health, chemical fertilizers may provide faster and direct growth stimulation during the later stages[15]. The control treatment had the lowest plant height showing that the absence of fertilizers negatively affected cassava growth. Without the necessary nutrients, cassava plants could not achieve optimal growth which aligns

Table 3: Effect of fertilizer management on Huai Bong 60 cassava growth at 3, 6, 9 months after planting

	3 month		6 month		9 month	
Treatment	Height (cm)	Branch	Height (cm)	Branch	Height (cm)	Branch
T1	118.67	2.90	192.07^{b}	3.00	233.67^{b}	2.97
T2	119.67	2.67	204.80^{ab}	2.93	267.00^{a}	2.83
T3	124.33	2.67	208.97^{ab}	3.10	251.17^{ab}	2.87
T4	125.00	2.57	211.17^{ab}	2.83	242.83^{ab}	2.77
T5	128.50	2.67	219.73^{a}	2.90	253.60^{ab}	2.67
F-test	ns	ns	-	ns	-	ns
CV (%)	4.99	8.82	6.05	9.98	6.85	8.28

"Means followed by the same letter are not significantly different at p<0.05"

Table 4: Effect of fertilizer managements on Huai Bong 60 cassava yield at 9 months after planting in lopburi soil

Treatment	Stem and Leaf fresh weight (kg/ha)	Storage root fresh weight (kg/ha)	Starch (%)
T1	4,785.63^{c}	17,276.06^{b}	32.13
T2	6,729.88^{bc}	21,692.25^{a}	33.77
T3	7,840.88^{ab}	21,845.06^{a}	32.40
T4	7,754.81^{ab}	22,173.75^{a}	32.87
T5	8,796.31^{a}	23,676.38^{a}	33.10
F-test	-	-	ns
CV (%)	31.25	11.57	3.63

"Means followed by the same letter are not significantly different at p<0.05"

with research by Thompson *et al.*[13]. Moreover, this result similar to Parkes *et al.*[16] who reported that using high concentration of 15-15-15 chemical fertilizer stimulated cassava grow and gave higher yields because they got more important nutrients.

The number of branches was determined. The results showed no statistically significant differences in the number of branches among treatments at any of the three time points at 3, 6 and 9 months after planting as shown in Table 3. The lack of significant differences in branching observed in this study was consistent with findings by El-Sharkawy[17] and Nassar and Ortiz [18]. They emphasized that cassava's branching pattern was predominantly determined by genotype rather than agronomic treatments during the early growth stages.

Cassava yield at harvest stage: Growth of above-ground parts and fresh root yield of cassava showed similar trends as shown in Table 4. The fresh weight of above-ground parts was significantly different among treatments. The highest weight was found in T5 (organic fertilizer+100% chemical fertilizer) at 8,796.31 kg/ha, followed by T3 and T4 at 7,840.88 and 7,754.81 kg/ha, respectively. The T2 had 6,729.88 kg/ha as only chemical fertilizer. T1 had the lowest at 4,785.63 kg/ha as a control.

For fresh storage root yield, there was no significant difference among T2-T5, but the trend showed that using chemical fertilizer alone or with organic fertilizer increased yield as shown in Table 4. Yields ranged from 21,692.25 to 23,676.38 kg/ha, while the control treatment (T1) had the lowest yield at 17,276.06 kg/ha. This showed that chemical fertilizer plays an important role in promoting cassava growth and yield. Regarding quality, starch content showed no significant difference among treatments. All treatments had more than 30% starch, ranging from 32.13 to 33.77%. This result similar to Sungthongwises *et al.*[7] that they used less chemical fertilizer by mixing in organic fertilizer and chemical fertilizer to reduce the amount of chemical fertilizer use. Using farm waste like chicken manure or starch factory waste together with reduced chemical fertilizer can help farmers get high yield while saving costs. Thompson *et al.*[13] reported that these mixed methods can reduce chemical use and still keep good production. This approach is good for the environment and helps maintain soil health. Using organic fertilizers like green plants and animal manure can help increase cassava yield and make soil better in the long term. Bilong *et al.*[14] showed that applying *Tithonia diversifolia* and chicken manure gave very high cassava yield (up to 52 ton/ha) and helped improve soil structure and water holding capacity. This method is useful for farmers who want to use less chemical fertilizer and make their land more sustainable.

Economic efficiency: The cost and profit from 9 month cassava production were calculated using a fresh root price of 0.0685 USD/kg as shown in Table 5. The control plot which did not use any fertilizer, had no fertilizer cost. The highest fertilizer cost was in treatment T5 as 279.72 USD/ha which used both organic and chemical fertilizers based on soil analysis. The T4, T2 and T3 had lower fertilizer costs at 191.28, 177.06 and 145.52 USD/ha, respectively. After subtracting

Table 5: Cost and profit analysis of Huay Bong 60 cassava variety, 9 months post-harvest

Treatment	Organic fertilizer cost (USD/ha)	Chemical fertilizer cost (USD/ha)	Total cost (USD/ha)	Storage root fresh weight (kg/ha)	Yield price (USD/kg)	Profit (USD/ha)	Net profit (USD/ha)
T1	0	0	0	17,276.06[b]	0.0685	1,183.09	1,183.09
T2	0	177.06	177.06	21,692.25[a]	0.0685	1,486.43	1,309.39
T3	102.72	42.80	145.52	21,845.06[a]	0.0685	1,496.88	1,350.58
T4	102.72	588.56	191.28	22,173.75[a]	0.0685	1,519.89	1,327.68
T5	102.72	177.06	279.72	23,676.38[a]	0.0685	1,621.84	1,340.39

1 USD = 36.507 THB and "Means followed by the same letter are not significantly different at $p<0.05$"

fertilizer costs, T3 had the highest net profit of 1,350.58 USD/ha. The T3 used a combination of organic and only 25% of the recommended chemical fertilizer. Although T5 had the highest yield, its high fertilizer cost resulted in a lower net profit than T3 as shown in Table 5. The control plot had the lowest net profit of 1,183.09 USD/ha due to low yield. Without fertilizer, the yield may decrease even more in future seasons and more fertilizer might be needed to maintain productivity. Using high rates of chemical fertilizer can increase yield but also raises costs. An integrated fertilizer approach combining organic and reduced chemical fertilizer, helped lower production costs and increase farmer profits. This result supports the idea that using organic fertilizer together with a small amount of chemical fertilizer can reduce cost and still give good yield. Bilong *et al.*[14] also found that combining organic materials like *Tithonia diversifolia* with animal manure improved cassava yield and soil health. Another study by Thompson *et al.*[13] showed that cassava grown with poultry manure and Plant Growth-Promoting Rhizobacteria (PGPR) gave high yield and profit. In addition, micronutrients like zinc can also improve cassava yield and farmer profit. Kunlanit *et al.*[15] found that using zinc fertilizer with NPK gave better plant growth and increased income, especially in soils that lack micronutrients. This suggests that not only the type and amount of fertilizer matter, but also the presence of micronutrients. Sungthongwises *et al.*[7] also reported that the best way to use fertilizer is to apply 15-7-18 chemical fertilizer between 312.5 and 625 kg/ha, combined with organic fertilizer that replaces 25 to 100% of the chemical fertilizer. This method seems like a good way to reduce chemical use.

CONCLUSION

Using 6.25 ton/ha of organic fertilizer with 25% of chemical fertilizer based on soil analysis (T3) gave similar cassava yield as using 100% chemical fertilizer. This method could reduce chemical fertilizer costs by 75% and gave the highest net profit of 1,350.58 USD/ha. Although using more chemical fertilizer could increase yield, the difference was not significant and the profit was lower due to higher costs. Therefore, combining organic and chemical fertilizers based on soil analysis was an effective way to increase yield, reduce costs and satisfy farmers.

SIGNIFICANCE STATEMENT

This study highlights the economic and agronomic benefits of integrating organic fertilizers with reduced rates of chemical fertilizers in cassava production. Although full chemical fertilization increased yield, it also raised production costs. The combination of organic fertilizer with 25% of the recommended chemical fertilizer (T3) provided the highest net profit indicating that integrated nutrient management could optimize cassava yield while minimizing production costs. These findings support the promotion of sustainable farming practices that enhance productivity and profitability for cassava farmers, particularly in resource-limited settings.

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