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Knowledge and opinions towards fertilizer application technology based on soil analysis and soil nutrient management of durian farmers in Rayong province, Thailand

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Phumthong, J., Suwanmaneepong, S., Khurnpoon, L. and Kerdsriserm, C. (2024). Knowledge and opinions towards fertilizer application technology based on soil analysis and soil nutrient management of durian farmers in Rayong province, Thailand.

Abstract Soil management knowledge and understand farmers' perspectives on adopting fertilizer application technology was investigated. 92 durian farmers were interviewed in Rayong Province and results of the descriptive analysis showed that soil management knowledge indicated that farmers demonstrated a commendable grasp of the fundamental principles. The essential plant nutrients of Nitrogen, Phosphorus and Potassium (NPK) was 98.91% of respondents provided accurate responses. Similarly, awareness regarding the significance of soil pH in plant growth was substantial with 97.83% accuracy. However, the area where respondents displayed a lower level of perceived know-how is related to alkaline soil management, with only 28.26% answering correctly. Lime, marl and dolomite were recommended to improve soil. Moreover, fertilizer application technology based on soil analysis and nutrient management was conducted across eight key dimensions. The outcomes revealed that participants held positive opinions in three prominent areas. The farmers exhibited a strong inclination (average score of 4.18) toward the sustained utilization of this technology. Subsequently, a notable belief emerged (average score of 4.12) regarding the potential cost-reducing effects attributed to its adoption. In addition, respondents perceived that implementing this technology correlated with greater yields and expressed an average sentiment score of 4.11.

Keywords: Soil analysis, Soil nutrient, Durian farmer, Fertilizer applicati

Introduction

Durian is a vital fruit export of Thailand a large perennial fruit tree. This kind of fruit can grow and produce well in areas with a hot and humid climate with an optimum temperature of about 10 - 46 degrees Celsius with a rainfall of not less than 2,000 millimeters per year; there is a good distribution of rain. The relative humidity of the air is high, approximately 75 to 85 percent. The soil has a pH of approximately 5.5 to 6.50. Therefore, durian is classified as a fruit in the tropical fruits group or group of fruits. Overview of durian production in Rayong province in 2022. There are 7,173 farmers, and the total durian growing area is 119,373 rai,. Durian production has reached 73,796 rai, with an average yield of 2,027 kilograms per rai. Moreover, a total production volume of 149,585 tons (plant production conditions, district level economic crop information), which at present durian production in Rayong province production costs were used at 18,701.50 Baht per rai (Regional Office of Agricultural Economics, 2020).

Statistics found that a large amount of chemical fertilizer is used yearly in crop production. By 2022, Thailand imported chemical fertilizers, a total of 4,103,668 tons, with a total value of 103,205 million baht. Meanwhile, in 2022, agricultural hazardous

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substances such as herbicides, insecticides, plant disease prevention, and eradication substances are imported, totaling 113,640 tons. Disease outbreaks and pests are increasing, and chemicals are being used more than necessary, affecting drug resistance. Most farmers use chemical fertilizers, which cause high costs. The soil is acidic because of its dense soil structure. Microorganisms in the soil decrease low organic matter. Low output quality productivity is different from demand. It may also cause a loss of nutrient balance and affect plant growth. Therefore, use chemical fertilizers effectively. Farmers consider the number of nutrients in fertilizer that corresponds to the fertilizer price. Therefore, it should be applied appropriately to the analysis values of soil nutrients.

Moreover, the efficient use of chemical fertilizers depends on more than just evaluating plant nutrients from soil analysis. However, it also depends on many other factors, such as soil fertility. Different soil characteristics, soil management, and fertilizer application by farmers, including the amount of rainfall that is not consistent each year and the climate, also make chemical fertilizers inefficient. (Regional Office of Agricultural Economics, 2022). Fertilizer management meet the needs of plants and replace it with fertilizer equal to the number of nutrients lost. During planting, it is a way to increase fertilizer efficiency. It can avoid the intake of too many macronutrients, leading to micronutrient shortages, and help reduce soil degradation problems (Stewart, 2002). This matter is consistent with Tisdale *et al.* (1985), who said that plants exposed to different concentrations interact with each type of nutrient. Therefore, plant nutrients should be managed so that plants receive sufficient nutrients to grow and produce good results in balanced proportions.

Soil sampling to analyze chemical properties Agriculture should collect soil samples in shaded areas at 0-15 cm depth. This depth is influenced by fertilization compared to soil samples outside the shade, which received little fertilizer. Soil samples should be collected from plants that have similar growth and maintenance, such as fertilizing and watering—using a shovel or a tool that can drill to a depth of approx.0-15 centimeters from under the shade of 10-20 fruit trees, 1-2 spots per spot, then mix the soil in each spot. Then, divide approximately 1 kilogram into plastic bags to send for analysis. As for the soil outside the shade, do the same. Information such as the name of the owner of the land, location, shaded soil, shaded soil, history of fertilizer use, and soil improvement should be recorded and sent to the laboratory to analyze nutrients in the soil (Onthong, 2002).

Soil nutrient analysis is a technology used in soil and fertilizer management. It is beneficial to farmers to apply fertilizers appropriately to the needs of the plants grown in that area. This technology is the one way to solve the problem of high production costs caused by chemical fertilizers. However, the use of chemical fertilizers is effective. Organic fertilizers should be used to manage nutrients and improve soil physical properties. Therefore, using fertilizers based on soil analysis values to manage nutrients in the soil is reliable and accepted. Farmers can implement and improve soil and fertilizer management practices before planting durian. (Department of Agriculture, 2016). The research project as aimed to study on demographic information about farmers who grow quality durian in Rayong Province, knowledge of soil and fertilizer management of farmers who grow quality durian in Rayong Province and farmers' opinions on soil analysis values.

Materials and methods

Sample farmer

The sample farmer used in this study is quality durian farmers in Rayong province, Thailand, who participated in training in soil analysis activity under the project of Production and Marketing Information Management Innovation for Enhancing the Quality of Durian Production Entering into Premium Markets, totaling 92 farmers.

Study area

This study is conducted in Rayong province, located in the eastern region of Thailand. Evaluating the suitability of the soil with a soil test kit: Assessing the soil's suitability with a soil test kit is a way to know how fertile and suitable it for growing crops in the farmer's gardening area is. In order to find ways to improve and maintain, make the soil suitable for growing crops, such as adding fertilizer or various soil improvement materials. Analysis of soil samples in the area using a field soil testing kit (LDD Test Kit) to measure pH, nitrogen, phosphorus, potassium (NPK), and the amount of organic matter in the soil. Farmers could know the soil analysis results in the area within approximately 30 minutes. The analysis values will be approximate.

Table 1. Evaluation of soil nutrients for growing crops (adapted from Osotsapa *et al.,* 2008)

Analysis	Low	Moderate	High
Organic (%)Level indicators N	<2	2-3	>3
P Useful (mg.kg.)	<15	25-45	>45
Exchangeable K (mg. kg.)	<50	50-100	>100

Soil analysis: A very acidic pH may reduce the usefulness of some nutrients. The soil suitable for growing plants should have a pH. Neutral or slightly acidic (5.5-6.5) because the soil's acidity is crucial to the solubility of various nutrients contained in the soil. Nutrients in the soil change due to reactions occurring in the soil. Various reactions are controlled by soil pH (Suphakamnerd, 2015).

Figure 1. Soil test kit activities

Data collection ans data analysis

The questionnaires were employed to gather data divided into three parts.

Part 1: General information of farmers who grow quality durian, consisting of gender, age, education level, experience in durian gardening, and area for durian gardening.

Part 2: Knowledge about soil and fertilizer management with eight questions, with farmers choosing the answer for each question, true or false. If the farmer can answer the question correctly based on the facts, they will receive 1 point (Petthong, 2009). Analyzed the obtained data using the criteria for dividing knowledge levels into three levels, which incorporates Bloom's concept (Bloom, 1956), namely having a low level of knowledge (0-59 percent) have a medium level of knowledge (60-79 percent) and a high level of knowledge (80-100 percent). The criteria for interpreting the meaning of knowledge are detailed in the table.

Table 2. Knowledge score criteria for soil and fertilizer management of farmers who grow quality durian in Rayong Province

Score	Mean score	Knowledge level
Less than 4 points	0 – 59 %	Low
5-6 points	60 – 79 %	Moderate
7-8 points	80 – 100 %	High

Part 3: Opinions on fertilizer use technology based on soil analysis and soil nutrient management. The nature of the question expresses farmers' opinions on fertilizer use technology based on soil analysis and soil nutrient management according to the concept (Ratharatanasakul, 2012 and Maneepen, 2012). The nature of the questionnaire is a 5-level rating scale based on the Likert concept (Prasitratthasin, 2012). The average score of opinions on fertilizer use technology based on soil analysis and soil nutrient management of farmers was used to determine the opinion level. The criteria for interpreting the opinions and details are shown in the table.

Table 3. Score criteria for opinions on fertilizer use technology based on soil analysis and soil nutrient management

Score	$\bar{x}$	Opinions level
5	4.21-5.00	Strongly agree
4	3.41-4.20	Agree
3	2.61-3.40	Moderate
2	1.81-2.60	Disagree
1	1.00-1.80	Strongly disagree

Descriptive statistics analyzed data to explain farmers' knowledge and opinions of farmers growing quality durian in Rayong province who participated in training under the activities of the project of Production and Marketing Information Management Innovation for Enhancing the Quality of Durian Production Entering into Premium Markets.

Results

Demographic information

Regarding gender, most of the farmers are female, accounting for 53.3%, aged between 41-45 years of age, accounting for 33.7%. Regarding education level, it shows that farmers with bachelor's degrees account for 48.9%. Farmers have experience in durian gardening, with 1-5 years of experience in durian farming, accounting for 60.9%. Results show that farmers have more than ten rai of durian gardening area for the durian gardening area, accounting for 50%, as shown in Table 4.

Table 4. Demographic information of durian farmers in Rayong province

Items	Farmers	
	Frequency	**Percent**
Gender		
Male	43	46.7
Female	49	53.3
Age (Years)		
Younger than 30	7	7.6
30-40	27	29.3
41-50	31	33.7
Older than 50	27	29.3
Education level		
vacational	15	16.3
Diploma	22	23.9
Bachelor's degree	45	48.9
Post-Graduate	9	9.8
Experience in durian farming (Years)		
1-5	56	60.9
6-10	20	21.7
11-15	2	2.2
16-20	4	4.3
More than 20	8	8.7
Cultivated area (Rai)		
Less than 10	46	50
11-20	27	29.3
21-30	9	9.8
31-40	3	3.3
41-50	2	2.2
More than 50	5	5.4

Knowledge of soil and fertilizer management of farmers who grow quality durian in Rayong Province

Investigating farmers' knowledge of soil and fertilizer management shows that the total number of questions was 7. It was found that soil and fertilizer management of quality durian farmers in Rayong province participated in training under the activities. There was an average knowledge score of 6.26 points, a minimum of 4 points, and a maximum of 8 points, considered in the middle range. Most have a moderate knowledge level (57.61 %), followed by a high level of knowledge (39.13%) and a low level of knowledge (3.26 %), as shown in Table 5.

Table 5. Knowledge level on soil and fertilizer management of farmers who grow quality durian in Rayong Province

level	Frequency	Percent
Low	3	3.26
Moderate	53	57.61
High	36	39.13
Total	92	100.0
(Mean= 6.26, Max=8, Min= 4)		

When considering the sub-issues in each item, the correct answer for farmers who grow quality durian in Rayong province is Nitrogen, Phosphorus, and Potassium (NPK), the primary nutrients for plants, accounting for 98.91%, followed by pH value, which affects plant growth accounting for 97.83%. The question that farmers answered least correctly was alkaline soil, corrected by adding various types of cement, such as lime, marl cement, and dolomite cement, accounting for 71.74%, as shown in Table 6.

Table 6. Farmers' knowledge of soil nutrient management of durian farmers in Rayong province

Items	% answer	
	True (%)	False (%)
1. Nitrogen, phosphorus, and potassium or N-P-K are the main nutrients for plants.	98.91	1.09
2. Plants receive N-P-K nutrients, and plants do not need any other nutrients.	93..48	6.52
3. Organic fertilizer provides plant nutrients in high concentration.	84.78	15.22
4. The pH value of the soil or pH value (pH), affects plant growth.	97.83	2.17
5. If want the plants to grow quickly You have to add a lot of chemical fertilizer at a time.	93.48	6.52
6. Alkaline soil is corrected by adding various types of lime, such as lime, Marl, and dolomite cement.	28.26	71.74
7. If we use organic fertilizer in large quantities	82.61	17.39
There is no need to add additional chemical fertilizers.	46.74	53.26

Opinions on soil analysis and soil nutrient management of durian farmers in Rayong province

All eight were for opinions on fertilizer use technology based on soil analysis values and soil nutrient management. The result found that the items with the highest average of 3 were farmers' opinions that they would continue to use this technology, with an average of 4.18, followed by farmers' confidence that this technology would be able to reduce costs with an average value of 4.12. Farmers believed this technology increased yield with an average of 4.11, as shown in Table 7.

Table 7. Opinions on soil analysis and soil nutrient management of durian farmers in Rayong province

Items	Mean	S.D.	Opinions level
1. Soil sample collection is easy to understand and practice.	3.76	0.10	Agree
2. Soil sample collection is easy to understand and practice.	3.67	0.25	Agree
3. Practice recommendations from soil analysis results, such as mixing your own fertilizer. Using substances to improve soil quality.	3.68	0.36	Agree
4. It is believed that this technology will be able to reduce costs.	4.12	0.15	Agree
5. Using this technology, productivity increases.	4.11	0.25	Agree
6. Using this technology, production does not increase.	4.09	0.45	Agree
7. It is thought that this technology will continue to be used indefinitely.	4.18	0.38	Agree
8. Will share this technology with relatives, neighbors, etc.	4.04	0.50	Agree

Discussion

The results show that farmers who grow quality durian in Rayong Province were female (53.3%), aged between 41-45 years (33.7%), graduated with a bachelor's degree (48.9%), and had experience in durian farming. 1-5 years (60.9%). The area for durian orchards is less than 10 rai (50.00%), consistent with the (Fertilizer soil management promotion group, 2016). Knowledge of soil nutrient management of durian farmers in Rayong province.

Farmers know nitrogen, phosphorus, and potassium or N P K, the primary plant nutrients. Farmers answered correctly on average 98.91%, probably because members received adequate soil and fertilizer management training. Farmers have long experience in farming, and knowledge is still the first step of the decision-making process. (Rogers and Shoemaker, 1971). The procedure is the stage at which people know that an innovation exists and is sufficient. To understand how innovation works, what knowledge is needed for how to use innovation? This knowledge can be obtained from news that will help correctly—the more complex the innovation, the greater the need for this knowledge. Therefore, farmers know about the soil's primary nutrient, N P K, consistent with the (Phuwarodom *et al.,* 2001) studied the nutrient needs and introduction of durian fertilizer. The study found that nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and boron (B). In samples of durian leaves of the Mon Thong variety with leaf ages of 45-60 days, it was found that the concentrations of major nutrients (N, P, and K), trace elements (Mg), and micronutrients (Zn, Cu, and B) of each fertilization treatment were within the range. Element standards food suitable for the growth of the durian.

The pH value of the soil affects plant growth, and farmers answered correctly, with an average of 97.83%. The appropriate soil pH for the durian is in the range of 5.5-6.5 because this is the range that allows the durian to absorb nutrients well (Suphakamnerd, 2015). The soil suitable for growing plants should have a pH. Neutral or slightly acidic

(5.5-6.5) because the soil's acidity is crucial to the solubility of various nutrients contained in the soil. Nutrients in the soil change due to reactions occurring in the soil. Various reactions are controlled by soil pH.

Results of the opinion-level study showed that farmers believe they will continue to use this technology with an average value of 4.18; farmers have a high level of practice. Most farmers believe soil nutrient analysis technology is used in soil and fertilizer management. It is beneficial to farmers to apply fertilizer and manage soil nutrients appropriately to the needs of plants grown in that area. This technology is one way to solve the problem of high production costs caused by chemical fertilizers. Farmers can apply nutrient analysis effectively and improve soil and fertilizer management practices before planting durian, in line with the (Soil and Fertilizer Management Promotion Group, 2016). Studying factors affecting technology adoption. Applying fertilizer according to soil analysis values, the results found that most farmers are confident that this technology will reduce costs and when using this technology. t was noticed that this technology could reduce production costs and will share it with relatives and keep using it with opinions at the highest level.

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References

Bloom, B. S. (1956).Taxonomy of Educational Objectives Handbook I: Cognitive Domain. 17^{nd} ed. NewYork. : David Mackay.

Department of Agriculture. (2016). Nutrient management and fertilization of durian. [Online]. Retrieved from: https://www.doa.go.th/share/attachment.php?aid=2975.

Fertilizer Soil Management Promotion Group Plant Protection and Soil and Fertilizer Management Promotion Division Department of Agricultural Extension, (2016). Factors affecting the acceptance of fertilizer use technology according to the Soil analysis fee. [Online]. Retrieved from http://www.ppsf.doae.go.th/wordpress.

Maneepen, W. (2012). Knowledge, attitude and good agricultural practices of beekeepers in Chiang Mai Province. Master of Science Thesis, Major: Agricultural Extension Graduate School, Chiang Mai University.

Onthong, k. (2002). Soil and plant analysis manual. Department of Geosciences, Faculty of Natural Resources. Prince of Songkla University Hat Yai Campus.

Osotsapa, Y., Wongmaneeroj, A. and Hongprayoon, C. (2008). Fertilizer for sustainable agriculture. Publisher Kasetsart University, Bangkok.

Phuwarodom, S., Thawinthung, N., Mairiang, S., Kasetsayom, P. and Prasitkhet, J. (2001). Project on Nutrient Demand and Fertilize Recommendation in Durian: Complete Research Report. Office of the Science Promotion Commission Research and innovation.

Prasitratsin, S. (2012). Social science research methods. 15th printing. Samlada: Bangkok.

Petthong, P. (2009). Acceptance of farmers' compliance with correct and appropriate agricultural production systems for rambutan. Ban Na San District Surat Thani Province. (Master Thesis). Graduate School, Prince of Songkla University.

Ratharattanasakul, P. (2012). Attitudes of farmers in San Sai District. Chiang Mai Province towards organic farming according to good agricultural practices. Master of Business Administration Thesis Field of Study: Agricultural Industry Management Graduate School, Chiang Mai University.

Regional Office of Agricultural Economics (2022). Durian. [Online]. Retrieved from :https://misapp.oae.go.th/product.

Regional Office of Agricultural Economics (2020). Situation of important agricultural products and trends in 2021, (2463). [Online]. Retrieved from: https://www.opsmoac.go.th/nakhonphanom.

Stewart, W. M. (2002). Nutrient balance in the Great Plains region. News and Views. Retrieved from http://www.ipni.net/ppiweb/ppinews.nsf.

Suphakamnerd, N. (2015). Soil and fertilizer management for horticultural crops, Horticultural Research Institute. Department of Agriculture. Retrieved from http://www.nsdoae.doae.go.th/homepage.

Effect of difference plastic bags on corn silage quality for animal feed

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Pongcha-umdee, T., Chotchutima, S. and Nitthaisong, P. (2024). Effect of difference plastic bags on corn silage quality for animal feed.

Abstract The effect of packaging on the quality of corn silage to maintain the quality of a corn silage due to limited supplies over the dry season was investigated. The results revealed that the corn silage of all packages with the difference type of plastic bag type 1, type 2, type 3 and type 4 were stored under the shelf life of 30 and 60 days which showed very good range of physical characteristic including odor, texture, color, and pH. The flavor of fermented plants was similar to the smell of pickled fruit or vinegar. The leaves and stems revealed intact, and the texture was firm. The fermented plants had a pH between 3.8 to 4.2, and the color of all treatment was greenish yellow. In packages of each plastic bag had moisture contents of type 1 (69.24%), type 2 (71.29%), type 3 (68.93%), and type 4 (70%). Lactic acid content was found in package of plastic bag type 2 at 5.07% for 60 days of shelf life but not difference significant.

Keywords: Corn silage, Packaging, Plastic bag, Lactic acid

Introduction

The trend of beef and dairy cattle farming in Thailand has continuously increased. From 2018 to 2022, the global beef consumption demand trend to increased by 0.63 percent annually. In 2022, beef consumption amounted to 56.961 million tons, up from 56.865 million tons in 2021, an increase of 0.17 percent (Office of Agricultural Economics, 2022). Animal feed preservation can be achieved through both hay and silage. However, hay of animal feed has limitations as excessive moisture can stimulate the growth of fungi. The process of making silage is a popular method for preserving on animal feed. Animal feed may be preserved for a long time without significantly reducing all its nutritional value in fermentation and storing it as silage and made from fresh animal feed crops and preserve its nutritional value for a long time (Sayan, 2004). In addition, corn silage has several characteristics which are attractive to livestock cattle farmers, such as its consistent and stable quality, as well as its ability to yield higher production and energy compared to most other animal feed crops (Roth and Undersander, 1995), when compared to other silage crops as alfalfa silage and Napier grass silage, corn silage is proven to have a higher nutritional value for animals (Chokchai *et al*., 2005).

Although, corn silage has relatively high nutritional value and is commonly used as animal feed, the packaging or preservation methods cannot effectively extend its shelf life for an extended period. This is due to the lack of suitable technologies or packaging solutions for this purpose. The extension of food shelf life to preserve quality until consumption is a significant objective in the context of packaging. A study has been conducted on the packaging density that affects the quality of animal feed, it involves the

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fermentation of barley in polyethylene tanks (30 liters) at different densities for 60 days, and the results showed that increasing the packaging density improved the digestibility and reduced the occurrence of Enterobacter (from 47.4% to 35.4%) and Clostridium (from 13.5% to 3.8%) (Lin *et al*., 2021).

However, there is currently no research regarding the difference of plastic bags that may affect the quality of corn silage as animal feed. Therefore, this research focused on difference plastic bag to improve the quality of corn silage for animal feed.

Materials and methods

The experiment was performed in Completely Randomized Design (CRD) with four replicates. It started by planting hybrid corn Suwan 5819 and harvested at 85 days (at the milk line stage, which covered 50-75%). Then, the whole plant was chopped into pieces of 1-2 centimeters. Subsequently, the maize was packed into different plastic bags type, including type 1, type 2, type 3, and type 4, with each bag weighing 20 kilograms. Data were recorded every 30 days for 3 months.

Physical quality assessment

The physical characteristics of smell of the corn silage similar to a pickled fruit or vinegar was evaluated as 12 points, not fragrant with slightly pungent smell (8 points), strong unpleasant odor and slightly smelly (4 points) and moldy or rotten odor (0 point). In terms of the fermented plant material's quality, corn silage had densed plant materials as stems and leaves which were still initial shape and no impurities evaluated as 4 points, leaves and stems are slightly decomposed and slimy (2 points), stems and leaves are strongly rotted and impurities (1 point), slimy and very dirty (0 point). The color of corn silage was evaluated as yellowish green (3 points), greenish yellow or dark green color (2 points), golden-brown color (1 point), and dark brown or black color (0 point). pH was evaluated as 3.5-4.2 (6 points), 4.4-4.7 (4 points), 4.7-5.1 (2 points) and >5.1 (0 point). The scores were combined which the quality of the corn silage was divided into four groups of 20-25 = very good, 15-19 = good, 6-14 = medium and 0-5 = low (Department of Livestock Development, 2004).

pH values

Silage subsample of 20 g was diluted with 180 mL of distilled water to obtain silage extracts, filtered through 2 layers of cheesecloth, and immediately measured pH using a digital pH meter (HANNA instruments HI98103).

Moisture content

The moisture content was calculated using fresh weight and dry weight measurements as the following equation:

$$\text{Moisture Content (\%)} = \frac{\text{Fresh Weight (kg)} - \text{Dry Weight (kg)}}{\text{Dry Weight (kg)}} \times 100$$

Lactic acid content analysis

The random sample of 1 g corn silage was mixed with distilled water for 1: 10 ration, then pipetted 1 ml of corn silage sample into a 100 ml Erlenmeyer flask, added 49 ml of distilled water, and dropped in 0.15 ml of phenolphthalein, and titrated with 1 N sodium hydroxide standard solution until the end point (the solution turns pink), recorded the standard quantity of sodium hydroxide solution used and calculated the quantity of lactic acid (Adapted from Oh and Marshall Method, 1993).

Statistical analysis

Lactic acid content was compared using analysis of variance (ANOVA) using R-stat version 4.3.0 (R Core Team, 2022). Group means were compared using Fisher' s Least Significant Difference (LSD) test.

Results

Physical properties

The physical properties of the corn silage included odor, color, texture, and pH. The data were recorded at 30 and 60 days. Results revealed that different plastic bags type including type 1, type 2, type 3, and type 4 were shown to be excellent physical characteristics, the average total scores was 25 in all the different plastic bags. The corn silage had a smell with similar to pickled fruit or vinegar, it had densed plant materials of stems and leaves in initial shape and no impurities, the color of corn silage was yellowish green. The pH level was 3.8 – 4.2, the moisture contents was 69.24%, 71.29%, 68.93% and 70% respectively (Table 1).

Lactic acid content analysis

The experiment of corn silage in bags with different plastic bags type, including type 1, type 2, type 3, and type 4 for 30 and 60 days was not statistically significant difference in the lactic acid content when the corn was stored for 30 and 60 days (Table 2).

Table 1. The effect of physical properties includes odor, texture, color, pH and moisture content of corn silage packed in the different plastic bags type

Storage period	Plastic bags type	Score	Quality	Moisture content (%)
30 days	Type 1	25	Very good	69.24
	Type 2	25	Very good	71.29
	Type 3	25	Very good	68.93
	Type 4	25	Very good	70.01
60 days	Type 1	25	Very good	71.08
	Type 2	25	Very good	70.91
	Type 3	25	Very good	70.84
	Type 4	25	Very good	72.12
Average score on a period of storage	Type 1	25	Very good	
	Type 2	25	Very good	
	Type 3	25	Very good	
	Type 4	25	Very good	

Note: 20-25 Point = Very good, 15-19 Point = Good, 6-14 Point = Medium, 0-5 Point = Low.

Table 2. The effect of lactic acid content of corn silage packed in different plastic bags type

Plastic bags type	Storage period (days)	
	30	60
Type 1	5.63	4.78
Type 2	6.75	5.06
Type 3	6.75	4.89
Type 4	7.88	4.84
F-test	ns	ns
C.V. (%)	36.00	6.15

Note: * = Significant difference at 0.05, ns = non-significant difference

Discussion

The study investigated corn silage using packaging with different type to maintain the quality of corn silage. It was found that the corn silage stored for 60 days had an average overall physical property score of 25. It had a smell similar to pickled fruits or vinegar, a dense texture, intact leaves and stems, no impurities, and a greenish yellow color, the pH level was 3.4 – 4.2. The pH value of fermented food is an important indicator of its quality. The standard pH value for well fermented food is set at four point two. The fermentation process typically occurs over a period of 7 to 28 days (McDonald *et al*., 2002), this is consistent with the reports of Subepang *et al*. (2018) studied the quality of fermented food using cassava as a dense source of raw materials. They fermented it in plastic bags with a capacity of 300 kg. for a duration of 15 to 30 days, and they found that the pH values fell within the range of 3.82 to 4.31. Furthermore, the research of Wanna *et al*. (2020) on the quality of fermented maize variety Suwan 4452, fermented for 21 and 60 days, falls within the good range. The average pH values in their study were approximately 3.66 - 3.73, and the levels of lactic acid ranged from 6.35 - 7.14%. This is in line with the normal range for lactic acid typically found in corn silage, which is between 3 - 6% of dry matter (Kung *et al*., 2018). In summary, the study of corn silage using the different plastic bags type was able to preserve the corn silage for 60 days. The physical properties were within an excellent range, and the lactic acid content ranged from 4.7% to 7.8%, which is within the typical range for lactic acid found in corn silage.

References

Kung, L. Jr., Shaver, R. D., Grant, R. J. and Schmidt, R. J. (2018). Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. Journal of Dairy Science, 101:4020-4033.

Lin, S., Na, N., Xiaomei, L., Ziqin, L., Chao, W., Xiaoguang, W., Yanzi, X., Guomei, Y., Sibo, L., Zhiping, L., Yanlin, X. and Fuyu, Y. (2021). Impact of Packing Density on the Bacterial Community, Fermentation, and In Vitro Digestibility of Whole-Crop Barley Silage. Agriculture, 11:14.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D. and Morgan, C. A. (2002). Animal Nutrition. 6th ed. Longman Scientific and Technical, New York, NY, 543 p.

Office of agricultural Economics (2022). Situation of important agriculturalproducts and trends in 2023. Bangkok, Office of Agricultural Economics Ministry of Agriculture and Cooperatives, pp.27-36.

Roth, G. and Undersander, D. (1995). Corn Silage Production, Management, and Feeding. American Society of Agronomy, Inc., in Crop Science Society of America, pp.30-42.

Subepang, S., Suzuki, T. Phonbumrung, T. and Sommart, K. (2018). Enteric methane emissions, energy partitioning, and energetic efficiency of zebu beef cattle fed total mixed ration silage. Asian-Australasian Journal of Animal Sciences, 32:548-555.

Effect of combination fertilizer on growth and yield of Cassava cv. Rayong 9 in Thailand

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Srifa, T., Somwang, T, Panitnok, K., Yusuk, P. and Nitthaisong, P. (2024). Effect of combination fertilizer on growth and yield of Cassava cv. Rayong 9 in Thailand.

Abstract The result showed that cultivation of cassava rayong9 cultivar by using NPK 15-15-15 + Bio-fertilizer showed the cassava height of significant different compared to Bio-fertilizer only at 90 and 150 days, while used of NPK 15-15-15 + Bio-fertilizer showed that highest SPAD value significant different ($p<0.05$) with treatment of non-fertilizer application (control) and Bio-fertilizer at 90, 120 and 150 days after planting. In contrast, 6 months after planting, the cassava yield non-significantly different, but using NPK 15-15-15 + Bio-fertilizer gave the highest fresh weight yield of 12,238 $kg^{-1}ha^{-1}$ and in dry weight yield 5,260 $kg^{-1}ha^{-1}$.

Keywords: Rayong 9 Cassava, Bio-fertilizer, Chemical fertilizer, Fertilizer

Introduction

Cassava is one of the world's most important tropical crop plants Cock (1985) and Fregene *et al*. (2001) and the fourth most important food calorie crop in the tropics and has been growing in importance both for food security and for multiple commercial and industrial uses Dedouck *et al*. (2011). Cassava is an essential economic crop in the country. In 2022, Thailand had approximately 1.6 million hectares of cassava production area. Cassava exports were 6, 10, and 11 million tons, valued at 82,000, 123,000, and 150,000 million baht, respectively. Cassava exports consistently trended from 2020 to 2022 (The Office of Agricultural Economics, 2023a).

Cassava cultivation in Thailand relies heavily on chemical fertilizers to meet domestic and international market demand. Consequently, farmers often apply excessive amounts of chemical fertilizers, leading to higher production costs and long-term soil degradation issues. Wongsuwan *et al*. (2021) One practical approach to addressing this issue involves combining chemical, organic, or biological fertilizers, which aims to enrich the soil, increase plant nutrients, and enhance the physical properties of the soil (The Office of Agricultural Economics, 2023b). Bio-fertilizers, such as Bio-fertilizer (Plant Growth-Promoting Rhizobacteria), play a crucial role in promoting plant growth. Chotinan (2023) report that bio-fertilizers consist of a several group of bacteria that inhabit various parts of plants, including the root area, root surface, inside the roots, stems, and leaves. The study of Otaiku *et al*. (2019) demonstrated that combining bio-fertilizers with chemical fertilizers results in higher cassava yields and improved growth than using no fertilizers.

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The objective was to investigate the effect of combining Bio-fertilizer with chemical fertilizers on the growth and yield of cassava cv. Rayong 9.

Materials and methods

The experiments were conducted at the Khao Hin Son Research Station in the Khao Hin Son Subdistrict, Phanom Sarakham District, Chachoengsao Province. The Rayong 9 cassava planting in sandy soil: mabbon series. (Latitude, Longitude13°44'46.7"N 101°33'48.3"E).

The randomized complete block (RCBD) experiment was planned, consisting of 5 treatments with 4 replications: 1.) No fertilizer (Control). 2.) Bio-fertilizer (12.5 $kg^{-1}ha^{-1}$). 3.) Chemical fertilizer NPK 15-15-15 (437.5 $kg^{-1}ha^{-1}$). 4.) Chemical fertilizer NPK 15-15-15 (437.5 $kg^{-1}ha^{-1}$) + Bio-fertilizer (12.5 $kg^{-1}ha^{-1}$).

The fertilizer application divided for fertilizer were two times: The first time when the cassava were 45 days after planting and the second time when the cassava were 75 days after planting. The bio-fertilizer treatments are blended with chemical fertilizers and then gave immediately.

Data collection

Growth of cassava: Cassava height was measured randomly selecting eight plants per plot, by using a meter stick measured from the ground to the shoot, SPAD Chlorophyll Meter (SCMR) were measured three points upper, middle, and lower canopy then averaged.

Cassava yield: Cassava were harvested 6 months after planting. Cassava yield data were recorded by collect data 4 plants per plot. Cassava yield was determined by digging up the root separating it from the plant. The cassava tuber to find the total weight.

Statistical analysis

The data obtained from the experiment were used to statistical variance analysis (Analysis of Variance; ANOVA). Differences in means were compared using Fisher's Least Significant Difference (LSD) through the R-program version 4.0 (R Core Team, 2022).

Results

The results showed that there was significant different($p<0.05$) effect of the Bio-fertilizer on the cassava height (Table 1). The growth at 90 and 150 days found that used of NPK 15-15-15+Bio-fertilizer gave higher height than Bio-fertilizer only. However, plant height was not different at 75 and 120 days after plating.

The result showed that Bio-fertilizer were significant different ($p<0.05$) effect on SPAD Chlorophyll Meter (SCMR) at 75, 90, 120 and 150 days but chemical fertilizer the SCMR of significant different compared to control and Bio-fertilizer only but did not significant with the treatment of NPK 15-15-15 + Bio-fertilizer at 75 days (Table 2). The growth at 90 and 120 days found that used of NPK 15-15-15 + Bio-fertilizer gave higher than other treatments, while used of NPK 15-15-15 + Bio-fertilizer gave higher than control and Bio-fertilizer only. The maximum SCMR in the used of NPK 15-15-15 + Bio-fertilizer at 51.51, 51.51 and 46.10 during 90-, 120- and 150-days cassava after planting.

Table 1. Effect of Bio-fertilizer on height cassava (cm) cv. Rayong 9

Treatment	Growth period (days)1/			
	75	90	120	150
Control	74.78	84.85ab	89.18	91.81b
Bio-fertilizer	72.81	83.34b	98.90	95.32b
Chemical fertilizer	83.94	97.22ab	101.33	113.61a
Chemical fertilizer + Bio-fertilizer	84.50	98.99a	107.20	116.10a
F-test	ns	*	ns	*
C.V.%	9.87	9.91	17.05	10.06

*= Significantly different at p<0.05, ns= non significantly different

Table 2. Effect of Bio-fertilizer on SPAD Chlorophyll Meter (SCMR) of cassava cv. Rayong 9

Treatment	Growth period (days)1/			
	75 days	90 days	120 days	150 days
Control	40.70b	47.68c	48.33b	42.78b
Bio-fertilizer	40.63b	46.07c	46.07c	41.87b
Chemical fertilizer	44.62a	49.47b	49.47b	45.23a
Chemical fertilizer + Bio-fertilizer	43.64a	51.51a	51.51a	46.10a
F-test	*	*	*	*
C.V.%	4.15	2.20	1.71	3.09

*= Significantly different at p<0.05, ns= non significantly different at p<0.05

Total fresh weight yield and dry weight yield found that no significant different (p<0.05). The results showed in the Chemical fertilizer + Bio-fertilizer in fresh weight yield were 12,238 $kg^{-1}ha^{-1}$ and dry weight yield were 5,260 $kg^{-1}ha^{-1}$, while in other treatment range 10,810 to 8,713 $kg^{-1}ha^{-1}$ in fresh weight yield, 4,367 to 3,718 $kg^{-1}ha^{-1}$ in dry weight yield (Table 3).

Table 3. Effect of Bio-fertilizer on fresh weight yield and dry weight yield of cassava cv. Rayong 9

Treatment	Yield ($kg^{-1}ha^{-1}$) at 6 months	
	Fresh weight	Dry weight
Control	8,713	3,718
Bio-fertilizer	10,810	4,730
Chemical fertilizer	10,381	4,367
Chemical fertilizer + Bio-fertilizer	12,238	5,260
F-test	ns	ns
C.V.%	27.25	28.87

*= Significantly different at p<0.05, ns= non significantly different

Discussion

The research demonstrated that Biofertilizer impacts the growth yield of cassava. cv. Rayong9 the studied found that NPK 15-15-15 + Bio-fertilizer were significantly different ($p<0.05$) than treatment of control and Bio-fertilizer only, which used of Bio-fertilizer only did not enough for cassava plant growth. Similarity with those reported in studies of Meunchang *et al*. (2011) found that cassava height increased 5.06%when combined application of Bio-fertilizer and Chemical fertilizer. The harvest yield of cassava cv. Rayong9 at 6 months showed that there were non-significantly different in fresh weight yield and dry weight yield, while fresh weight yield tends to increase in the Chemical fertilizer + Bio-fertilizer (12,238.13 $kg^{-1}ha^{-1}$). This finding similar with report of Wongsuwan *et al*. (2021) reported that impact of Bio-fertilizer on cassava yield more than non-fertilizer. The cassava yield tends to increase 16.2%. Amawan (2012) also reported that the Bio-fertilizer were increased plant growth and yield for cassava because Bio-fertilizer act as bio-fertilizer provide nitrogen via nitrogen fixation moreover phytostimulators can directly promote the growth of plant, usually by the production of hormones. Plant hormones was ethylene, jasmonic acid (JA) and salicylic acid (SA) Teaumroong *et al*. (2005).

The results showed that use Chemical fertilizer + Bio-fertilizer gave fresh weight yield than other treatment. However, the recommended that use Bio-fertilizer is good enough in harvest cassava at 6 months after planting. From this result the Bio-fertilizer can reduce costs for cassava production.

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References

Amawan, S. (2012). Effect of Plant growth promoting rhizobacteria on quality & quantity increasing of cassava yield. (Master thesis). National Institute of Development Administration. Thailand.

Chotinan, N. (2023). Bio-fertilizer (PGPR) Increase growth fertilizer. Kasikorn, 96:11-15.

Cock, J. H. (1985). Cassava: new potential for a neglected crop, Boulder, Westview Press.

Dedouck, D., Dominique, D., Alexandra, J., Hershey, C. and Llerme, R. (2011). Conservation of cassava genetic resource. Retrieved from http://cropgenebank.sgrp.cgiar.org

Fregene, M., Suarez, M., Mkumbira, J., Kulembeka, H., Ndedya, E., Kulaya, A., Mitchel, S., Gullberg, U., Rosling, H., Dixon, A., Dean, R. and Kresovich, S. (2003). Simple sequence repeat marker diversity in cassava landraces: genetic diversity and differentiation in an asexually propagated crop. Theor Appl Genet, 107:1083-1093.

Meunchang, S., Amawan, S., Thongra-ar, P., Prongjunthuek, K., Kueanoon, S., Amonpon, W. and Thiprak, S. (2011). Effect of utilization of biofertilizer for increase quality and yield of cassava. Department of agriculture 16 p.

Otaiku, A. A., PC, M. and AO, A. (2019). Biofertilizer Impacts on Cassava (Manihot Esculenta Crantz) Rhizosphere: Crop Yield and Growth Components, Igbariam, Nigeria-Paper1. World J Agri &Soil, 3:1-15.

Teaumroong, N., Teamtaisong, K. and Boonkerd, N. (2005). Overview of PGPR (Plant Growth Promoting Rhizobacteria). Suranaree Journal of Science and Technology, 12:252-261.

The Office of Agricultural Economics. (2023a). Information of agricultural economics 2023. Retrieved from https://www.oae.go.th/view/1/.

The Office of Agricultural Economics. (2023b). Product manufacture of agricultural 2023. Retrieved from http://www.oae.go.th/view/1/.

Wongsuwan, N., Khaengkhan, P., and Sinsiri, N. (2021). Effects of bio-fertilizer (PGPR-3) Organic fertilizers and chemical fertilizers of growth, yield and quality in the production of Rayong 9 cassava Rayong 9 and Kasetsart 50 in the Korat soil. Prawarun agricultural journal, 18:103-111.

Growth and yield of Cassava cultivar KU-80 by using biofertilizer

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Thaikeaw, P., Panitnok, K., Somwang, T. and Nitthaisong, P. (2024). Growth and yield of Cassava cultivar KU-80 by using biofertilizer.

Abstract Cultivation of cassava cultivar KU-80 with fertilizer management was investigated. In terms of growth, the results showed that cultivation of cassava by using treatment 3 chemical fertilizer (15-15-15) at a rate of 437.5 kg^{-1} ha^{-1} gave the highest cassava height, stem girth, canopy diameter and SPAD value. In terms of yield, cultivation of cassava by using treatment 3 chemical fertilizer (15-15-15) at a rate of 437.5 kg^{-1} ha^{-1} gave the higher fresh weight and dry weight of cassava yield but not different significant with all treatment by the reason of the harvest period is 180 days cassava was still in the stage of developing leaves and stem.

Keywords: Cassava cultivar KU-80, Fertilizer management, Bio-fertilizer

Introduction

Cassava (*Manihot esculenta* Crantz) is a tuber and food crop used as a source of carbohydrates, an annual crop widely grown in tropical and subtropical areas, it is commonly used as a forage crop. It is a plant that is simple to cultivate, and drought tolerant. If considering the world's production of food crops, cassava ranks 5th among the top 10 world economic crops. (Institute of Research and Development Kasetsart University, 2015).

Nowadays, most farmers cultivate cassava by using more chemical fertilizers, causing high production costs and degraded soil. The way to solve the problem to increase higher products and reduce production costs is to use a combination of chemical fertilizers and Biofertilizer to improve the soil. The use of bio-fertilizer was developed for use with cassava. This type of PGPR comprises with several species of rhizobacteria inhabiting the rhizophere (Hellriegel and Wilfarth, 1888). It can promote growth, fix nitrogen, contribute substantial amounts of nitrogen to plant nutrition and production of phytohormones (Glick *et al*., 1999; Weid *et al*., 2000). Therefore, using chemical fertilizers combined with biofertilizers as a reduces the amount of chemical fertilizer. It may be an option to reduce production costs and chemical residue, increase products, improve soil quality and farmers earn more profit in cultivate of cassava, and in the area of Chachoengsao province, there is no experimentation study on cultivate Kasetsart 80 cassava.

The objective was to combine biofertilizer and chemical fertilizer application on the growth and yield of cassava cv. Kasetsart 80.

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Materials and methods

Experimental design and treatment

The experiment was used a Randomized Complete Block Design (RCBD) consisting of 5 treatments with 3 replications. T1 = non-fertilizer (Control), T2 = biofertilizer 12.5 kg^{-1} ha^{-1}, T3 = chemical fertilizer (15-15-15) 437.5 kg^{-1} ha^{-1} and T4 = chemical fertilizer (15-15-15) 437.5 kg^{-1} ha^{-1} + bio-fertilizer 12.5 kg^{-1} ha^{-1}. The place used in this experiment is the Mabbon soil series at Khao Hin Son Subdistrict, Phanom Sarakham District, Chachoengsao (13°44'46.7"N 101°33'48.3"E).

Methodology

There was ploughed 2 times to prepare the soil, plowed with 3-disc plows and 7-disc plows. Then divided into 15 blocks of size 11 x 6 meters to plant cassava KU-80, planting space is 1 x 1 meter, and remove weeds again before 15-day fertilizing. After that, fertilized to the cassava for the first time at 45 days and second time on 75 days after cultivation. Applying fertilizer by (T2) fertilize bio-fertilizer (12.5 $kg^{-1}ha^{-1}$), (T3) fertilize N-P-K 15-15-15 (437.5 $kg^{-1}ha^{-1}$) and N-P-K 15-15-15 (437.5 $kg^{-1}ha^{-1}$) mixed with bio-fertilizer (12.5 $kg^{-1}ha^{-1}$) together and fertilized around the canopy of cassava.

Data collection and analysis

Plant growth data were collected with cassava height, stem girth, canopy diameter, and leaf greenness index measured by the SPAD Chlorophyll Meter Reading (SCMR). The fresh weight and dry weight of cassava tuber were harvest when cassava was 6 months after planting.

The analysis was using one-way Analysis of variance (ANOVA) and comparing the difference in means between treatments using Fisher's Least Significant Difference (LSD) using the program R-stat version 4.0 (R Core Team, 2022).

Results

Growth of cassava

The results from experiments on growth of KU-80 cassava showed that chemical fertilizer only gave a higher plant height, stem girth and canopy diameter of cassava, followed by Control, Biofertilizer only and the lower is N-P-K 15-15-15 + bio-fertilizer. Leaf greenness index in chemical fertilizer only gave higher followed by biofertilizer, N-P-K 15-15-15 + Biofertilizer and control respectively (Table 1).

Table 1. Effect of chemical fertilizer and biofertilizer application on growth of KU-80 cassava

Treatment	Plant height	Stem girth	Canopy diameter	Leaf greenness index
	(cm.)	(cm.)	(cm.)	(SPAD values)
Control	86.3	10.1^{ab}	86.3	40.4
Biofertilizer	80.3	9.6^{b}	91.7	42.5
15-15-15	93.7	10.9^{a}	96.0	44.4
15-15-15 + Biofertilizer	76.8	10.1^{ab}	83.0	40.7
F-test	ns	*	ns	ns
C.V. (%)	19.62	4.81	9.42	10.37

ns = Non-Significantly different, * = Significantly different at $p < 0.05$ by LSD

Yield of cassava

The yield collection from cassava KU-80 cultivar show that all four treatments were not significant different, but the treatment of chemical fertilizer only gave higher fresh weight at 9,870.8 $kg^{-1}ha^{-1}$ and dry weight at 3780.5 $kg^{-1}ha^{-1}$, followed by control treatment at 8,041.7 $kg^{-1}ha^{-1}$ and 3,080 $kg^{-1}ha^{-1}$, Biofertilizer only at 7,132.5 $kg^{-1}ha^{-1}$ and 2,731.8 $kg^{-1}ha^{-1}$ and the lower is chemical combine with Biofertilizer at 6,865.8 $kg^{-1}ha^{-1}$ and 2,629.6 $kg^{-1}ha^{-1}$ (Table 2.)

Table 2. Effect of chemical fertilizer and biofertilizer application on yield of KU-80 cassava

Treatment	Yield ($kg^{-1}ha^{-1}$)	
	Fresh weight	Dry weight
Control	8,041.7	3,080.0
Biofertilizer	7,132.5	2,731.8
15-15-15	9,870.8	3,780.5
15-15-15 + Biofertilizer	6,865.8	2,629.6
F-test	ns	ns
C.V. (%)	29.59	29.59

ns = Non-Significantly different

Discussion

Cassava yield and growth responses to fertilizer management with bio-fertilizer of KU-80 cassava on Mabbon soil series show that using only bio-fertilizer cannot increase yield and growth. In consistent with Wongsuwan *et al*. (2021) conducted an experiment on the effects of bio-fertilizer, organic fertilizer and chemical fertilizer on growth, yield and quality in production of cassava Rayong 9 and Kasetsart 50 varieties on Korat soil series results showed using bio-fertilizer not difference in plant height and dry weight of tuber yield because cassava is still in the stage of developing leaves and stems, and consistent with Amawan (2012) the results of this study the use of bio-fertilizer on cassava cultivation in sandy soil, using bio-fertilizer has an effect on cassava fresh yield different from treatment that not used biofertilizer on statistically significant, by cassava fresh tuber yield increase at 16.2 percent, in term of height, leaf weight and cassava stump are tendency to increase (Amawan, 2012).

In conclusion, all treatment showed not significant of yield by the reason of the harvest period is 180 days cassava is still in the stage of developing leaves and stem.

References

Amawan, S. (2012). Effect of Plant Growth Promoting Rhizobacteria on Quality and Quantity Increasing of Cassava Yield. (Master Thesis). National Institute of Development Administration, Thailand.

Glick, B. R., Patten, C. L., Holguin G. and Penrose, D. M. (1999). Biochemical and genetic mechanisms used by plant growth promoting bacteria. Imperial College Press, Waterloo, Ontario, Canada.

Hellriegel, H. and Wilfarth, H. (1888). Untersuchungen uber die Stickstoffnahrung der Gramineen und Leguminosen. Beilageheft zu der Zeitschrift des Vereins fur Rubenzucker-Industrie DeutschenReichs, pp.234.

Weid Von der, I., Paiva, E., Nobrega, A., van Elsas, J. D. and Seldin, L. (2000). Diversity of *Paenibacillus polymyxa* strains isolated from the rhizosphere of maize planted in Cerrado Soil. Research in Microbiology, 151:369-381.

Wongsuwan, N., Khengkhan, P. and Sinsiri, N. (2021). Effect of Biofertilizer (PGPR –3) Organic and Chemical Fertilizers on Growth Yield and Quality of Rayong 9 and Kasetsart 50 Cassava Varieties on Korat Soil Series. Prawarun Agricultural Journal, 18:103-111.

Comparison of cost and return of durian cultivation based on the orchard management techniques of farmers in Rayong Province, Thailand

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Thongtem, K., Suwanmaneepong, S. and Kerdsriserm, C. (2024). Comparison of cost and return of durian cultivation based on the orchard management techniques of farmers in Rayong Province, Thailand.

Abstract The costs and returns associated with durian cultivation using single and double orchard management techniques among farmers in Rayong province were comporeda. Through in-depth interviews with community innovators, data were gathered and analyzed using the cost and return analysis and t-test for statistical comparison. The findings revealed that under total cost of 50,871.18 THB per rai, generating 2,000 kg. per rai and a net profit of 149,128.82 THB per rai incurs a higher single durian tree cultivation, the total cost per rai amounts to 42,719.50 Thai baht (THB), yielding1,600.00 kg. per rai and a net profit of 149,280.50 THB per rai. In contrast, double durian orchard management. Notably, there was statistically significant differed between the fixed costs associated with durian cultivation at the 0.05 significance level in the two cases. However, regarding variable costs, total costs, total average yield, and net profit, the durian orchard management techniques in both scenarios was not statistically significantly differed. The implications arising from these findings showed significance for agricultural practitioners and policymakers, underlining the importance of tailored management strategies that account for the intricate interplay of costs, yields, and net profits. These insights are provided valuable guidance for farm management decisions and policy considerations in developing better durian cultivation.

Keywords: Cost and return, Durian, Farm management, Orchard management techniques

Introduction

In Thailand, durian is considered an economic crop that generates income in 2022, ranking number 1 in the country. There is a durian planting area of 1,340,692 rai, a harvest area of 943,765 rai, with a production of 1,246,098 tons and a yield per rai of 1,320 kg (Regional Office of Agricultural Economics, 2022a). Growing durian in Rayong province has the third highest yield per rai in Thailand, following Chanthaburi and Chumphon provinces in 2022; the durian cultivation area was 117,753 rai, with a harvest area of 71,104 rai. The total yield was 149,234 tons, resulting in a yield per harvested area of 2,099 kilograms per rai (Regional Office of Agricultural Economics, 2022a). The output in 2022 has increased in quantity due to the higher market price of durian. Import demand for important production factors such as fertilizer is expanding abroad. In 2021, the value of these imports was 70,102 million baht, while in 2022, it grew to 103,205 million baht, with prices also rising (Regional Office of Agricultural Economics, 2023). As a result, durian farmers have experienced an increase in production costs. Profits were lower than the previous year. In July 2023, the price of Monthong durian at Khao Din Central Market in Klaeng District, Rayong Province, was 110 Thai baht (THB) per kilogram (Regional Office of Agricultural Economics, 2022b).

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In addition, they were growing durian according to the durian orchard management techniques of farmers with single durian tree cultivation. Low production costs make managing the conversion convenient, easy, and fast. The plant receives regular light for optimal growth. The produce is of high quality. As for growing durian, according to the durian orchard management techniques of farmers who employ the method of double durian tree cultivation, it is a technique that can yield higher fruit production. This technique is helpful for straightforward post-harvest recovery, and the plants are not worn out due to the low yield per plant. Moreover, it could reduce the toppling of trees during storms, giving higher returns per unit of area (Rayong Agricultural Occupation Promotion and Development Center, 2020).

Durian farmers, however, encounter significant expenses in their production processes. Plantings typically require 6-7 years to reach completion (Sawaengkit, 2019). Access to most innovations is accompanied by a significant financial burden, particularly for small-scale farmers (Yigezu *et al.,* 2018). Moreover, adopting innovation depends on the cost (Toma *et al.,* 2016). If the costs and profits from implementing agricultural technology are minimized, it will lead to greater and faster acceptance (Rerkrai, 1984). The main reasons for its application are economic variables. Cost analysis is, therefore, a commonly used business tool for planning and deciding on implementing innovation. That will indicate the success or failure of implementing innovation (Suwanmaneepong *et al.,* 2020). Therefore, analyzing the costs and returns of durian production is essential (Thongkaew *et al.,* 2021; Wiangsamu and Wiangsamut, 2022). This research compares the costs and returns of growing durian based on farmers' different durian orchard management techniques. To utilize the information for planning and decision-making when implementing garden management techniques. The study was conducted in Mueang district and Klaeng district, Rayong province, which are essential durian growing areas in Rayong province. These areas have been promoted by the Rayong Provincial Agricultural Career Promotion and Development Center for cultivating durian techniques to serve as a guideline for other farmers in the area and facilitate their development.

Materials and methods

Population and sample

The sample group used in this study consisted of farmers who grow durian according to durian orchard management techniques. There were two cases in Rayong province—case 1: Single durian tree cultivation and case 2: Double durian tree cultivation. The selection criteria for the two farmers were compared. He is a model farmer in the area.

Study area

This study focused on the areas in Mueang district and Klaeng district. Rayong province is located in the eastern region of Thailand.

Figure 1. Single durian tree cultivation

Figure 2. Double durian tree cultivation

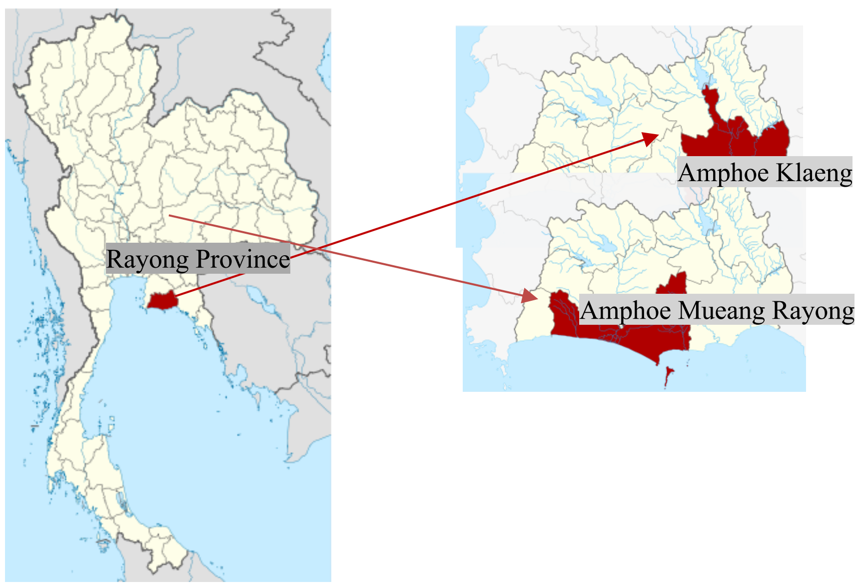

Figure 3. Place where farmers grow durian, Thailand.

Data collection

The tool used to collect data was a questionnaire created from theoretical concepts. The quality of the tools used in the research is created and checked, divided into two parts.

Part 1: General information about durian production among farmers, including gender, age, marital status, and education level. Number of household members, number of household workers involved in durian orchards, number of workers hired to grow durian orchards, principal occupation, debt burden, and farmers' loans. Durian gardening experience: Area for durian gardening and cultivation by farmers.

Part 2: Information on costs and returns for durian farmers, including various expenses associated with preparing the soil for durian orchards. Cost of durian varieties and labor costs in durian production.

Data collection

Data were collected through in-depth individual interviews—interviews in Klaeng district and Mueang district in Rayong province. The data is then collected and returned to farmers to confirm the analysis results.

Data analysis

Analysis of data on durian cultivation based on the orchard management techniques employed by farmers in Rayong province. In order to achieve the objectives of the study, it is divided two methods as follows.

1. Cost return analysis

It is a cost analysis. Farmers returns on durian production: Considering the cost and return on production area per rai, both cash and non-cash returns, using the following calculation method (Pridasak, 2004). Cost analysis and return from production will be analyzed using the following equation:

Total Cost (TC) = Total Variable Cost (TVC) + Total Fixed Cost (TFC)

Total income (TR) = total amount of produce (Q) x price received by farmers (P)

Net Revenue (NR) = Total Revenue (TR) – Total Variable Cost (TVC)

Net Profit (NP) = Total Revenue (TR) – Total Cost (TC)

Profit over monetary costs = Total Revenue (TR) – monetary costs (CC)

2. T-test statistics to compare average costs and returns from growing durian based on farmers' durian orchard management techniques. Are they different or not? (Mankeb, 2016)

Results

Costs and returns of durian cultivation based on the orchard

The cost of single durian tree cultivation showed that farmers had an average total variable cost of 37,327 THB per rai (87.38 %), with the highest being the cost. The highest variable cost is the cost of production factors, about 12,725.00 THB per rai (29.79 %). The critical fixed costs are opportunity costs, a non-cash cost of 5,000.00 THB per rai (11.70 %). An average total income is 192,000.00 THB per rai; the average profit is 149,280.50 THB per rai, the break-even yield is 356.00 kg per rai, and the break-even price is 26.70 THB per rai.

Meanwhile, costs of double durian tree cultivation were averaged a total variable cost of 44,699.45 THB per rai (87.87%), with the highest being the cost of production factors in money 16,947.27 THB per rai (33.31 %). Significant fixed costs are found to be opportunity costs. It was a non-cash cost of 5,000.00 baht/rai (9.83 %). In terms of return, it showed an average total income of 200,000.00 THB per rai, average profit of 149,128.28

THB per rai, break-even yield of 508.71 kg per rai, and break-even price of 25.44 THB per rai, as shown in Table 1.

Table 1. Costs and returns of single durian tree cultivation and double durian tree cultivation (Unit: Baht per rai)

Items	Single durian tree cultivation THB	%	Double durian tree cultivation THB	%
1. Variable costs	37,327.00	87.38	44,699.45	87.87
1.1.1 Labor costs for preparing planting areas	6,000.00	14.05	1,963.64	3.86
Labor costs for preparing soil and adjusting the area	5,000.00	11.70	1,500.00	2.95
Labor costs for digging planting holes	1,000.00	2.34	463.64	0.91
1.1.2 Labor costs for growing durian	1,140.00	2.67	654.55	1.29
Labor costs for planting	1,060.00	2.48	600.00	1.18
Labor costs for applying fertilizer	80.00	0.19	54.55	0.11
1.1.3 Durian orchard maintenance costs	8,262.00	19.34	14,770.36	29.03
Weed management costs	1,040.00	2.43	820.36	1.61
Water management costs	2,125.00	4.97	840.91	1.65
Pest management costs	467.00	1.09	436.36	0.86
Pest management costs	1,110.00	2.60	8,727.27	17.16
Durian fruit wrapping management fee	240.00	0.56	690.91	1.36
Pruning cost	3,280.00	7.68	3,254.55	6.40
1.1.4 Harvest + after harvest	9,200.00	21.54	10,363.64	20.37
Collected fees from the beginning of collection	8,600.00	20.13	10,181.82	20.01
Other values	600.00	1.40	181.82	0.36
1.2 cost of production factors	12,725.00	29.79	16,947.27	33.31
Plant value	3,600.00	8.43	4,000.00	7.86
Chemical fertilizer cost	1,000.00	2.34	3,320.00	6.53
Cost of chemical- organic fertilizers	1,590.00	3.72	4,336.36	8.52
Cost of herbicides / pests / hormones	2,335.00	5.47	2,072.73	4.07
Fuel cost	200.00	0.47	272.73	0.54
Agricultural electricity costs	3,600.00	8.43	2,400.00	4.72
Other expenses	400.00	0.94	545.45	1.07
2.Fixed costs	5,392.50	12.62	6,171.73	12.13
Opportunity cost of land use	5,000.00	11.70	5,000.00	9.83
Tool depreciation	392.50	0.92	1,171.73	2.30
3. Total cost	42,719.50	100.00	50,871.18	100.00
4. Total Revenue	192,000.00		200,000.00	
5. Total output (Kg. per rai)	1,600.00		2,000.00	
6. Selling price (Baht per kg.).	120.00		100.00	
7. Net profit	149,280.50		149,128.82	
8. Break-even production (Kg. per rai)	356.00		508.71	
9. Break-even price (Baht per kg.)	26.70		25.44	

Comparison of cost-returns in single durian tree cultivation and double durian tree cultivation

A comparison of cost-returns in single and double durian tree cultivation between two farmers in Rayong province was made. It was found that there is a significant difference in pruning cost, plant value, harvest and after harvest, Cost of herbicides/pests/hormones, and chemical-organic fertilizers at a significance level of 0.05. As for the collected fees from the beginning of the collection, weed management costs, cost of production factors, fuel, Labor for growing durian, labor for planting, labor for growing durian, agricultural electricity costs, labor costs for digging planting holes, water management costs, durian fruit wrapping management fee, tool depreciation, labor costs for preparing soil and adjusting the area, chemical fertilizer cost and pest management costs. There were no significant statistical differences according to the order as shown in Table 2.

Table 2. Table comparing the cost of single durian tree cultivation and double durian tree cultivation. (Unit: Baht per rai)

Items	**Single durian tree cultivation**	**Double durian tree cultivation**	**t-test**	**Sig.**
1. Variable costs	37,327.00	44,699.45	11.126	.057
1.1.1 Labor costs for preparing planting areas	6,000.00	1,963.64	1.973	.299
Labor costs for preparing soil and adjusting the area	5,000.00	1,500.00	1.857	.314
Labor costs for digging planting holes	1,000.00	463.64	2.729	.224
1.1.2 Labor costs for growing durian	1,140.00	654.55	3.697	.168
Labor costs for planting	1,060.00	600.00	3.609	.172
Labor costs for applying fertilizer	80.00	54.55	5.286	.119
1.1.3 Labor costs for growing durian	8,262.00	14,770.36	3.539	.175
Weed management costs	2,125.00	840.91	8.470	.075
Water management costs	467.00	436.36	2.310	.260
Pest management costs	1,110.00	8,727.27	1.291	.419
Durian fruit wrapping management fee	240.00	690.91	2.065	.287
Pruning cost	3,280.00	3,254.55	256.760	.002
1.1.4 Harvest + after harvest	9,200.00	10,363.64	16.812	.038
Collected fees from the beginning of collection	8,600.00	10,181.82	11.874	.053
Other values	600.00	181.82	1.870	.313
1.2 cost of production factors	12,725.00	16,947.27	7.028	.090
Plant value	3,600.00	4,000.00	19.000	.033
Chemical fertilizer cost	1,000.00	3,320.00	1.862	.314
Cost of chemical-organic fertilizers	1,590.00	4,336.36	14.841	.043
Cost of herbicides / pests / hormones	2,335.00	2,072.73	16.806	.038
Fuel cost	200.00	272.73	6.500	.097
Agricultural electricity costs	3,600.00	2,400.00	3.444	.180
2.Fixed cost	5,392.50	6,171.73	6.500	.097
Tool depreciation	392.50	1,171.73	2.007	.294

Comparative table of returns for single durian tree cultivation and double durian tree cultivation

A comparison of returns for single durian tree cultivation and double durian tree cultivation by farmers in Rayong province found that the total cost of growing a single durian tree was 42,719.50 THB. The total variable costs were 37,327.00 THB, while the total fixed costs are 5,392.50 THB. The total income generated from this venture was 192,000.00 THB, with an average production of 1,600.00 kg per Rai, the total net profit was 149,280.50 THB, and the break-even production is 356.00 THB, a reasonable price. The cost was 26.70 baht for cultivating durian as a double tree. The total cost was 50,871.18 THB. Total variable costs amounted to 44,699.45 THB. Total fixed costs were 6,171.73 THB. The total income was 200,000.00 THB. The total average production was 2,000.00 kilograms per rai. The total net profit was 149,128.82 THB, the break-even production was 508.71 THB, and the break-even price was 25.44. In both cases, durian cultivation was significantly different net profit, total revenue, and break-even prices at 0.05. As for variable costs, the total cost, variable costs, fixed cost, total output, and break-even production were not significantly different, as shown in Table 3.

Table 3. Comparison cost and returns from single durian tree cultivation and double durian tree cultivation. (Unit: Baht per Rai)

Items	Single durian tree cultivation	Double durian tree cultivation	t-test	Sig.
Total cost	42,719.50	44,699.45	11.481	0.55
Variable costs	37,327.00	35,694.55	11.126	.057
Fixed cost	5,392.50	6,171.73	6.500	.097
Total revenue	192,000.00	200,000.00	49.00	.013
Total output (Kg. per rai)	1,600.00	2,000.00	9.000	.070
Net profit	149,280.50	149,128.82	1967.361	.000
Break-even production (Kg. per rai)	356.00	508.71	5.662	.111
Break-even price (Baht per kg.)	49.99	20.82	41.381	.015

Discussion

The cost of growing durian according to the farmer's orchard management techniques. the results showed that single durian tree cultivation and double durian tree cultivation. Farmers have areas of 10 and 11 rai, as found in the research conducted (Makthasae and Churin, 2021) and consistent with the research (Chanasuk, 2017)

In terms of returns on growing durian based on farmers' orchard management techniques, the result found that to be grown using single-tree orchard management techniques. The average yield was 500 kilograms per rai. The total income was 50,000 baht per rai, and the net profit was 25,004.25 THB per rai. Growing durian using the double-tree orchard management technique was averaged yield of 2,000 kilograms per rai, an average income of 200,000 THB per rai, and a net profit of 158,363.41 baht per rai as shown in the research conducted by Pomsanam (2012).

Comparing the cost and return of growing durian using single durian tree cultivation and double durian tree cultivation showed that the fixed costs and variable costs of growing durians using double durian tree cultivation were higher than those of single durian tree cultivation. Additionally, the average yield, total income, and net profit of growing durians using the double durian tree cultivation were higher than those of growing durians using the single orchard management technique. This finding aligned with the findings of the Rayong Provincial Agricultural Career Promotion and Development Center (2020), which conducted a study on modern durian plantations. The study found that durian cultivation can be done using double and single durian tree cultivation. There were different average incomes and net profits. Growing durian using double durian tree cultivation is found to be superior to using single durian.

Based on the research findings, this study suggested as follows.

1. Planting single and double durian tree cultivation requires different water management techniques that are suitable and meet the needs of each tree. Double rows of trees require the installation of additional water sprinkler systems between them since the cost of production inputs and production management expenses increase.

2. Farmers should analyze the soil before fertilizing and properly managing the fertilizer for single and double durian trees is essential.

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References

Chanasuk, K. (2017). Evaluation of Cost, Revenue Structure and Financial Ratio for Pomelo Cultivation in Nakhon Pathom Province**.** Christian University of Thailand Journal, 23:575.

Mankeb, P. (2016). Using Computers for Agricultural Analysis. 2nd printing. Bangkok: Faculty of Agricultural Technology. King Mongkut's Institute of Technology Ladkrabang.

Makthasae, N and Churin, P. (2021). Analysis of Costs and Returns in Durian Cultivation by Farmers in Village No. 13, Nakha Subdistrict, Lang Suan District, Chumphon Province. Special Research. Surat Thani Rajabhat University.

Pomsanam, N. (2012). Costs and Returns on Long Laplae Durian Cultivation of Farmers in Laplae District, Uttaradit Province. Special Research. Chiang Mai University.

Pridasak, P. (2004). Principles of Microeconomics. Bangkok: PublisherThammasat University.

Rerkrai, D. (1984). Principles and Methods of Agricultural Promotion. Bangkok: Thai Watthanaphanich Printing House.

Rayong Agricultural Occupation Promotion and Development Center (2020). Modern Durian Plantation. [Online]. Retrieved from http://www.aopdh02.doae.go.th.

Regional Office of Agricultural Economics (2022a). durian. [Online]. Retrieved from https://mis-app.oae.go.th/product.

Regional Office of Agricultural Economics (2022b). Monthong durian. [Online]. Retrieved from https://www.oae.go.th/view/1/%E0%B8.

Regional Office of Agricultural Economics (2023). Factors of production. [Online]. Retrieved from https://www.oae.go.th/view/1.

Suwanmaneepong, S., Kerdsriserm, C., Lepcha, Cavite, H. and Liones, C. (2020). Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand. Organic agriculture, 10:369-378. https://doi.org/10.1007/s13165.

Sawaengkit, N. (2019). Costs and Returns of Durian Intercropping Farmer Village No. 4 Trok Nong Subdistrict, Khlung District, Chanthaburi Province. (Special Research). Kasetsart University.

Thongkaew, S., Jatuporn, C., Sukprasert, P., Rueangrit, P and Tongchure, S. (2021). Factors affecting the durian production of farmers in the eastern region of Thailand. International Journal of Agricultural Extension, 9:285-293.

Toma, L., A. P. Barnes, L.-A. Sutherland, S. Thomson, F. Burnett and K. Mathews (2016). Impact of information transfer on farmers' uptake of innovative crop technologies: a structural equation model applied to survey data. The Journal of Technology Transfer, 43:864-881.

Yigezu, Yigezu Atnafe, Mugera, Amin, El-Shater, Tamer, Aw-Hassan, Aden, Piggin, Colin, Haddad, Atef, Khalil, Yaseen, Loss and Stephen (2018). "Enhancing adoption of agricultural technologies requiring high initial investment among smallholders," Technological Forecasting and Social Change, Elsevier, 134:199-206.

Wiangsamut, B. and Wiangsamut, M. E. L. (2022). Effects of paclobutrazol on flowering of juvenile durian trees cv. 'Monthong' and its costs and returns of production. International Journal of Agricultural Technology, 18:2315-2328.

The analysis of total flavonoid contents in Thai White Rice Landrace

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Abstract Total flavonoid was analyzed in ten germplasm of Thai white rice landrace consisting of G. S. No. 528, G. S. No. 1531, G. S. No. 18018, Jasmine rice, G. S. No. 21717, G. S. No. 22208, G. S. No. 22211, G. S. No. 22212, G. S. No. 23207, and G. S. No. 23208. According to the analysis the total flavonoid contents were in the range of 252.44 to 514.67 mg QE 100 g^{-1} with significantly difference ($p \leq 0.05$) and the highest flavonoid content was found in G.S. NO 21717 (514.67 mg QE 100 g^{-1}). This could be used as information for breeding programs to enhance flavonoid content.

Keywords: Total flavonoid, Thai white rice landrace, Phytochemical

Introduction

Rice (*Oryza sativa* L.) is a staple food of the world population especially in Asia, more than 95% of the population consumes rice as their main food (Bhattacharjee *et al*., 2002; Fresco, 2005) and it is a source of carbohydrates, proteins and vitamins which are important to the human health (Kennedy and Burlingame, 2003). In addition, rice is also rich in many important phytochemicals including phenolic compounds, niacin, riboflavin, and flavonoids (Isaac *et al*., 2012). Flavonoid compounds have been reported to possess antioxidant efficacy and inhibit the occurrence of various diseases (Adom and Liu, 2002; Hu *et al*, 2003; Dykes and Rooney, 2007).

Flavonoids are the most ubiquitous group of plant secondary metabolites (Prasain *et al*., 2004). Flavonoids are phenolic compounds that generally consist of two aromatic rings linked by three carbons that become part of a heterocyclic ring (Hosoda *et al*., 2018). They are divided into several subclasses, which include anthocyanins, flavanols, flavanones, flavonols, flavones and isoflavones (Khan *et al*., 2012). Flavonoids have strong antioxidant activity that interferes with the generation and multiplication of free radicals, including anti-inflammatory activities, antibacterial, antifungal and antivirus. Moreover, many studies have found that flavonoids could inhibit the activity of the tyrosinase enzyme which can help reduce the production of melanin pigment from being stimulated by UV rays (Panche *et al*., 2016). Flavonoids are important substances in the seed colour of plants and are compounds have antioxidant properties, which are the compound in rice (Tian *et al*., 2004).

Therefore, the objective was to examine the flavonoid compounds in ten varieties of Thai white rice landrace. The results of this study can provide rice farmers or the food

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industry with new opportunities to promote the production of rice or rice products. Furthermore, it is important genetic background information for breeders to improve rice varieties.

Materials and methods

The experiments were performed in Complete Randomized Design (CRD) with three replicates. Ten Thai white rice landraces were provided by Sakon-nakhon Rice Research Center, Sakon-Nakhon, Thailand. The germplasm rice samples included G. S. No. 528, G. S. No. 1531, G. S. No. 18018, Jasmine rice, G. S. No. 21717, G. S. No. 22208, G. S. No. 22211, G. S. No. 22212, G. S. No. 23207, and G. S. No. 23208. (Figure 1).

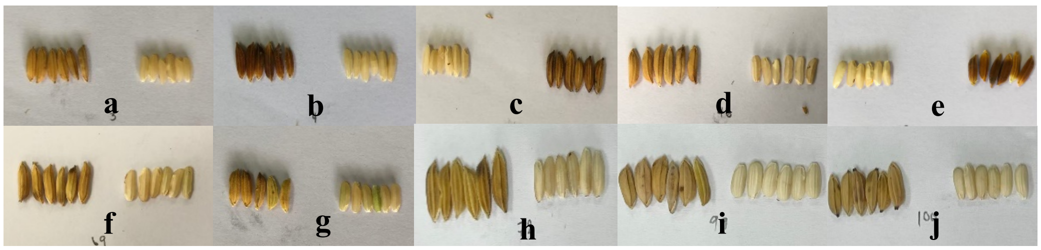

Figure 1. Thai White Rice Landrace used in the study **(a)** G. S. No. 528, **(b)** G. S. No. 1531, **(c)** G. S. No. 18018, **(d)** Jasmine rice, **(e)** G. S. No. 21717, **(f)** G. S. No. 22208, **(g)** G. S. No. 22211, **(h)** G. S. No. 22212, **(i)** G. S. No. 23207 and **(j)** G. S. No. 23208.

Sample extraction

The husk of the rice was removed and the whole rice of each accession was powdered by. The rice powder was extracted with aqueous-acidic ethanol to obtain the total flavonoid with minor modification (Arifin *et al*., 2021). One hundred mg of the rice powder was mixed with 1 ml 70 % ethanol (containing 0.1 % acetic acid) at 25 °C for 48 hours using a mini–Rotator ACR-100. The sample was then centrifuged at 15,000 g for 10 min at 4 °C and the supernatant was used for analysis. Three replicates of each rice varieties were used in each of these assays.

Total flavonoids

The total flavonoid content in each rice sample was determined by the aluminum nitrate nonahydrate colorimetric assay with slight modification (Arifin *et al*., 2021). The experiments were performed in triplicates in 96-well microtiter plates with 3 replicates of each rice sample. The reaction mixture was prepared by mixing 4.3 mL of 80 % ethanol, 0.1 mL of 10 % aluminum nitrate nonahydrate, and 0.1 mL of 1 mol L^{-1} potassium acetate. A quercetin standard solution and sample (20 µl) were placed in each well followed by adding 180 µL of the aluminum nitrate nonahydrate mixture. The mixture was incubated for 40 min, after which the absorbance at 415 nm was measured using a microplate reader Synergy H1 (Biotek, USA). Total flavonoid content was calculated using the quercetin standard curve and expressed as mg quercetin equivalent per 100 g (mg QE 100 g^{-1}).

Statistical analysis

The mean of each rice cultivar was compared using analysis of variance, (ANOVA) using R-stat version 4.3.0 (R Core Team, 2022). Group means were compared using Fisher's Least Significant Difference (LSD) test.

Results

Total flavonoid

The total flavonoid content in ten Thai white rice landraces ranged from 252.44 to 514.66 mg quercetin equivalents 100 g^{-1} (Table 1). There was a significant difference statistically ($p \leq 0.05$). The lowest total flavonoid content was present in G. S. No. 1531 (252.44 ± 33.55 mg QE 100 g^{-1}). The highest total flavonoid content was found in G.S. No. 21717 (514.67 ± 100.64 mg QE100g^{-1}).

Table 1. Total flavonoid content of 10 Thai White Rice Landrace

Germplasm	TFC (mg QE 100 g^{-1})
G. S. No. 528	283.56^{b} ± 53.89
G. S. No. 1531	252.44^{b} ± 33.55
G. S. No. 18018	465.78^{ab} ± 100.13
Jasmine rice	363.56^{ab} ± 88.77
G. S. No. 21717	514.67^{a} ± 100.64
G. S. No. 22208	258.12^{b} ± 32.26
G. S. No. 22211	409.33^{ab} ± 46.18
G. S. No. 2212	347.11^{ab} ± 130.87
G. S. No. 23207	396.00^{ab} ± 40.00
G. S. No. 23208	373.78^{ab} ± 30.79

Data are means of triplicate measurements ± standard deviation. Different letters mean significant differences ($p \leq 0.05$).

Discussion

Flavonoids have the capacity to act as antioxidants. In this study, significant differences between in ten germplasm of Thai white rice landrace were observed for total flavonoid content. G. S. No. 21717 shows the highest total flavonoid content. The total flavonoid content of G. S. No. 21717 was two-fold a higher than that of G. S. No. 1531 (Table 1). This is possibly due to the difference of pericarp; G. S. No. 21717 is an ivory rice pericarp, while G. S. No. 1531 is a regular white rice pericarp (Figure 1). Previously, in the study for the colour of the rice pericarp, Ghasemzadeh *et al*. (2018) suggested that the red and purple rice showed higher contents of quercetin, apigenin, catechin, luteolin and myricetin than the white rice. The results of this study were consistent with those reported in studies by Akiri *et al*. (2010); the total flavonoid content of four rice varieties ranged from 1.68-8.5 mg quercetin equivalent g^{-1} rice. Pintusirn *et al*. (2011) also reported that the range of total flavonoid in Dawk Mali 105 white rice was 26.01 mg rutin hydrate g^{-1} rice extract, which was similar with the results of Venkatesh *et al*. (2018). They have studied flavonoid content of ten rice and found that the content was ranged from 2.20 ± 0.11 to 7.18 ± 0.52 mg 100 g^{-1} rice extract. The previous studies have different ranges of flavonoid content, suggesting the dissimilarity in rice varieties. The content of phytochemicals and active substances in rice often varies with the varieties (Gong *et al*., 2020; Chan *et al*., 2022).

In conclusion, the finding suggested that rice from ten Thai white rice landrace has significant amounts of flavonoid content and G.S. no 21717 shows the highest flavonoid. The results could be used as information for breeding programs and provide rice producers with new opportunities to promote the production of rice with enhanced levels of flavonoids.

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References

Adom, K. K. and Liu, R. H. (2002). Antioxidant activity of grains. Journal of Agricultural and Food Chemistry, 50:6182-6187.

Akiri, R., Reddy, G. S., Babu, P. P. and Reddy, (2010). The antioxidant and antiproliferative activities of methanolic extracts from Njavara rice bran. BMC Complementary and Alternative Medicine, 10:1-9.

Arifin, H., Hashiguchi, T., Nagahama, K., Hashiguchi, M., Muguerza, M., Sakakibara, Y., Tanaka, H. and Akashi, R. (2021). Varietal difference in flavonoid and antioident activity in Japanese soybean accession. Biotechnology and Biochemistry, 85:916-922.

Bhattacharjee, P., Singhal, R. S. and Kulkarni, P. R. (2002). Basmati rice: A review. International Journal of Food Science & Technology, 37:1-12.

Chan, Y., Wang, Z., Wang, C., Li, H., Huang, D. and Zhou, D. (2022). Comparisons of metabolic profiles for carbohydrates, amino acid, lipids, fragrance, and flavones during grain development in *indica* rice cultivars. Rice science, 29:155-165.

Dykes, L. and Rooney, L.W. (2007). Phenolic compounds in cereal grains and their health benefits. Cereal Food World, 52:105-111.

Fresco, L. (2005). Rice is life. Journal of food composition and analysis, 18:249-253.

Ghasemzadeh, A., Karbalaii, M. T., jaafar, H. Z. E. and Rahmat, A. (2018). Phytochemical constituents, antioxidant activity, and antiproliferative properties of black, red, and brown rice bran. Chemistry central journal, 12:1-13.

Gong, R., Huang, D., Chen, Y., Li, H., Huang, D. and Zhou, D. (2020). Comparative metabolomics analysis reveals the variation of eating quality among three high-quality rice cultivars. Molecular Breeding, 40:112-120.

Hosoda, K., Sasahara, H., Matsushita, K., Tamura, Y., Miyaji, M. and Matsuyama, H. (2018). Anthocyanin and proanthocyanidin contents, antioxidant activity, and in situ degradability of black and red rice grains. Asian-Australas Journal Animal Sciences, 31:1213-1220.

Hu, C., Zawistowski, J., Ling, W. and Kitts, D. D. (2003). Black rice (*Oryza sativa* L. indica) pigmented fraction suppresses both reactive oxygen species and nitric oxide in chemical and biological model systems. Journal of agricultural and food chemistry, 51:5271-5277.

Isaac, R. S. R., Nair, A. S., Varghese, E. and Chavali, M. (2012). Phytochemical, antioxidant and nutrient analysis of medicinal rice (*Oryza Sativa* L.) varieties found in South India. Advanced Science Letters, 5:1-5.

Kennedy, G. and Burlingame, B. (2003). Analysis of food composition data on rice from a plant genetic resources perspective. Food Chemistry, 80:589-596.

Khan, B. A., Akhtar, N., Rasul, A., Khan, H., Murtaza, G., Ali, A. and Mahmood, T. (2012). Human skin, aging and antioxidants. Journal of Medicinal Plants Research, 6:1-6.

Panche, A., Diwan, A. and Chandra, S. (2016). Flavonoids: an overview. Journal of nutritional science, 5:1-15

Pintusirn, H., Srisawat, U., Itharat, A. and Lerdvuthisopon, N. (2011). Phenolic and Flavonoid Contents of Thai Rice Extracts and Their Correlation with Antioxidant Activities using Chemical and Cell Assays. Journal Med Assoc Thai, 94:122-130.

Tian, S., Nakamura, K. and Kayahara, H. (2004). Analysis of phenolic compounds in white rice, brown rice and germinated brown rice. Journal of Agricultural and Food Chemistry, 52:4808-4813.

Venkatesh, R., Sivakumar, P. H., Marichamy, I. and Sundararajan, S. (2018). Phytonutrients analysis in ten popular traditional Indian rice landraces (*Oryza sativa* L.). Journal of Food Measurement and Characterization, 12:2598-2606.