PROCEEDINGS OF

THE 10th INTERNATIONAL CONFERENCE ON INTEGRATION OF SCIENCE AND TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT 2022 (10th ICIST)

"Soil, Water and Environmental Conservation, Biological Diversity, Food Security/Safety and Sustainable Agriculture"

King Mongkut's Institute of Technology Ladkrabang

Bangkok, Thailand

November 25, 2022

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Effects of varying concentrations of organically sourced nutrients on Vitamin C, and yield of Okra (*Abelmoschus esculentus*)

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Abstract Farmers are heavily and used to be solely reliant on synthetic fertilizers for production. Consequently, problems such as deteriorating soil fertility and decreasing yields become a- production issue in the long run. To mitigate the problems caused by the unsustainable use of these synthetic resources, organic production of crops has been promoted. Effects of using organic nutrient sources such as biochar, fish amino acid (FAA) and vermicompost on the vitamin C content and yield of okra were investigated. Biochar served as a soil amendment, FAA acted as an organic plant supplement, and vermicompost served as an organic fertilizer and soil conditioner. Sixteen treatments were used in this research. Abundant amounts of vitamin C were found in T12 (1FAA+1VC), which was 111.08 mg/100g, followed by T10 (1BC+1VC) with 76.91 mg/100g, and T8 (1BC+1FAA) was 46.8 mg/100g. Significantly lowest vitamin C was found in T2 (1BC), which only 6.97 mg/100g. The highest number of fruits and fresh fruit yield in T11 (2BC+2VC) was highly significant with the control and other treatments such as T3, T4, T5, T6, T7,T8, T9, T10, T12, and T13.

Keywords: Biochar, Fish amino acid, Organic farming, Vermicompost

Introduction

The use of chemically produced fertilizers and pesticides in modern agriculture systems has drastically increased in most agricultural countries. According to World Data Atlas (2019), as of 2018, Hong Kong (3,573.9 kg/ha) ranks first in fertilizer consumption globally, followed by Malaysia, Bahrain, New Zealand, and Ireland. The Philippines ranks fiftieth (50th) in the world's fertilizer consumption with 169.0 kg ha^{-1}. Farmers tend to use synthetic fertilizers because it has readily available nutrients for crop uptake (Sabry, 2015).

Although these conventional practices have promised an increase in crop yields, persistent and excessive application of these chemicals caused severe soil and environmental degradation. Chemical fertilizer's residual toxicity can cause eutrophication and groundwater pollution through leaching and surface runoff. It also has a significant contribution to greenhouse gas emissions that worsens global warming. To mitigate the problems caused by the unsustainable use of these synthetic resources, organic production of crops has been promoted. The aim of organic agriculture is to alleviate the damage and destruction caused by the injudicious use of chemical fertilizers and pesticides and correct the unwanted results of these wrong production practices with the help of biological resources and methods. It was reported that organic production continues to grow worldwide due to human awareness, the demand of consumers, and its higher market value (Loef and Walach, 2012). Many studies have proven the increased efficiency of organic farming in producing yields close to the average produce of conventional production (Yang *et al*., 2014). Based on the experiment conducted by

Schrama *et al*. (2017), they have concluded that in a matter of time, a close yield gap between organic and conventional farming can be attained.

In this scenario, there is a need to identify cost-effective and eco-friendly organic nutrient resources that will mainly help farmers obtain higher yields and income. These organic fertilizers can be made using agricultural wastes such as animal manure and plant and animal tissues as the main ingredient.

Biochar is one of the alternative soil amendments that has gained popularity in the agriculture sector because of the promising benefits in improving soil quality for crops The International Biochar Initiative (2012) defines biochar as “a solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment.” The technique used in processing biochar is called pyrolysis or charring, which is similar to making charcoal, using a very high temperature of at least 250 0C (Lehmann and Joseph, 2009). Among the agricultural wastes commonly used as feedstocks are corn stovers, straw from rice, corn or wheat, animal manure, coconut husk, waterlily, and sugar bagasse.

Another effective organic input used as a plant supplement is fish amino acid (FAA). Studies have been suggesting its efficiency in enhancing crop growth, especially during the vegetative stage. It can be produced with the use of fish wastes as its primary ingredient. Fish amino acid contains abundant amounts of nutrients and various amino acids that constitute a high nitrogen source for plants; thus, it is recommended to apply to leafy vegetables to increase yield continuously. The application of FAA also increased yield and improved morphological characteristics of crops (Krishnamoorthy *et al*., 2018).

Vermicompost is considered a soil amendment and organic fertilizer. Vermicomposting was defined by Chung (2011) as “a bio-oxidative, mesophilic natural decomposition process in which earthworms and microorganisms synergistically mineralize organic waste substrates and convert them into the nutrient-rich organic matter,” wherein in this process two useful products are gained, namely vermicompost and earthworms. For the past few decades, vermicomposting has gained popularity globally due to its technical simplicity and effectiveness (Abbassi, 2018). A wide range of wastes can be used as raw material in composting, such as animal wastes, agricultural wastes, industrial wastes, and municipal wastes. Vermicompost is used as a soil conditioner and has several advantages over chemical fertilizers used for crops. It contains nutrients in plant-available form, growth hormones, and humic acid and is extensively used at a large scale in organic farming as organic fertilizer (Edwards, 2011). Several authors have conducted researches and found out that the use of vermicompost may improve seed germination, vegetative growth of crops, and yield without compromising the health of the soil.

This study sought to determine the effect of using organic amendments such as biochar, produced from the pyrolysis of carabao dung, FAA, used as the organic supplement, and vermicompost as an organic fertilizer, and soil conditioner in the production of okra was investigated. Moreover, this research determined the influence of different rates of biochar, FAA, and vermicompost or its combination on the vitamin C and yield of okra. The study also sought to characterize the prevailing weather condition in the experimental site, and to formulate recommendations on the combinations of the organic nutrient sources suitable for okra to provide optimum yield.

Materials and methods

Time and place of study

The study was conducted at Brgy. Sto. Domingo Bay, Laguna, approximately 14.1770, 121.2677, the elevation of the coordinates were estimated at 9.4 meters above mean sea level. The experiment started last October 2020 to March 2021.

Analysis of organic nutrient sources

Samples of biochar, vermicompost and FAA were brought to the Regional Soils Laboratory, Region IV-A, Marawoy Lipa City Batangas, for the analysis of pH, total nitrogen, total phosphorus, and total potassium content.

Experimental design and treatments

The study carried out using a completely randomized design (CRD). There were sixteen (16) treatments (Table 1with three replications.

Table 1. Treatments for the experiment

Treatment Code	**Treatment Description**
T0 - Control	Unfertilized soil
T1 – SF	14-14-14 complete synthetic fertilizer
T2 – 1BC	8 t/ha biochar
T3 – 2BC	16 t/ha biochar
T4 – 1FAA	10,000 ppm fish amino acid
T5 – 2FAA	20,000 ppm fish amino acid
T6 – 1VC	4 t/ha vermicompost
T7 – 2VC	8 t/ha vermicompost
T8 - 1BC+1FAA	8 t/ha biochar + 10,000 ppm fish amino acid
T9 – 2BC+2FAA	16 t/ha biochar + 20,000 ppm fish amino acid
T10 – 1BC+1VC	8 t/ha biochar + 4 t/ha vermicompost
T11– 2BC+2VC	16 t/ha biochar + 8 t/ha vermicompost
T12- 1FAA+1VC	10,000 ppm fish amino acid + 4 t/ha vermicompost
T13- 2FAA+2VC	20,000 ppm fish amino acid + 8 t/ha vermicompost
T14– 1BC+1FAA+1VC	8 t/ha biochar + 10,000 ppm fish amino acid + 4 t/ha vermicompost
T15- 2BC+2FAA+2VC	16 t/ha biochar + 20,000 ppm fish amino acid + 8 t/ha vermicompost

The application rate of synthetic fertilizer was based on the fertilizer recommendation rates of the Department of Agriculture (2017), which were two to three bags per hectare of 14-14-14 complete fertilizer or equivalent to 150 kilograms.

Biochar application rates were set up based on the previous field experiment on okra conducted by Akpa *et al*. (2019) They have recommended using cow dung and biochar at 12 t/ha and 8 t/ha for effective growth and development of okra. Based on these findings, the present study applied 8t/ha and 16 t/ha of biochar. It was computed and applied at 24 g and 48 g per pot with 6 kg of unfertilized soil, respectively.

The fish amino acid (FAA) application rates were based on the study conducted by Krishnamoorthy *et al*. (2016), wherein they applied FAA at a rate of 2% or 20,000 ppm. The results of their study showed a highly positive impact on the growth, development, and yield of okra and improved soil fertility, as the solution has an increased microbial population. Based on these findings, FAA was applied in 10,000 ppm and 20,000 ppm respectively via foliar spray, with seven days intervals.

The levels of vermicompost that were applied were based on the study conducted by Oroka (2016), which has a recommended rate of 4 t/ha. Their research concluded that vermicompost alone and in combination with NPK significantly increased the okra's morphological characteristics. Hence, the amount of vermicompost applied in this study was 4 t/ha and 8 t/ha, which is 12 g and 24 g, as computed and applied in each pot.

Potting and fertilizer application

A thoroughly mixed soil of 6 kg was potted using a polyethylene bag size of 6 x 12 inches. Biochar was applied only before planting, while vermicompost was applied before planting, three and five weeks after sowing. Fish amino acid was used as a foliar spray every seven days before flowering.

Meteorological data

The weekly weather information data such as minimum and maximum air temperature, average relative humidity, and total rainfall were obtained from the National Agrometeorological Station, University of the Philippines, Los Banos.

Data collection and parameters

Vitamin-C content (mg/100g)

Samples of okra fruits were brought to Optimal Laboratories Inc. for the analysis of vitamin C content. The vitamin C content of okra fruits was measured using the titrimetric method.

Number of fruits per hectare basis

After harvest, okra fruits per plant were manually counted and recorded. Then, number of fruits were calculated per hectare basis.

Fresh fruit yield of okra (kg ha^{-1})

After harvest, the yield was determined by getting the biomass of the fresh fruits of okra per treatment and replicates. It was done with the use of a digital weighing scale. The average yield per treatment was calculated and compared to determine which treatment can provide the highest yields. The yield per hectare was determined by getting the yield taken from each pot from the first to the last harvest, and it was computed using the formula shown below.

$$\text{Yield per hectare}\left(\text{kg ha}^{-1}\right)=\frac{\text{Yield per pot (g)*10000 m}^2}{\text{1000g per kg*area harvested}\left(9\text{m}^2\right)}$$

Statistical analysis

One Way Analysis of Variance (ANOVA) was used to test the hypothesis of the data, which satisfied the assumption of normality and equality of variances. Otherwise, Kruskal Wallis was used, which is a non-parametric test. Treatment means were compared using Least Significant Difference (LSD) (Gomez & Gomez, 1984). Moreover, SPSS version 26.0 was used to generate the test statistics indicated.

Results

Properties of the organic nutrient sources

The organic nutrient sources applied were subjected to analysis to determine the nutrient content and how many minerals were present to improve the growth and development of okra (Table 2). It was observed that biochar (8.36) has the highest pH level followed by vermicompost (8.11) which are both strongly alkaline, while fish amino acid (FAA) has the lowest (4.23) and is considered to have an extremely acidic pH level. The total nitrogen content of vermicompost was the highest with 2.423%, seconded by biochar with 1.663%, and FAA being the lowest with 0.655%. In terms of total phosphorus, content biochar gained the highest (2.594%), followed by vermicompost (1.362%), and the lowest was FAA (0.504%). The vermicompost has 1.106% total potassium content, FAA has 1.062%, and the carabao dung biochar has 0.973%.

Table 2. Biochar, fish amino acid, and vermicompost characteristics

Organic Nutrient Sources	Moisture Content (%)	pH	Total Nitrogen (N) %	Total Phosphorus (P_2O_5) %	Total Potassium (K_2O) %
Biochar	23.63	8.36	1.663	2.594	0.973
Vermicompost	73.87	8.11	2.423	1.362	1.106
Fish amino acid		4.23	0.655	0.504	1.062

Meteorological data

Based on the gathered secondary data (Table 3), the cumulative amount of rainfall for the entire duration of the experiment was 336.9 mm, had an average relative humidity of 86.4%, and had an average maximum and minimum temperature of 29.4 ^{0}C and 23.0 ^{0}C, respectively. The seeds of okra germinate in approximately warm soils, and they cannot germinate at a temperature below 16 ^{0}C. Okra grows optimally in a long, warm season, with an average monthly temperature of 20-30 ^{0}C, which favors the growth, flowering, and fruiting development of the crop (Department of Agriculture, 2017). Therefore, the climate on the duration of the experiment favored the requirement of okra to grow optimally, and because of the ample amount of precipitation, manual irrigation was minimized.

Table 3. The total weekly rainfall, average weekly maximum and minimum temperature, and relative humidity during the experimental period (December 13, 2020 – March 01, 2021)

			Temperature (^{O}C)		
	Week	**Rainfall (mm)**	Maximum	Minimum	**Relative Humidity (%)**
1	Dec. 13-19	70.8	29.8	23.8	85.4
2	Dec. 20-26	57.9	29.8	23.9	88.9
3	Dec. 27 - Jan. 02	31.6	28.5	23.2	90.6
4	Jan. 03-09	34.9	29.1	23.0	86.4
5	Jan. 10-16	0.0	27.7	22.8	79.0
6	Jan. 17-23	31.6	29.2	23.8	90.6
7	Jan. 24-30	15.0	29.9	22.6	81.9
8	Jan.31-Feb. 06	1.3	28.9	22.7	79.9
9	Feb. 07-13	52.9	29.4	23.4	86.3
10	Feb. 14-20	3.5	28.8	21.0	78.3
11	Feb. 21-27	33.7	29.7	22.7	87.6
12	Feb 28-Mar. 06	3.7	31.3	23.0	80.4
	Total	336.9	352.2	275.9	1015.1
	Mean	28.1	29.4	23.0	84.6

Vitamin C content

Vitamin C is just one of the abundant nutrients found in okra. This vitamin is required by our bodies to form blood vessels, cartilage, muscles, collagen in bonds and vital in the healing process of our bodies. Also, it serves as an antioxidant and helps protect the cells against the harmful effects of free radicals. Fruits of okra in this study showed a significant difference in vitamin C content upon applying the treatments (Table 4). Abundant amounts of vitamin C were found in T12 (1FAA+1VC), which is 111.08 mg/100g, followed by T10 (1BC+1VC) with 76.91 mg/100g, and T8 (1BC+1FAA), having 46.8 mg/100g. Significantly lowest vitamin C was found in T2 (1BC), which only 6.97 mg/100g.

Number of fruits per hectare basis

The number of fruits increased with the application of the treatments. Based on the statistical analysis, there were significant differences among the treatments (Table 5). The highest number of fruits obtained (8,272) was in T11 (2BC+2VC), which is highly significant with the control (2,099) and other treatments such as T3, T4, T5, T6, T7,T8, T9, T10, T12, and T13. The rest of the treatments has increased the number of fruits but don’t have significant differences.

Table 4. Vitamin C content of okra

Treatment	Vitamin C Content (mg/100g)
T0 - Control	8.11 h
T1 - SF	13.92 ef
T2 - 1BC	6.97 h
T3 - 2BC	13.31 efg
T4 - 1FAA	10.42 fgh
T5 - 2FAA	10.40 fgh
T6 - 1VC	9.25 gh
T7 - 2VC	9.24 gh
T8 - 1BC+1FAA	46.80 c
T9 - 2BC+2FAA	27.08 d
T10 - 1BC+1VC	76.91 b
T11 - 2BC+2VC	22.83 d
T12 - 1FAA+1VC	111.08 a
T13 - 2 FAA+2VC	13.54 efg
T14 - 1BC+1FAA+1VC	10.46 fgh
T15 - 2BC+2FAA+2VC	17.21 e
Standard Deviation	28.65
c.v. (%)	10.79

Means within a column with similar letter(s) are not significantly different at 5% level by Least Significant Difference

Table 5. Effect of different organic nutrient sources on fresh fruit yield and number of fruits of okra

Treatments	Yield (kg ha^{-1})	Number of fruits
T0 - Control	17.67 g	2,099 g
T1 - SF	65.65 ab	7,654 ab
T2 - 1BC	60.85 abcd	6,296 abcd
T3 - 2BC	40.41 cdefg	4,938 cdef
T4 - 1FAA	35.84 efg	3,580 efg
T5 - 2FAA	46.15 bcdef	5,185 cde
T6 - 1VC	38.86 defg	5,185 cde
T7 - 2VC	30.35 fg	4,074 defg
T8 - 1BC+1FAA	50.78 bcdef	5,679 bcde
T9 - 2BC+2FAA	46.48 bcdef	5,432 bcde
T10 - 1BC+1VC	30.11 fg	5,432 bcde
T11 - 2BC+2VC	78.61 a	8,272 a
T12 - 1FAA+1VC	29.75 fg	3,704 efg
T13 - 2 FAA+2VC	21.99 g	2,840 fg
T14 - 1BC+1FAA+1VC	54.09 bcde	6,173 abcd
T15 - 2BC+2FAA+2VC	62.88 abc	6,914 abc
Standard Deviation	20.29	
c.v. (%)	31.74	

Means within a column with similar letter(s) are not significantly different at 5% level by Least Significant Difference

Fresh fruit yield (kg ha^{-1})

The study results showed a significant increase in the yield of okra with the application of different organic nutrient sources compared to the control (Table 5). A significantly highest yield (78.61 kg ha^{-1}) was obtained in T11 (2BC+2VC), while the lowest (17.67 kg ha^{-1}) was observed in T0 (control. This shows that the combination of 16t/ha carabao-dung biochar and 8t/ha vermicompost can improve the crop yield more than those applied with synthetic fertilizers.

Discussion

Vitamin C content

Okra is a powerhouse of important nutrients. It is a source of calories (4550Kcal/kg) for human consumption (Edet and Etim, 2010), contains 86% water, 2.2% protein, 10% carbohydrate, 0.2% fat, and vitamins A 14% of the daily value (DV), 14% B6 of the DV, and 26% C of the DV (Christo and Onus, 2005). Vitamin C or ascorbic acid is a water soluble vitamin and has an excellent source of antioxidant properties (Arkoub-djermoune *et al*., 2016). The recommended levels of vitamin C for each body is 16 to 29 mg and okra has about 30% of it (Gemede *et al*., 2015).

The purpose of determining the vitamin C content of okra in this study was to contribute information that okra can be a good source of the said nutrients. Having said that, it could be an alternative or an addition to other vitamin C source crops such citrus fruits. Since okra is not commonly known to be a high source of this nutrients.

Highest vitamin C was obtained in treatments with vermicompost. Basnet et al. (2017) reported the significantly highest vitamin C content of cauliflower when applied with vermicompost. An increase in vitamin C caused by vermicompost could be due to the essential elements in it that improved the synthesis of vitamin C. Furthermore, Abo Sedera *et al*. (2010) reported that the foliar application of amino acid significantly increased some of the macronutrients, total sugars and the vitamin C content of strawberry fruits compared to control-treated crops.

It was also observed that the okra applied with synthetic fertilizer has significantly lower vitamin C than those applied with organic nutrients sources (T8, T9, T10, T11, and T12). Hamouz *et al*. (2009) reported that increased levels of nitrogen fertilization negatively affected vitamin C production, while fertilization of higher concentrations of potassium and magnesium in potatoes has no effect. Benbrook *et al*. (2008) suggested that plants trigger activity of the biosynthetic pathway of vitamin C when the reproductive cycle of the plant has started. In conventional farming with periodic excess of nitrogen, a deter in the production of vitamin C maybe caused by prolonged vegetative cycle (Salandanan *et al*., 2009). According to Carl & Winter (2006), significantly higher contents of vitamin C, Mg, P, and Fe were found in organic crops, and it has lower amounts of some heavy metals and significantly decreased nitrates than conventional crops. Santos *et al*. (2019), also concluded that the application of organic fertilizer (30t/ha) significantly increased the vitamin C content of okra by 52% compared to the control. Significant increase in vitamin C in hot peppers under organic management was also observed in the study conducted by Premamali *et al*. (2019).

The production of vitamin C depends primarily on the metabolism of plant, and water and nutrient supply of the soil, although the influence of soil microbes on assisting the production of compounds such as ascorbic acid in plants cannot be underestimated (Premamali *et al*., 2019). Hence, the application of synthetic fertilizer and insufficient nutrient supply may result to unsatisfactory vitamin C production. This supports the results of this study since highest vitamin C content was observed in treatments with lower concentrations of mixed organic nutrient sources (T12, T10, and T8 and these treatments could have the sufficient amount of nitrogen for vitamin C production), while lower contents were observed in treatments with combined higher rates of the organic nutrient sources (T9, T11, T13, T14 and T15 and these treatments could have the excessive amounts of nitrogen that triggered the reduction of vitamin C production). Lin *et al*. (2004), found out that only high quantities of nitrogen fertilization leads to significant reduction of vitamin C content and yield of tuber crops. Furthermore, lower amounts of vitamin C was also observed in control and treatments applied with single nutrient source in different rates (T0, T1, T2, T3, T4, T5, T6, and T7 and these treatments could have insufficient amount of nitrogen the caused the decreased vitamin C production).

In literature, there are limited studies investigating the nutrient content of okra plants influenced by the application of different organic nutrient sources. This research could be a basis for future studies in aiming for quality production of okra in the Philippines. To support the exportation since Philippines starts to export okra fruits in Korea (Department of Agriculture, 2021).

Number of fruits per hectare basis

The combined application of biochar and vermicompost in increased amounts produced the highest number of fruits per hectare. A similar result was reported by Ebrahimi *et al*. (2021), wherein the applied mixture of biochar and vermicompost significantly increased the number of eggplant fruits, and he also reported that these organic amendments cause the highest early yields.

Fresh fruit yield (kg ha^{-1})

Okra started to flower at 42 DAP, and fruits were first harvested at 50 DAP, however, based on literature expected harvest stage of okra is at 62 DAP. Early crop yield is a relevant factor in production since farmers prefer early yielding varieties of vegetables to gain a higher price of produce to compensate for the production cost. Ebrahimi *et al*. (2021) reported that biochar alone or combined with vermicompost resulted in the highest early yield of eggplant and increased its plant growth and yield.

Treatments applied with the combination of higher amounts of biochar and vermicompost (T11 and T15) obtained a significantly higher fresh fruit yield and the number of fruits than the other treatments. Also, crops treated with inorganic fertilizer resulted in significantly higher yields. This proves that the application of biochar and vermicompost can help in improving the yield of okra. Wu *et al.* (2018) reported the synergistic influence of biochar on the functioning of vermicompost, specifically in promoting rice yield. Furthermore, El-Aal *et al.* (2010) reported that the use of different bio-stimulants improved all the morphological characteristics of eggplant, including plant length, the number of leaves and branches, fresh and dry weight of leaves, and yield compared to non-treated plants. The increased yield was manifested with fish amino acid (FAA) application, but there were no observed significant differences on crops applied with FAA alone and in combination with the other organic amendments. Relative increment in yield with foliar application of FAA compared to the control may be due to the rapid absorption of nitrogen, phosphorus, potassium, and other micronutrients present in FAA (Priyanka *et al.*, 2019). It would have enhanced the metabolic activities and cell division, leading to increased plant height, number of leaves, and chlorophyll content that subsequently improved the photosynthetic rate, leading to yield attributes. Abbasi *et al.* (2003) obtained the same results; their tomato yield was increased by weekly sprays of fish emulsion but didn't show any significant difference. Some periods of the experiment did not increase the total tomato yield, the same as the other organic spray treatments. Priyanka *et al*. (2019) also suggested that foliar spray of egg amino acid and fish amino acid alone did not provide an adequate amount of nutrients for crop growth, resulting in lower grain yield in rice. Hence it was recommended to be applied alongside the recommended dose of fertilizer for better results.

This suggests that these organic amendments enhance the plant growth parameters and yield by increasing the soil organic matter content, enhancing nutrient uptake, and maintaining soil moisture (Prasad *et al*., 2018). According to Ebrahimi *et al.* (2021), biochar and vermicompost contains substantial amounts of N, P, Ca, Mg, which eventually lead to enhanced plant growth parameters and yield. Biochar increases nutrient availability and improves the physical properties of the soil, which includes the reduced bulk density that ultimately leads to enhanced plant growth (Chan *et al.*, 2008 & Wildeatt *et al.*, 2014). Treatments combined with biochar, FAA, and vermicompost also increased the CEC. which improves the plant/s access to nutrients leading to better growth and yield of crops.

This short-term pot experiment demonstrated that the application of biochar, fish amino acid (FAA) and vermicompost could provide a solution in enhancing soil fertility that was reflected in best plant growth and yield. Results also show better effects of using these organic nutrient sources than applying complete synthetic fertilizer (14-14-14) in the soil.

The conclusion drawn suggests that the organic nutrients sources applied to the soil specifically the mixed treatments of 16t/ha biochar, 8t/ha vermicompost and 20,000 ppm FAA (T11 and T15) can enhance the overall growth and yield attributes of okra even better with the use of complete fertilizers. The highest amounts of vitamin C were observed in T12 (1FAA+1VC) and T10 91BC+1VC), which were both applied with 4t/ha vermicompost. The fresh fruit yield and number of fruits was significantly highest in T11 (2BC+2VC).

This study can also prove the synergistic effect of biochar, fish amino acid, and vermicompost on growing crops. Moreover, the application of each organic nutrient sources alone even in higher concentrations cannot supply the nutrient requirement of crops that leads to reduced growth, and development, nutrient uptake, and yield.

Since the experiment results showed positive effects in improving the soil used that was initially analyzed as suboptimal for plant growth, this may suggest sustainable, cost-effective agriculture with economic and environmental benefits on the croplands.

However, the different response of plants to the FAA, biochar, and vermicompost utilized in the experiment suggests the further investigation, as well as field trials, are needed to understand better the effects of type and rate of organic amendments able to enhance the productivity of crops while efficiently using the resources.

The mixes of carabao dung biochar and vermicompost used in the study had the potential to replace synthetic fertilizers to grow okra plants and led to increased growth and yield. The treatment of 16t/ha and 8t/ha biochar and vermicompost, respectively used in the experiment, could be recommended as the suitable organic amendment to grow plants. This study is relevant for the future use of the combination of biochar and vermicompost in the pot or container culture for greenhouse or nursery plant production and also in the further study for field production to provide an environmentally friendly and sustainable way to substitute conventional agriculture. Also, to add value or utilize the agriculture wastes used in the production of biochar, vermicompost, and fish amino acid.

Acknowledgements

The author would like to offer particular thanks to DOST-ASTHRDP-NSC, for the scholarship grant which provided the financial support. This study would not be possible without this scholarship program.

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Factors affecting farmers' adoption of *Trichoderma* spp. application to control plant diseases in Chachoengsao Province, Thailand

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Abstract *Trichoderma* spp. has been widely used as antagonistic fungal agents against several pests as well as plant growth-promoting fungus and plant diseases. Therefore, this study aimed to investigate the socio-economic characteristics, knowledge, attitude and adoption of farmers who apply *Trichoderma* spp., and to identify factors affecting farmers' adoption of *Trichoderma* spp. application to control plant diseases in Chachoengsao province, Thailand. A structured interview was used to collect data from 83 farmers who had registered with the Chachoengsao Provincial Agriculture Office (CPAO) and also a member of the *Trichoderma* biological control user group. Descriptive statistics and multiple regression analysis were employed to analyze the data. The results revealed that most respondents were rice farmers (61.45%). The annual income of agriculture was an average of 164,148.19 baht and the average non-farm income was 24,626.51 baht, respectively. The average experience of using *Trichoderma* was 2.54 years. Most information about *Trichoderma* application was obtained from Agricultural Extension Officials (AEO) (92.77%) and used for plant disease control in rice farming (57.83%). *Trichoderma* products were used as a leavening agent (produced and propagated by themselves) (62.65%), most received from the District Agricultural Office (DAO) (81.93%). Regarding farmers' knowledge, attitude, and adoption of *Trichoderma*. The farmers had a moderate level of knowledge (48.19%), a high level of attitude (63.85%), and a moderate level of adoption (57.83%), respectively. The regression results pointed out that four factors affected statistically significant: age, educational level, and knowledge were statistically significant ($P<0.01$) while attitude was statistically significant ($P<0.05$). It was also observed that knowledge and attitude were positive and significantly correlated whereas age and educational level were found to be negatively correlated.

Keywords: farmers' adoption, biological control, plant disease, *Trichoderma* spp.

Introduction

The agricultural sector has a significant role in the economic and social growth of Thailand. It's a production base contributing to added value for trade and exports as well as the development of the world's major food production source. Due to the geographical and climatic suitability, production and application knowledge, modified agricultural products, and strong and diverse food culture, Thailand has become the world's major exporting food producing country (Ministry of Agriculture and Cooperatives, 2016).

Thailand's agricultural products are not only limited to production for domestic consumption but various products are also demanded and sold in foreign countries. Consumers demand products enriched with quality, hygiene, and safe. Therefore, modern technology is necessarily applied in the production process to meet the needs of consumers as well as to reduce the use of labor and shorten the production cycle time (Suteera *et al.*, 2012).

Based on the above reasons, to meet the needs and production to ensure quality with the maximum quantity, various chemicals have been introduced to play an increasingly significant role in the agricultural sector of Thailand. According to a report from the Office of Agricultural Economics (2019), it was found that within 11 years (2008-2018), Thailand imported 1,663,780 tons of chemicals such as pesticides and fungicides with a total value of 246,715 million baht, indicating obvious increasing user.

In the agricultural production system, the use of more chemicals and pesticides has resulted in many both positive and negative impacts. For a positive impact, it increased productivity while, for a negative impact, it affected farmers' and consumers' health with the deterioration of natural resources, environment, ecosystems, soil, and water. It also affected the economy, causing an increase in the production cost for farmers due to higher expenses from pesticides and medical expenses from illness.

Consequently from the problem, there have more studies on disease control by biological means have been conducted with the direct use of an antagonistic micro organism. Useful microorganisms are used to control disease and promote plant growth. It was found that *Trichoderma* spp. was an antagonistic microorganism used as an effective biological agent for controlling many plant pathogens (Jiradej *et al.,* 1990; Supaporn *et al.,* 1994). *Trichoderma* spp. is a fungus that could be found every where in the soil, plant debris, animal remains and oraganic matter. It has a fast growth able to produce spores. In addition to direct control of plant diseases, Trichoderma sp. could promote growth and increase the productivity of many plants (Inbar *et al*., 1994; Vidic and Jasnic, 2011). It also induced plant resistance to plant pathogens (Jiradej, 2003; Intana, 2003).

While Chachoengsao Province was a part of the province that has a significant role in economic agriculture. It is the source of food production to feed the people in the region and Bangkok. More than 70 percent of the people in Chachoengsao province make a living in agriculture which generates their main income for them. Famous products of Group Crop that the province is rice, cassava, factory sugar cane, coconut, mango, betel nut, etc. as well as having clear strategies and goals to promote and develop agricultural products to meet safety standards (Office of Agriculture and Cooperatives, Chachoengsao Province. 2018). Because Chachoengsao is a province that aims high income from agricultural both production and exports, so plant disease is an important problem for the farmers. Therefore, chemically was become to the main solution to control plant pathogens. Department of Agricultural Extension (DOAE) has promoted the use of biological substances to control plant pests and pathogens, by supporting leavening agents of fungus, training, produce and propagation for self, especially Trichoderma. in the prevention and elimination of plant diseases to be able to substitute chemicals control since 2016 until the present, with the support of the Chachoengsao Provincial Agriculture Office. From the past promotion of agricultural extension, it was found that some farmers accepted Trichoderma bio substance. They used it to produce non-toxic crops and reduce the cost of chemical. But there are still some farmers, who are unacceptable and still holding on to chemical control such as pesticides and fungicides because They worry about the potential decrease in income if they change their methods, while chemicals still show clear efficacy in the prevention to plant pests and pathogens.

Therefore, this study aimed to study factors affecting the adoption of *Trichoderma* spp. to control plant pathogens for farmers in Chachoengsao Province. The findings would benefit agricultural extension officers and related agencies as a guideline to develop and promote the use of Trichoderma to reduce the use of chemicals for the safe and standardized production of crops with effectiveness.

Materials and methods

The study area

The study was conducted in the Chachoengsao province, eastern region Thailand. (Latitude, Longitude 13°30′N 101°27″E). Chachoengsao has a territory adjacent to Bangkok, Pathum Thani province, Nakhon Nayok province, Prachinburi province, Sa Kaeo province, Chanthaburi province, Chonburi province and Samut Prakan province. There is divided into 11 districts these are further divided into 93 subdistricts and 859 villages.

Chachoengsao is the province that has an important role in agriculture both within trade in the country and for export, so agriculture has become to be the main income of the province. There has an area of approximately 3,344,375 rai. Most of the land use in agricultural land is approximately 2,433,075 rai or equivalent to 72.75% of the total. Digest as an area of in-season rice 625,415 rai, off-season rice 392,074 rai, cassava 211,774 rai, rubber 201,516 rai, mango 24,210.25 rai, coconut 21,651 rai and other agricultural areas. The featured product of Chachoengsao are ‘Nam Dok Mai See Thong Bang Khla Mango’ and ‘Sweet young coconut’.

Population

The population of this study was 83 respondents who registered the farmers with the Chachoengsao Provincial Agriculture Office (CPAO) and were members of the Trichoderma user group. (CPAO, 2020)

Data collection and analysis

The data were collected in the seasonal crop year 20020/2021 by structured interview. The questions covered the socio-demographic background of the respondents and their knowledge, attitudes, and adoption of *Trichoderma* spp. application to control plant diseases. The structured interview was verified for content validity by 3 experts and try-out with 30 who were members of the Trichoderma user group in Samut Prakan province. Testing the reliability of knowledge on the use of *Trichoderma* spp. to control plant diseases used the Kuder-Richardson reliability coefficient (KR-21) with a reliability value of 0.712. (Kuder and Richarson, 1937). The semantic differential scaling methods of adoption on Trichoderma spp. application and attitude towards Trichoderma application were obtained by internal consistency using Cronbach’s alpha with the values of 0.933 and 0.708 respectively (Cronbach, 1951).

The data analysis utilized both descriptive and inferential statistics. Frequencies, percentages, arithmetic means, and standard deviations were used to describe socio-demographics, farmers’ knowledge, attitude, and adoption of Trichoderma application. The multiple regression analysis (MRA) was applied for some factors of the respondents related to their adoption of the Trichoderma application.

Protecting the rights of the sample group, the proposal was endorsed by the Human Research Ethics Committee (HREC) of King Mongkut's Institute of Technology

Ladkrabang (KMITL) document number EC-KMITL_64_076 dated 1 November 2021 with exemption from considering research project ethics.

Analytical model

The regression model is expressed implicitly as:

$$Y = \beta_0+\beta_1x_1+\beta_2x_2+...\beta_{10}x_{10} +\varepsilon i$$

Where;
Y = Adoption on Trichoderma application
β_0 = Constant
β_k = Coefficients
ε_i = Error term
x_1 = Gender (male = 1, female = 0)
x_2 = Age (Years)
x_3 = Education level of household head (Number of years of formal education)
x_4 = No. household members (person)
x_5 = Social position (Yes = 1, No = 0)
x_6 = Training on the use of *Trichoderma spp*. (X6)
x_7 = Farming area (Rai)
x_8 = Farming income (THB)
x_9 = Knowledge of Trichoderma application
x_{10} = Attitude toward Trichoderma application

Results

Socio-demographic and economic backgrounds of respondents

Most of the farmers were male (67.47%), had an average age of 53.59 years, were married (80.70%). They completed primary school education (45.78%), had an average household member of 3.42 people, and an average of 1.64 household workers, with an average agricultural area of 34.05 rai (5.45 ha.), are members of the Bank for Agriculture and Agricultural Cooperatives (BAAC) (31.30%), have a social position (36.14%). The main occupation is farming (61.45%). The average annual agricultural income of 164,148.19 baht (THB) and the average annual non-farm income is 24,626.51 THB per year.

Trichoderma to prevent plant diseases of farmers' application

The results of the study revealed that more than half of the farmers used Trichoderma for the prevention and control of rice diseases (57.83%), with the most experience using Trichoderma for 2 years (33.73%). The average training was 2.54 times. Most of them received information on Trichoderma applications from agricultural extension staff (92.77%). Most of the product forms of Trichoderma were inoculated (self-cultivation) (62.65%), and obtained from the district/provincial agricultural offices (81.93%).

Farmers' knowledge of the use of Trichoderma

Table 1 presents that the farmers' knowledge about the use of Trichoderma was at the moderate level followed by high and low level accounting for 48.20%, 45.78% and 6.02%, respectively.

Table 1. Farmers' knowledge of Trichoderma application

Knowledge level	Frequency	Percentage (%)
Low (<60%)	5	6.02
Moderate (61-80%)	40	48.20
High (>80%)	38	45.78

Farmer’s attitude toward the use of Trichoderma

Table 2 presents that most farmers had attitudes towards the use of Trichoderma at a high level (63.86%), followed by the highest level (20.48%) and a moderate level (15.66%), respectively

Table 2. Farmer’s attitude toward the use of Trichoderma

Attitude level	Frequency	Percentage (%)
Very high (4.21-5.00)	17	20.48
High (3.41-4.20)	53	63.86
Moderate (2.61-3.40)	13	15.66

Farmers’ adoption of Trichoderma spp. application to control plant diseases

Table 3 presents that more than half of the farmers adopted the use of Trichoderma at a moderate level (57.83%), followed by a high level (33.73%) and low (8.43%) respectively.

Table 3. Level of Farmers’ adoption of *Trichoderma* spp. application to control plant diseases

Adoption level	Frequency	Percentage (%)
Low (0.00-14.66)	7	8.43
Moderate (14.67-29.33)	48	57.83
High (29.34-44.00)	28	33.73

Factors affecting farmers’ adoption of Trichoderma spp. application to control plant diseases

Multiple regression analysis revealed factors affecting the adoption of Trichoderma to prevent and eliminate plant pathogens for farmers in Chachoengsao Province with a statistical significance included 4 factors: age (X_2), education of household head (X_3), knowledge (X_9), and attitudes towards the use of Trichoderma spp. (X_{10}). Age, education, and knowledge affected the adoption of Trichoderma with a statistical significance at level 0.01 while attitudes affected the acceptance of Trichoderma with a statistical significance at level .05, which can forecast 36% (R^2). An error in a forecast (SEest) was 4.786. The correlation coefficients of age and education were negative. To clarify, yong farmers with primary education accepted the use of Trichoderma to prevent and eliminate plant pathogens higher than older and more educated farmers while knowledge and attitudes had positive correlation coefficients. When farmers had increased knowledge and attitudes toward the use of Trichoderma, it would affect the acceptance of Trichoderma. Age mostly affected the acceptance of Trichoderma (ß = -0.587), followed by education of the household head (ß = -0.419), knowledge (ß = 0.398), and attitudes towards the use of Trichoderma (ß = 0.247), respectively (Table 4).

Table 4. Multiple regression analysis estimated factors affecting farmers' adoption of *Trichoderma spp*. to control plant disease in Chachoengsao province

Attribute	B	Std. Error	Beta	t	p-value
Constant	6.361	7.201		.883	.380
Gender (X_1)	-1.870	1.187	-.157	-1.576	.120
Age (X_2)	-.241	.059	-.587	-4.122	.000**
Edu (X_3)	-.479	.160	-.419	-2.997	.004**
No. household members (X_4)	.222	.400	.055	.554	.581
Social position (X_5)	-.328	1.172	-.028	-.280	.780
Training on the use of *Trichoderma spp*. (X_6)	-.708	.396	-.215	-1.788	.078
Farming area (X_7)	.006	.012	-.062	-.529	.599
Farming income (X_8)	1.173E-005	.000	.209	1.825	.072
Knowledge of Trichoderma application (X_9)	1.080	.346	.398	3.121	.003**
Attitudes towards the use of *Trichoderma spp* (X_{10})	3.375	1.347	.247	2.505	.014*
Multiple R =0.600	F = 4.052				
Multiple R^2 = 0.360	Sig F = 0.000				
SE. = 4.786	Dubin Watson = 1.577				

* significance at level 0.05; ** significance at level 0.01

Discussion

The results reveal that most farmers were male (67.53%) and have an average age of 53.59 years support to Somkid Chalermkiet (2005) were studied the asparagus growers in Kanchanaburi Province found that most farmers were male (59.40%). In education, the factor found that most farmers (45.78%) had graduate primary school support to Charun *et al* (2016). The occupation factor (61.45%) was rice farmers. While the factors affecting the adoption of Trichoderma spp. application to control plant disease has only age and education with a statistical significance at level 0.01 supporting the finding obtained by Siddeswari et.al (2017) whereas age was found negative and significant at 1 percent level of significance with an impact of farmer field schools on the profitability of the participant and non-participant rice farmers.

Age was associated with the farmers' adoption of Trichoderma spp. application to control plant diseases in Chachoengsao Province with statistically significant. Most of the farmers aged 40 – 60 years had a negative correlation level, this's showing that farmers of different ages resulting in different levels of adoption when farmers get older there will be a lower acceptance level. This is consistent with the research of Rerkrai (1981) said that farmers' fundamentals play an important role in the adoption of that agricultural technology or practice which individuals in adolescence accepted the fastest and slowed down accordingly as they age.

Education was a relationship with the farmers’ adoption of Trichoderma spp. application to control plant diseases in Chachoengsao Province with statistically significant. It was found that farmers with different levels of education resulted in differences in adoption. A negative correlation level showed that farmers with low education levels have a higher level of adoption than farmers with higher education levels. This may be due to people with higher education levels should have the ability to recognize, access, and seek information to use for more self-contemplation. This was consistent with the research of Srika (1999). While those with low educational levels more access to information from government agencies and extension officials.

Gender, marital status, household size, farm household labour, social position, member, farming income, non–farm income, main occupation, secondary occupation, Trichoderma experience, kind of plant, data source, product form, and the origin of Trichoderma spp. and landholder are nonsignificant variables in case of adoption of Trichoderma spp. application to control plant diseases. The result supports the finding obtained by Rajbhar *et al* (2018) that occupation was a nonsignificant variable in the case of the adoption of chickpea cultivation. Also obtained by Thepburi (2019) that landholder was a nonsignificant variable with the adoption of Trichoderma (*Trichoderma harzianum*) utilization in oil palm disease control of farmers in Ao Luek district, Krabi province.

Knowledge about the use of Trichoderma spp. and attitudes towards the use of Trichoderma, there was a relationship with the farmers’ adoption of Trichoderma spp. application to control plant diseases in Chachoengsao Province.

Knowledge of the use of Trichoderma has a relationship to the adoption of Trichoderma spp. to control plant disease for farmers with a statistical significance at level 0.01. Possibly because the farmers have knowledge, understanding, and know about the benefits of using Trichoderma spp. very well. However, if farmers don’t have any knowledge in various matters whether production or in use. This may cause a decrease in understanding of the effectiveness of Trichoderma spp., resulting in the farmers having lower adoption. Consistent with research by Nantachan (2007). It was found that knowledge of using biotechnology was positively correlated with the adoption of biotechnology among soil improvement volunteers in Kamphaeng Saen District, Nakhon Pathom Province.

Attitudes toward the use of Trichoderma to prevent and eliminate plant pathogens were related to the adoption of Trichoderma spp. to control plant disease for farmers with a statistical significance at level 0.05. Different attitudes towards the use of Trichoderma resulted in the different acceptance of the use of Trichoderma use since if farmers already had good attitudes towards Trichoderma. It would have a level of adoption higher than farmers with negative attitudes towards Trichoderma. Moreover, government agencies and agricultural extension officers could access to encourage farmers to have more acceptance and practice. Rokeach (1970) reported that attitudes were a mixed order in what people believe in something or any one situation, and the sum of this belief would determine a person's tendency to react favorably or unfavorably. This is consistent with the study by Samrithnok (2017), revealing that attitudes toward the use of Trichoderma were related to the acceptance of Trichoderma with a statistical significance at level of 0.05.

Conclusion

The study pointed out that 48.19% of farmers' knowledge had a moderate level while 63.85% of attitude belonged to a high level, and 57.83% of adoption had a moderate level, respectively. The regression results pointed out that four factors affected statistically significant: age, educational level, and knowledge were statistically significant ($P<0.01$) while attitude was statistically significant ($P<0.05$). It was also observed that knowledge and attitude were positively and significantly correlated whereas age and educational level were found to be negatively correlated. The study recommends efforts to enhance farmers' adoption of Trichoderma spp. application to control plant disease should be focused on age, education level, knowledge, and attitude toward the use of Trichoderma. Moreover, extension courses should be implemented more to improve farmers' knowledge and skills in terms of isolation and mass production of Trichoderma for households and community.

Acknowledgements

The author would like to offer particular thanks to gratefully thank you to all staff of the plant protection service group in the Chachoengsao district agricultural extension office for their assistance, information and advice. Also the farmers in Chachoengsao province for their good cooperation and the King Mongkut's Institute of Technology Ladkrabang, Bangkok for support.

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Screening of antagonistic bacteria to control *Colletotrichum* sp. causing anthracnose disease in tropical fruits

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Abstract The purpose of this study was to screen for antagonistic bacteria that are effective in controlling *Colletotrichum* sp., a causative agent of anthracnose disease in postharvest fruits. A total of 72 bacterial isolates were collected from the rhizosphere soil around the roots of the mango tree planted in Prachuap Khiri Khan Province, Thailand. Preliminary screening for fungal control efficacy against *Colletotrichum* sp. isolated from mango and papaya fruits by dual culture assay showed that the SP-51 isolate inhibited mycelial growth at 62.8% and 62.9%, respectively. The SP-51 isolate demonstrated the mycelial inhibition of the *Colletotrichum* sp. isolated from mango fruits at a maximum of 48.5% on day 2 and 31.9% for 7 days on average by the volatile organic compounds (VOCs) assay. VOCs assay of *Colletotrichum* sp. isolated from papaya showed a 7-day average inhibition of 31.4% by SP-51. A morphological study of *Colletotrichum* sp. mycelial growth cultured with SP-51 under a light microscope showed swelling and thinner fiber walls compared to the control. The characteristic study of SP-51 showed that was a gram-positive, rod-shaped, spore-forming bacteria with heat tolerance up to 80 ℃. In conclusion, the SP-51 isolate shall be further studied and developed as an alternative bioagent to control *Colletotrichum* sp. in mango and papaya fruits.

Keywords: Dual culture, Fungal control, Postharvest, VOCs

Introduction

Anthracnose is a severe disease with a great economic impact on various tropical and sub-tropical crops; especially, mango, papaya, chili, strawberry, pear, and banana (Ciofini *et al*., 2022). This disease is caused by *Colletotrichum* spp. fungal pathogen (Shi *et al*., 2021). The genus *Colletotrichum* comprises more than 200 fungal species and can be informally classified into 15 species complexes (Talhinhas and Baroncelli, 2021). Many of them are pathogens of important crops such as *C. gloeosporioides* species complex, *C. acutatum* species complex, *C. capsica*, and *C. musae* (Shi *et al*., 2021).

Anthracnose caused by the fungi *Colletotrichum* spp. is an important disease in Thailand. Several host species can be affected including mango and papaya. Fungal infections can occur both in the field and at the post-harvest stage. However, the fruit damage caused by severe lesions of anthracnose during postharvest storage produced the highest impact on economic losses (Ciofini *et al*., 2022). Shelf-life of papaya in India is seriously lessened by *Colletotrichum* spp., determining losses up to 93% (Darshan *et al*., 2019). The incidence of anthracnose in mango can reach up to 100%, causing a shortened shelf-life and reduction in economic values (Arauz, 2000).

Synthetic fungicides such as prochloraz and benzimidazole are used conventionally together with physical treatments to control anthracnose in many crops (Ciofini *et al*., 2022). However, in addition to the environmental toxic effect, the improper and long-termed use of fungicides could reduce the sensitivity of the fungi to the chemicals and consequently develop resistant fungal strains (Chung *et al*., 2006; Sanders *et al*., 2000;

Zhang *et al*., 2020). Thus, the need for innovative, ecology-safe, and sustainable anthracnose control strategies is important.

The biocontrol approach is one of the important strategies to improve agricultural sustainability. In the past decades, numerous studies reported the identification of biological agents with the antagonistic potential to *Colletotrichum* species. (Carmona-Hernandez *et al*., 2019). Among these agents, bacteria in the genus *Bacillus* was shown as a notable candidate with strong efficacy toward *Colletotrichum* species (Shi *et al*., 2021). The advantage of *Bacillus* spp. is they are endospore-forming bacteria so they can survive during environmental stresses and most of them can produce antimicrobial agents (Emmert and Handelsman, 1999). However, despite numerous reports of the biocontrol efficacy of many biological agents, to date, only two biocontrol agents are recommended for the management of *Colletotrichum* species and are commercially available (Shi *et al*., 2021). Therefore, the search for more bioagents with the potential to suppress *Colletotrichum* spp. should be ongoing to provide alternative choices of agents to develop sustainable bio-fungicides.

Since mango and papaya are the important economic fruits of Thailand. Here we are interested in the control of anthracnose disease that severely affects the shelf-life and market price of these fruits. The objectives of the present study were to select antagonistic bacteria from the mango rhizosphere soil for controlling *Colletotrichum* of postharvest mango and papaya fruits. The selected antagonistic bacterial strains were evaluated for their ability to produce antagonistic extracellular metabolites and volatile organic compounds (VOCs) in suppressing *Colletotrichum* from postharvest mango and papaya fruits.

Materials and methods

Isolation of anthracnose fungal pathogen from Mango and Papaya fruits

Mango and papaya fruits showing symptoms of Anthracnose were collected from Hua Hin District, Prachuap Khiri Khan Province, Thailand in 2021. The causative fungus was isolated using the tissue transplanting method. Plant parts with disease symptoms were cut into pieces approximately 3x3 mm in size, washed with 10% Clorox, rinse twice with sterile water, and pat dry with sterile paper. The cleaned piece of tissue was placed on Potato Dextrose Agar (PDA) medium and incubated at room temperature for 7-10 days. Fungal colonies were sub-cultured on new PDA dishes to obtain pure fungi for further experimentation. Isolated postharvest pathogenic fungi were examined for morphology under a microscope and classified based on Bernett and Hunter's book Illustrated Genera of Imperfect Fungi, 1972 (Bernett and Hunter, 1972).

Soil sampling and bacterial isolation

Rhizosphere soil samples were collected from mango orchards located in Sila Loi Subdistrict, Sam Roi Yot District, Prachuap Khiri Khan Province, Thailand. Briefly, five soil samples at a depth of about 0-15 cm from the soil surface were collected and pooled as one sample. The sample was air-dried for 2 days. Spore-forming bacteria isolation was done with minor modifications (Zhang *et al*., 2020). The soil sample was placed in sterile water (1:10 ratio) and heated in a water bath at 80 ℃ for 10 min to kill non-spore-forming bacteria and vegetative cells of spore-forming bacteria. The solution was then serially diluted (10-folded) in sterile 0.85% NaCl solution and spread onto Nutrient Agar (NA) medium plates. The culture was incubated for 1 day at 37 ℃. Then bacteria with different colony characteristics were collected. A pure culture of each isolate was kept on NA medium at 4 ℃ for further study.

Screening antagonistic bacteria

The collected bacterial isolates were tested for antagonistic activity against Anthracnose fungal pathogen, *Colletotrichum* sp. isolated from mango and papaya fruits by dual-culture assay on PDA with modifications (Zhang *et al*., 2020). Briefly, each fungal *Colletotrichum* sp. was cultured on a PDA plate for 5 days, then transfer the growing mycelium (5-mm disc) onto the center of 9-cm diameter Petri dishes containing PDA. Bacterial isolates were streaked 4 cm long at 1.5 cm away from the edge of the plate. Four bacterial isolates were streaked in each plate. Blank control was done without a bacterial streak. The culture plates were incubated at 30 ℃ for 5 days. All treatments and control were done in triplicate. The mycelial growth inhibition percentage was calculated using the following formula: Inhibition of mycelium growth (%) = [(⌀ of control − ⌀ of treatment)/ ⌀ of control] × 100 ; when ⌀ = diameter.

Antagonistic assay of volatile organic compounds (VOCs)

Antagonistic activity of VOCs against *Colletotrichum* sp. was done by following the methods of Zhang *et al*. (2020) with minor modifications. Briefly, the bacterial isolate (200 µl, 1×10^8 CFU/ml) was spread onto the Petri dish containing NA medium and incubated at 30 ℃. After 24 h, the bacterial culture dish was covered face to face with a Petri dish containing a 5-mm mycelium disc of *Colletotrichum* sp. on the center of the PDA medium. The two Petri dishes were sealed firmly using parafilm and incubated at 30 ℃ for 7 days. NA plates without bacterial inoculum were used as a control. All treatments were done in triplicate. The diameters of the fungal colony were measured every day and calculated for the mycelial growth inhibition percentage using the formula: Inhibition of mycelium growth (%) = [(⌀ of control − ⌀ of treatment)/ ⌀ of control] × 100 ; when ⌀ = diameter.

Statistical analysis

The experiment was performed under a completely randomized design with three replicates. The data were analyzed by an analysis of variance (ANOVA) and an analysis of means by the Turkey test using R-program version 4.2.1. Statistic differences in mean values were considered significant when $P < 0.05$.

Results

Isolation of anthracnose fungal pathogen from Mango and Papaya fruits

Mango and papaya fruits with anthracnose disease were used for the isolation of causative fungal pathogens (Figure 1A and 1D). The pure culture of causative fungal of anthracnose from mango and papaya fruits was grown on the PDA plate (Figure 1B and 1E). The fungal colony showed white color with some dark-brown pigment in fungal isolated from papaya. Single-cell conidia with an oval shape can be seen under a light microscope (Figure 1C and 1F). Due to its morphology of mycelium and conidia shape, the fungal can be identified as a member of *Colletotrichum* spp.

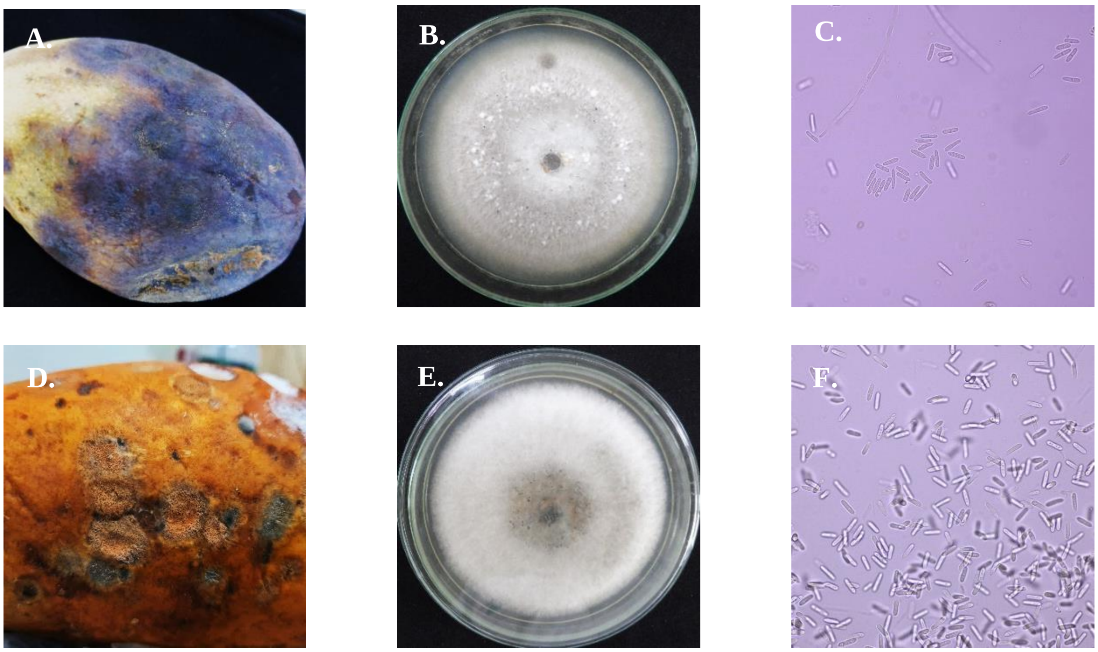

Figure 1 Mango (upper row) and papaya (lower row) fruits showing symptoms of anthracnose (A and D), mycelial growth of *Colletotrichum* sp. on PDA medium (B and E), and conidia morphology (C and F)

Screening antagonistic bacteria against Colletotrichum sp.

A total of 72 spore-forming bacterial isolates were obtained and screened for the antagonistic activity against *Colletotrichum* sp. isolated from mango with anthracnose disease using an *in vitro* dual culture antagonism assay. Most of the bacterial isolates inhibited mycelial growth of *Colletotrichum* sp. ranging from 0 – 30%. For *Colletotrichum* sp. isolated from mango fruits, five bacterial isolates showed inhibition higher than 30%. Among these isolates, SP-51 showed the maximum inhibition at 62.8% ($P<0.05$) (Table 1). There were four isolates that inhibit mycelial growth by more than 30% against *Colletotrichum* sp. isolated from papaya fruits. Similarly, the SP-51 was the isolate with the most efficacy at 62.9% inhibition ($P<0.05$) (Table 1). Morphological and microscopic appearance of fungal mycelium when incubated with SP-51 exhibited structural destruction of mycelium. The hyphae of both *Colletotrichum* sp. showed distorted, swelling, and had a thin wall (Figure 2).

Table 1. Antagonistic efficacy of bacteria isolates against the mycelium growth of *Colletotrichum* sp. using an *in vitro* dual culture antagonism assay

Bacterial isolates	**Mycelial inhibition (%)** [1/]	
	***Colletotrichum* sp. from mango**	***Colletotrichum* sp. from papaya**
SP-46	37.8 ±4.0 ^{a} [2/]	24.6 ±4.4 ^{a}
SP-49	38.4 ±3.4 ^{a}	35.6 ±5.0 ^{ab}
SP-50	34.7 ±4.5 ^{a}	31.1 ±5.3 ^{ab}
SP-51	62.8 ±6.2 ^{b}	62.9 ±7.9 ^{c}
SP-52	41.4 ±7.6 ^{a}	45.3 ±4.9 ^{b}
CV	10.7	0.36
P-value	0.000273	0.0000734

[1/]Data were shown as Means ±SD of triplicate.
[2/]Mean values with different letters in the same columns are statistically significant ($P<0.05$).

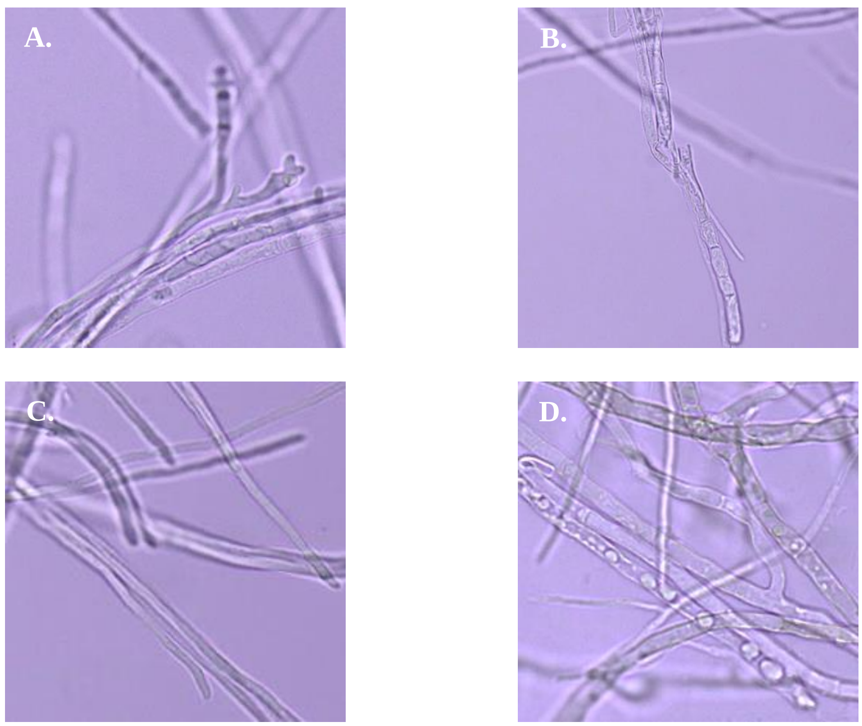

Figure 2 Mycelium morphology of *Colletotrichum* sp. under a light microscope. A= Control mycelium of *Colletotrichum* sp. from mango, B= SP-51 dual culture treatment of *Colletotrichum* sp. from mango. C= Control mycelium of *Colletotrichum* sp. from papaya, D= SP-51 dual culture treatment of *Colletotrichum* sp. from papaya

Antagonistic assay of volatile organic compounds (VOCs)

VOCs assay showed the inhibition efficacy of SP-51 against *Colletotrichum* sp. (Figure 3). The microscopic observation of fungal mycelium exposed to VOCs produced by SP-51 apparently showed abnormal structure with swollen and damaged cell walls. The VOCs produced by SP-51 reduced the mycelial growth by approximately 31.9% and 31.4% on average after 7 days of incubation for *Colletotrichum* sp. from mango and papaya fruits, respectively. The inhibition of mycelium was significantly different among days of incubation (P<0.05). The highest mycelial inhibition was found on day 2 for *Colletotrichum* sp. from mango fruits (48.5%) and slightly decrease after day 2 (Table 2). For *Colletotrichum* sp. from papaya, the inhibition showed similar inhibition efficacy from day 2 to day 7.

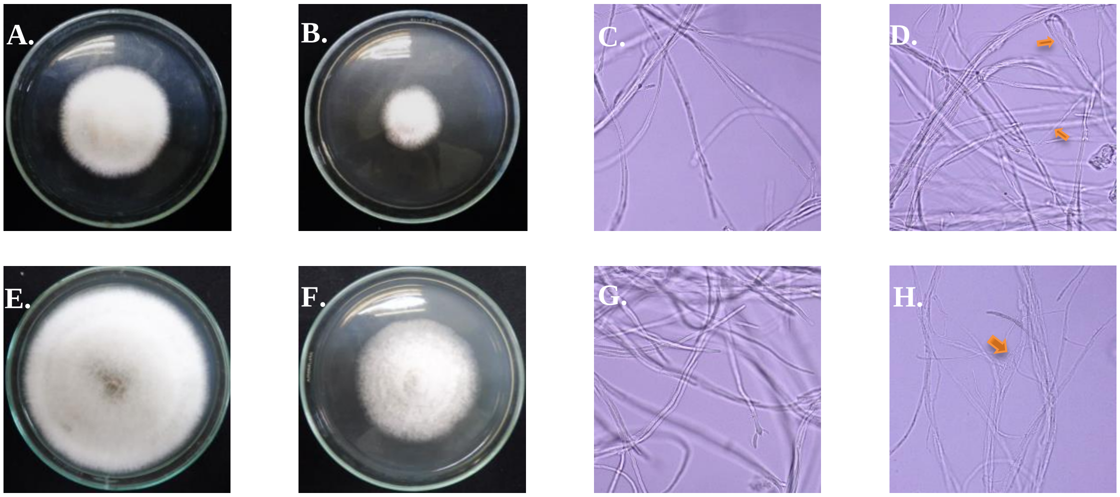

Figure 3 Mycelial growth inhibition by SP-51 against *Colletotrichum* sp. from mango and papaya by VOCs assay: Upper panel, A= control treatment of *Colletotrichum* sp. from mango, B= SP-51 VOCs treatment of *Colletotrichum* sp. from mango, C= mycelium of *Colletotrichum* sp. from mango, D: mycelium of *Colletotrichum* sp. from mango exposed to SP-51 VOCs. Lower panel, E= control treatment of *Colletotrichum* sp. from papaya, F= SP-51 treatment of *Colletotrichum* sp. from papaya, G= mycelium of *Colletotrichum* sp. from papaya, H= mycelium of *Colletotrichum* sp. from papaya exposed to SP-51 VOCs

Table 2 Mycelial inhibition (%) efficacy of the SP-51 VOCs against *Colletotrichum* sp. during 7 days of incubation

Days of incubation	**Mycelial inhibition (%)**[1/]	
	***Colletotrichum* sp. from mango**	***Colletotrichum* sp. from papaya**
Day 1	10.9 ±9.3 [a 2/]	22.7 ±3.1 [a]
Day 2	48.5 ±7.6 [c]	30.5 ±4.1 [ab]
Day 3	36.5 ±4.0 [bc]	31.7 ±2.6 [ab]
Day 4	39.3 ±3.9 [bc]	35.5 ±2.2 [b]
Day 5	35.2 ±4.1 [bc]	34.9 ±5.1 [b]
Day 6	25.6 ±6.5 [ab]	33.2 ±2.8 [b]
Day 7	24.4 ±1.8 [ab]	31.5 ±3.0 [ab]
CV	14.5	5.22
P-value	0.0000451	0.00752

[1/]Data were shown as Means ±SD of triplicate.
[2/]Mean values with different letters in the same columns are statistically significant (P<0.05).

Initial characterization of SP-51 isolate

Bacterial isolate SP-51 was initially characterized by morphological observation. Colony characteristics on NA medium showed a cream color with a smooth and shiny surface. Gram stain exhibited that it was a Gram-positive, rod-shaped bacteria.

Discussion

Biological control practices are of concern as alternatives to synthetic pesticides. Reports from several studies provide strong evidence that many naturally isolated bacteria significantly suppress the fungal pathogens of anthracnose disease from various hosts (Carmona-Hernandez *et al*., 2019). However, a tiny number of commercialized bioagents are registered in the market nowadays and much more bacterial isolates are continuously identified for their potent and broad-spectrum antifungal activity (Shi *et al*., 2021). Thus, exploring a new choice of antagonist is still ongoing.

In the present study, the SP-51 bacteria from the mango rhizosphere with promising antifungal activity against *Colletotrichum* spp., a causative agent of anthracnose, was isolated and tested for the production of active antagonistic VOCs. The results have shown that SP-51 inhibited mycelial growth of *Colletotrichum* sp. isolated from mango and papaya with the same level of approximately 60–65% on dual culture assay. The study by Živković *et al*. (2010) showed that *Streptomyces noursei* inhibit mycelial inhibition against C. *acutatum* and C. *gloeosporioides* 67–82%, followed by *S. natalensis* at 45–69% while *B. subtilis* showed a varying range from 25% to 48%. Screening of antagonistic bacteria against *C. musae* from bananas showed that *Enterobacter* sp. isolated from banana leaf showed 56% mycelial growth inhibition and showed a reduction of disease severity to 10% (Khleekorn and Wongrueng, 2014). Screening of bacterial isolated from mudflats of the western sea in South Korea obtained *B. amyloliquefaciens* that showed inhibition of mycelial growth on *C. acutatum* at 60.15% and *C. gloeosporioides* at 58.12% (Han *et al*., 2015). The dual culture assay of *B. velezensis* CE 100 with *C. acutatum*, *C. coccodes*, *C. dematium*, and *C. gloeosporiodes* showed maximum inhibition of 44.63%, 66.05%, 63.89%, and 56.47%, respectively (Kim *et al*., 2022). Besides bacteria, recently the isolated yeast *Trichosporon asahii* was shown to inhibit *C. gloeosporioides* (59.5% on dual culture) and suppress anthracnose disease in papaya fruits (Hassan *et al*., 2021). Therefore, the efficacy of SP-51 reported herein was comparably in the same range as those identified antagonists against *Colletotrichum* spp.

Volatile organic compounds (VOCs) are low-molecular-weight compounds belonging to several chemical groups, such as alcohols, aldehydes, ketones, esters, lactones, terpenes, and sulfur compounds (Carmona-Hernandez *et al*., 2019). Various VOCs produced by microorganisms have been shown to exhibit a negative effect on fungal growth (Carmona-Hernandez *et al*., 2019). The VOCs assay demonstrated that SP-51 can produce VOCs with a maximum inhibition of 48.5% (day2) against *Colletotrichum* sp. isolated from mango fruits. However, the average inhibition range is 30 – 40% during 7 days of incubation. This range was slightly lower than the mycelial inhibition of SP-51 performed by the dual culture technique (~60%). This might be due to the combined effect of both non-volatile and volatile compounds in dual culture assay. VOCs efficacy level of SP-51 was slightly comparable to *Streptomyces* sp. (PNM-149) against *C. gloeosporioides* (48% growth inhibition) on the VOCs assay (Gomaz *et al*., 2021). However, the inhibition efficacy obtained in this study was lower than the effect of *B. pumilus* and *B. thuringiensis* against *C. gloeosporioides* mycelia growth at 88.87% and 80.07%, respectively (Zhang *et al*., 2013). The VOCs antifungal efficacy was reported to be affected by the type of bacterial culture media and days of incubation (León *et al*., 2020). VOCs assay of *Paenibacillus ehimensis* against *C. gloeosporioides* mycelia growth using four different culture media (MH, NA, ISP2, and LB) revealed the highest efficacy (~40%) when *P. ehimensis* was grown over ISP2 and LB on the 3rd day of incubation (León *et al*., 2020).

One of the general effects of antagonistic bacteria in suppressing fungal growth is the alteration of the hypha. Dual culture and VOCs assay of *Colletotrichum* spp. with SP-51 showed an altered structure of mycelium. This is similar to many studies that have been showing the altered hypha structure after incubating with antagonistic bacteria (Ashwini and Srividya *et al*., 2014; Kim *et al*., 2022; Rahman *et al*., 2007). This may be due to the excretion of some lytic enzymes, diffusible antifungal metabolites, or volatile metabolites from the bacteria to distort the fungal mycelium (Carmona-Hernandez *et al*., 2019; Viswanathan *et al*., 2003). The destructive structure of mycelium might lead to leakage of cytoplasmic components and retard the growth of the fungi.

In conclusion, the isolation of SP-51 antagonistic bacterial isolate with potential antifungal activity against *Colletotrichum* spp. provides useful information for SP-51 as a biocontrol agent against *Colletotrichum* spp. in mango and papaya tropical fruits. Identification of genetic, biochemical properties, and *in vivo* biocontrol activities of SP-51 shell be further studied.

Acknowledgments

The author would like to thank the Faculty of Animal Science and Agricultural Technology, Silpakorn University, Thailand for supporting the laboratory facilities and chemicals for this research. The authors give special thanks to Associate Professor Dr. Bhutharit Vitayapanurak Raksasiri for help in soil sample collection.

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Potential development on smart farmer of alumni members of the future farmers organization in central region of Thailand

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Abstract Results of the study revealed that 37 out of 130 alumni members were engaged in agriculture. Based on its details, they grew field crops most (21.62%). This was followed by vegetable growing, beef/dairy cattle rearing, duck rearing, ornamental plant growing, organic farming, mixed farming, orcharding and seed producing (16.21, 13.51, 13.51, 10.81, 8.10, 8.10, 5.40 and 2.70%, respectively). The sample group adopted knowledge and experience gained from activities of the Future Farmers Organization of Thailand (FFT) for creating production cooperation networks most (86.52%), followed by marketing 63.75% and body of knowledge exchange (60.65%). The sample group needed potential development in production at a highest level ($\bar{x}$ =4.56, S.D.=0.132), followed by processing and product value addition ($\bar{x}$ =4.32, S.D.= 0.163). The following were approaches to increase production capacity the form of member network group of the Future Farmers Organization of Thailand: 1) creating a smart farming system; 2) product and service management; 3) branding, packaging development and accreditation; 4) agribusiness administration and marketing; and 5) financial and accounting management by establishing an accounting system and analyzing capital for business planning. Regarding a comparison of the development of agricultural production potential, there was statistically significant difference at 0.01 between female and male sample group members. The former put the importance on processing, creating innovation to reduce production costs and using technology to replace labor, respectively.

Keywords: Production potential development, Agricultural career, Smart farming, Agricultural innovation, Future Farmers Organization of Thailand (FFT)

Introduction

The current world society is progressive in information technology ang it changes rapidly all the tire which every one must always adapt themselves to cope with it. The teaching and learning facilitation in the college of Agriculture ang technology consisted of 3 forms: 1) classroom activities, 2) farm work, and 3) organizing extrar curricubir activities in the classroom. It puts the importance on learning and practicing in the actual situation in order to make students be aletophyte acquired knowledge and skills to planning and problem solving appropriately. Students can choose major field of study widely based on their interest and potemitial. Interestingly, they are able to select learning methods under supervised occupation experience program promoting teaching and learning under farm experiential learning. Siriwan (1989) claimed that teaching and learning facilitation on farm work of agricultural vocational statue can be classified into: school demonstration farm project, student experimental project and agricultural projects under supervision. Thais is normally under the college demonstration having the following characteristics:

The student does not own this project type and is not directly responsible for it in terms of farm work management and all farm incomes. All farm yields are belonged to the college, College admin istraors, Agriculture teachers and personal responsible for farm management lay guidelines for students to do farm under strict and close supervision various farm works of this project type are basic skill on the job as well as experience in agricultural occupation.

This project type was a master plan that giver students the operatory to work in various fields of farming and do various internships. Somudon (2006) and Maaneechot (2013) stated that activities to promote agricultural vocational education to train students to consider themselves as future farmer leaders are that of the future farmers of Thailand organigation this is adapted from the future farmars of America (FFA). It is an importaut tool used for developing of Agriculture/fisheries stwdents in terms of theories and practice. Noowattana (2010) claimed that the Future Farmer organization of Thailand under the progame in the college of Agriculture and technology. It emphasized on the development of leadership, personality, collaboration, sportsmanship, thrift and tolerance. A lof of students are interested in the future farmers of Thailand organization which has been carrying its tacks for a long time. It is created good relationship betaieen student s and teachers which has an effect on effective teaching and learning.

Materials and methods

Potential development of farmers being alumni of Future Farmers Organization of Thailand leading to do smart farming was a study employing as a mixed methodological research. The qualitative and quantitative technique was used in this research and data were collected (Chalakbang. 2017, Srisa-ard. 2010) and promoted the sample group to be a channel in the development of potential in agricultural production.

1. The general data and needs for potential development were explorated in agricultural production of farmers who were alumni of Future Farmers Organization of Thailand. A set of questionnaires and interview were used for date collection which conducted with a sample group 37 out of 130 alumni of future farmers organigation of Thailand. All of them were farmers and abtained by purposive sampling.
2. The grouping of agricultural production of the sampls was analyzed in order to form and support the development of production potential in various ways. In this study, however, it was done by holding a project to develop potential in agricultural production of the sample group. Monitoring was conducted after they had attended a training and assessment was done by interviewing and recorded data activities of agricultural production.

Research instruments in this study were questionnaire, recording form of strwctured–interview schedule and assessment form. There was inspection of correctness of contented consistency of objectives by using IOC value (0.06-0.10). The improvement was done in accordance with suggestions of experts. The obtained data were analyed by using descriptive statistics and t-test (Paired–samples) and data results were interpreted by using content analysis. The need and satisfaction rating were used as an estimation scale (5–rating–scales. Criteria for interpreting the formula calculation were as follows: (Leekitwattana. 2012 and Ruengpraprapan. 2000).

$$\frac{\text{The highesttheshold–the lowest threshold}}{\text{Total number of criteria}} = \frac{5-1}{5} = 0.80$$

Where

Score	Scale limits	Descriptive (need/satisfaction)
5	4.21-5.00	Highest
4	3.41-4.20	High
3	2.61-3.40	Moderate
2	1.81-2.60	Low
1	1.50-1.80	Lowest

Results

Results of the study on potential development of alumni of Future Farmers Organigation of Thailand (FFT) leading to do smart farming based on 3 periods were as follows:

Table 1. General data of the farmers who were alumni of FFT based on sex and educational attainment (Central unit)

Item	n=37	%
Sex		
- Male	15	40.54
- female	22	59.46
total	37	100.00
Educational level		
- Vocational certificate	13	35.14
- Higken vocational certificate	19	51.35
- Bachilor s degree	5	13.51
Total	**37**	**100.00**

It was found that more than one–half of the samples were female (59.46%). Most of the samples higher vocational certificate students most (51.35%) and few of them were bachelons degree students (13.51%).

Table 2. Data on occupation of the samples

Item	n=37	%
- Growing vegetables	6	16.21
- Growing field crop	8	21.62
- Rearing dairy / beef cattle	5	13.51
- Rearing ducks	4	10.81
- Growing ornamental plants	4	10.81
- Organic farming	3	8.10
- Mixed farming	5	5.40
- Orcharding (fruit trees)	2	5.40
- Producing seeds	2	5.40
- Producing organic fertiliger	1	2.70
Total		**100.00**

According to table 2, it was found that the samples grew field most (21.62%) followed by growing vegetables (16.21%) rearing dairy/beef cattle and rearing ducks. Only 5.40 precent produced seeds and 2.70 precent produced organic fertilizer.

Table 3. Adoption of knowledge and experieuce acquired from activities of FFT

Item	n=90	%
- Building a network of cooperation in agricultunal production	32	86.49
- Markting and diseribution	30	81.08
- Exchande of agricultural body of knowledge	28	75.67
- Planning of agricultural production body of knowledge	24	64.87
- Planning of agricultural production, project implementation and assessment need for being an agricultural leader	23	62.16
- Processing and value added of agricultural yield	23	62.16
- Agricultural production technology	19	51.35

According to table 3 the sample group adopted the knowledge and experience to built a network of cooperation in agricultural production most (86.49%) this was followed by marketing and distribution, exchange of agricultural body of knowledge, and assessment. (81.08, 75.67, and 64.86%, respectively). However, agricultural production technology was found least (51.35%).

Table 4. Need for potential development in agricultural production

Item	$\bar{x}$	S.D.	Description
- Reducing production costs	4.23	0.320	Hight
- Processing and yield value value – added	4.35	0.135	Highest
- New business enhancement and marketing	4.32	0.163	Highest
- Appropriate technology and tools for agricultural production	4.56	0.132	Highest
- agricultural production with database	3.53	0.423	Hight
- Smart farm and digital technology agricultural production	4.02	0.125	Hight
- Sustainable organic farming production	4.12	0.321	Hight
- Agricultural network system of the new age	3.80	0.231	Hight
Total	4.28	0.325	Hight

According to table 4, as a whole, the sample group hod a high level of need for potential development in agricultural production ($\bar{x}$ = 4.28; S.D. = 0.325) Based on its details, the following were found at a highest level: appropriate technology and tool for avicultural production; processing and yield value added; and new business enhancement and marketing ($\bar{x}$ = 4.56; S.D. = 0.132; $\bar{x}$ =4.35; S.D. = 0.135; and $\bar{x}$ = 4.32; S.D. = 0.163, respectively) the rest were found at a high level.

According to results, top five of guidelines for increasing potential in agricultural production in the form of member network group of future farmer organization of Thailand arere as follows: 1) creating smart farming system (94.59%), 2) management of fright and service system (91.89%), 3) branding, packaging development, and accreditation (83.74%), 4) new age of agricultural business and marketing (81.08%), and 5) financial and accounting management by establishing and accounting system and analyzing costs (78.37%), respectively.

Table 5. suggestions of guidelines for increasing potential in agricultural production in the form of member network group of FFT

Item	n = 37	%
- New age of agricultural production	22	59.45
- Agricultural processing and yield value - added	28	75.68
- New business enhancement and marketing	23	62.16
- Development of production and marketing network	21	56.77
- Creating smart farming system	35	94.59
- Management of fright and service system	34	91.89
- Branding, packaging development, and accreditation	31	83.78
- New age of agricultural business and marketing	30	81.08
- Finance and accounting management by establishing an accounting system and analyzing costs	29	78.37
- Appropriate technology in agricultural production	25	67.57
- Management of quality and cos reduction of agricultural	28	75.68
- Business planning for young agricultural entrepreneurs	24	64.86

Table 5. A comparision of needs for the development of potential in agricultural production based on sex

Item	n=37	$\bar{x}$	S.D.	T	Sig
- Male	15	4.02	0.134	-13.316*	0.000
- Female	22	4.34	0.253		

* Statistical significance level at 0.1

The comparison of needs for the development of potential in agricultural production based on sex, there was statistically significant difference at 0.01. That was the female sample group put the importance on processing and creating diversity of products and new marketing. However, the male sample group put the importance on production process, creating innovation to reduce production costs and use of technology to replace workforce, respectively.

In-depth interview was conducted with alumni of future farmers organization of Thailand (central unit) who did farming leading to be smart farming.

1. Acquired knowledge from joining activities of future farmers organization of Thailand adopted for farming were studied in the corrected methods of farming, they had passed on their knowledge to younger generations who worked in agriculture. They obtained a process of execution of main activities of future farmers organization of Thailand for farming used in the project was promoted to be a master plan for farming to the future effectively.

2. Activities of Future Farmers Organization of Thailand promoted agricultural occupation and there was a network in Farming in the following areas: 1) promotion of skills in analytical thinking process and effective career planning; 2) be able to create working networks by using main activity pattern and the main activity model was used community relations activities to build a stable network of farmers and 3) be able to prepare income and expense account correctly. Besides, the activities could help in planning to expense money fully and had efficiency the main activity model of Future Farmers Organization of Thailand, That was business enhancement and savings. It

involved the size of production per sales area, marketing or business size in the nature of large -scale marketing in agricultural export traders; and middle-level marketing in provincial areas e.g., Si Moeng, tai, Si Mum Maeng, and Nong Buoy markets in Phetchaburi province.

1) Tactivities of Future Farmers Organization of Thailand were participated in the form of participation in agricultural vocational seminars and exchanging knowledge in academic conference at unit, regional, and national levels. In this respect, main activities included activities promoting skills and experience of agricultural leaders. The selection was an outstanding alumnus of Future Farmers Organization of Thailand at unit, regional and rational levels. A report was presented to Her Royal Highness Princess Maha Chakri Sirindhorn. Besides, then was participation in agricultural development activities which concerned with Future Farmers Organization of Thailand. Public relations activities on news or information of Future Farmer Organization of Thailand and agricultural networks were shown. It was promoted in learning in the college of agriculture or alumnai house to access to learning the right farming methods. Activities are generated other agricultural supported information for interested farmers to use in decision–making such as information about a shop selling agricultural products and agricultural products and reduction on of agricultural production costs.

2) The additional needs of the sample group were learning by demonstrating the proper and safe farming practice performed by alumnus, and supported or agricultural inputs such as plant varieties and animal breeds from alumnus.

Discussion

According to results of the study conducted with the sample group of 37 alumnus of FFT, it was found that they grew field crops most (21.62%) this was followed by vegetable production, dairy/beef cattle rearing, duck rearing, ornamental plant growing, organic farming, mixed farming, orcharding, and seed production (16.21%, 13.51%, 13.51%, 10.81%, 8.10%, 8.10%, 5.40%, and 2.70%, respectively). It was successful in accordance with objectives of the agricultural vocational teaching/learning facilitation. It focused on making the learner to adopt acquired knowledge, skills and experience from agricultural education to do and develop farming (Siriwan. 2013, Intorted. 2015, Poungsuk. 2017). Infact, occupational development of the sample group who were farmers and alumni of FFT was done in the form of relationship westwork arised from participation in activities, results of the study revealed that the sample group communicated each other to exchange knowledge/experience in agricultural occupation and agricultural yields. This implied that activities of future farmers organization of Thailand promoted and supported agricultural development in the form of a professional group with creatine thinking. This was particularly on exchange of knowledge in agribusiness network. It is at the heart of today agricultural career with borderless communication (Sarakul and Sriboonruang. 2022, ETDA. 2019). Inaddition, it was found that both mall and fimale sample group had different needs for potential development with a statistical significance level at 0.01 this denoted that the farmer sample group was interested in self–potential developrut. That was the female group put the importance on processing creating diversity of products and new trend of marketing. Meanwhile, the mall group put the importance on production process, creation of innovation for production costs reduction, and use of technology to replace workforce. Thus, this denoted that gander had a relationship with potential development of humam. It conformed to study of (Subsiri *et al*. 2017, Poungsuk and Junlex. 2018) which found that male farmers were tested in production, agricultural machinery whereas female farmers were interested in self–development on online business and product development. In conclusion, the sample group had many issues of suggestions which were important to potential development of agricultural production in the digital age. It coped with the Covid–19 pandemic situations as well as change of communicative system related to production management with the assistance of appropriate technology. Importantly, it is possible transformed to business activities in the form of online marketing.

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Tree bank management pattern for sustainability of environmental and household economies in Thailand

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Abstract Intensifying global warming has reduced forest areas. COVID-19 epidemic has exacerbated the economic crisis amongst both urban and rural dwellers. Tree bank is a mechanism that can increase forest areas in individual and community lands which positively benefit household economy and community environment in accordance with environmental economy and sustainable development goals. This research aimed to analyse the tree bank management pattern for the sustainability of environmental and household economies. The study areas in three regions of Thailand, namely 1) Khao Chakan Agroforestry Bank, Sa Kaeo Province, 2) Ban Tham Suea Tree Bank, Phetchaburi Province and 3) Ban Khlong Ruea Tree Bank, Chumphon Province. The study adopted a qualitative research method. The data was collected by in-depth interviews, group discussions and field surveys the richness of trees by plotting a plot of 40 x 40 m. The sample groups have tree bank committees, tree bank members and representatives of the Bank of Agriculture and Agricultural Cooperatives. Analyze data by descriptive analysis. The results of study found that all three tree bank patterns had There are community enterprise groups, the group committee15 persons. Group members are required at least 9 trees each year in private plantation or public areas. Trees are used as collateral for loans from the Bank for Agriculture and Cooperatives. Trees must be between 1-50 years old and have a circumference of 15.40 centimeters or more. Measure around the starting point at chest level.Can borrow up to 400 trees per rai. Richness index(R2) obtained from plots in plots of 1 rai has an R2 value of 2.50-4.50. The plot with the highest R2 is Ban Khlong Ruea Tree Bank, Chumphon Province. Additional incomes of the households could be obtained from planting seedlings, making wood-smoked vinegar, and producing compost. The models were also used as learning centres, natural tourist spots, homestays and learning networks were continually established within the communities, government offices and international agencies which helped contribute to sustainbable development.

Keywords: Tree bank, Community environment, Household economy, Sustainable development

Introduction

Environmental problems are becoming more serious, including flooding, deteriorating forests. The soil has chemical residues. Higher temperatures, polluted water, and air pollution caused by human consumption have exceeded limits. Humans must work together to restore nature to balance (Suwaree Sripuna, 2020). Global warming caused by climate change and also affected by greenhouse gas emissions (Sukchart Lertwuthirak, 2022).When the world has a problem with the COVID-19 epidemic in 2019, it worsens the economic crisis for both urban and rural people.The country loses long-term economic opportunities. Environmental restoration, especially increasing forest areas and biodiversity as a base for economic development society and health by cooperating with both public and private sectors Therefore, it should be taken seriously (Sripoona *et al.*, 2021).Over the past 60 years, Thailand's forests have been in crisis and the area has been continuously decreasing. In 1972, Thailand's forest area accounted for 43.21% of the country's area, decreasing in 1987 and in 1997, the forest area remained 28.03 percent and 25.28 percent, respectively. After 1997, the forest area increased. In 2019, the forest area decreased from 2018 in the amount of 4,229.48 rai to 102,484,072.71 rai, representing 31.68 percent of the whole country and there have always been problems with people and forests. For almost 40 years, the Thai government has come up with ways to manage forest resources to solve such problems. In 1985, the National Forest Policy Committee was established. and set a framework for managing forest resources to have conserved forest areas and economic forests of not less than 40 percent of the country in 2017.has established a framework for forestry policy to cover economic, social, environmental and security aspects Later, in 2019, the National Forestry Policy was issued to cover 3 areas: forest management to have economic forests and community forests at least 15 percent of the country or 48 million rai, promoting comprehensive economic timber and providing ecological services. sustainable and development of administrative systems structures and laws in accordance with the situation. Have the agency review the plan every 3 years and in the 20-year national strategy has given importance to sustainable development by pushing for a sustainable environment in every province.Prescribed that forests for conservation and for the economy of not less than 40 percent of the country's total area. (Seub Naksathien Foundation from seub.or.th) However, forest restoration by the private sector and people outside the conservation area which are ready and have the potential to use household and community areas for planting agricultural forests to restore the environmen. and develop the grassroots economy in line with the community's way of life It is an alternative to adding green space to replace lost forest areas. It is a new concept that started in Thailand in 2006 under the name of the Tree Bank Project.that operates as 2 concepts 1) Tree Bank by the People's Party to Drive the Tree Bank By using it as an innovation of environmental work. (Thai Post - planting trees as pensions, 2021) It started with a group of people to find new alternatives to increase the amount of forest resources and use trees as capital for accumulation and savings. Including increasing other production continuously.By using the tree bank as a strategic innovation, laying the foundation for economic development and building a community resource management system together to form a network to be self-reliant. At the family, community and national levels (Bank for Agriculture and Agricultural Cooperatives, 2018). 2) From the products in the plots planted trees with various activities without the need to cut down the trees for sale to increase income and improve the economy. 2) Tree Bank by the Bank for Agriculture and Agricultural Cooperatives (BAAC) in collaboration with the National Community Leadership Committee. Initiative to promote planting trees to pay off debt to alleviate poverty.Adhere to the vision that trees are a type of asset that have a price that can be held. Therefore, people are encouraged to plant trees on their own land and communities according to the Royal Initiative, planting 3 forests, 4 benefits. Then evaluate the value of trees that have economic value for savings, property, and securities. as collateral Applies to state and state-designated financial institutions.Have tree planters in the same community or nearby communities set up a tree bank. To create self-sufficiency, wealth, sustainability, self-reliance Rely on each other and form a network of planting trees throughout the country. (Bank for Agriculture and Agricultural Cooperatives, 2021) Have tree planters in the same community or nearby communities set up a tree bank. To create self-sufficiency, wealth, sustainability, self-reliance Rely on each other and form a network of planting trees throughout the country. (Bank for Agriculture and Agricultural Cooperatives, 2021) and in the west At Ban Tham Suea Tree Bank Kaeng Krachan Subdistrict Kaeng Krachan District Phetchaburi Province.Later in the year 2008 in the eastern region at the tree bank Khao Chakan Agroforestry Khao Chakan District All 3 locations in Sa Kaeo Province were so successful that they became prototypes for expanding the results of the Tree Bank to other areas. Currently, there are 6,838 community tree banks with 123,424 members nationwide (Bank for Agriculture and Agricultural Cooperatives, 2022). The Tree Bank is an innovation for forest restoration and the holistic environment along with the development of a green economy from the community to the national level in line with the sustainable development goals. Therefore, you should find out how to have a successful tree bank management plan. This research aims to study a successful tree bank management model for the environment and household economy in order to extend the results towards sustainable development.

Materials and methods

Research model this research is a survey research. Using qualitative research methods and surveying tree diversity in tree bank plots by plotting.

The research area is a model community that has succeeded in operating a tree bank in 3 regions: 1) the western region at Ban Tham Suea Tree Bank. Kaeng Krachan District Phetchaburi Province 2) the Eastern region at the Khao Chakan Agroforestry Bank Khao Chakan District and 3) the southern region at Ban Khlong Ruea Tree Bank, Phato District, Chumphon Province (Figure 1).

Population used in research It's a tree bank board. tree bank member Bank representative or cooperating organization in the tree banks that are study areas, totaling 3 locations.

Sample A purpossive sampling was selected as a tree bank committee. tree bank member Bank or corporate representative who cooperate in the management of the tree bank who participated in activities continuously In order to provide key informants of the 3 study areas, 11 people each consisted of a chairman of the tree bank, three representatives of the tree bank committee, five representatives of tree bank members, two representatives of the bank or cooperating organizations, in total. 3 locations, 33 people.

Data collection using in-depth interviews. Data were collected from documents and observing actual conditions for interview about the tree bank management model. and surveying the diversity of plant species in the sample plots by surveying the agroforestry plots of tree bank members selected by the tree committee as the sample plots. By plots of 40 X40 square meters were placed in each of the 3 study areas, one for each plot, a total of 3 plots. Tools used for data collection were unstructured interviews. (Unstructured Interview) and plant diversity survey recorded form (Figure 2).

Data analysis. Content analysis and richness index (R2) of Menhinick (1964) were analyzed using the formula Menhinick index = $(S)/\sqrt{n}$ where S is the total number of species in the society and n is the number. all trees found

Figer 1. Study areas

Figure 2. Visiting all 3 areas to record the survey of species diversity

Results

Tree bank management schemes

A tree bank scheme of successful masters in the region included to be 3 effected places.

1. Ban Tham Suea Tree Bank, Kaeng Krachan Subdistrict, Kaeng Krachan District, Phetchaburi Province, was established in 2007 using its own land. then extended to the houses of the people in the village The original forest area was originally a farmer in Ban Tham Suea community. Kaeng Krachan Subdistrict Has depended on living close to the forest since the past.and there are community forest areas that have been illegally cut down to become degraded forest areas. At present, there is the development of community forest areas and the Baan Tham Suea Tree Bank project. that planted trees in the farmer's area It is a collaboration from farmers who have a heart to preserve the original forest condition and changes in the area. Development of Tree Bank Management. which later planted trees under the Tree Bank project It's an incentive to plant trees. Because it is a project that uses the principle of long-term joint investment. to improve debt structure and use trees as collateral A Study of the Ban Tham Suea Tree Bank Project Phetchaburi Province It's an interesting area. Because Ban Tham Suea originally had a community forest, but illegally cutting down the forest until it became a degraded forest area. monoculture use agricultural chemicals and problems with farmers' debt

Until 2006, Mr. Suthep Pimsiri, the leader of the community enterprise group, Ban If Suea Tree Bank Group, had attended the tree bank project training. to change farming from the original to a blended By using the guidelines of the BAAC and conserving the degraded community forest area Because it is consistent with the context of Ban Tham Suea community, it benefits in terms of working capital and has financial mechanisms to support the future. (area ratio of 1 rai per 25 trees) The administrative structure has a total of 15 tree bank committees and 70 members of households, regulations, plans, projects and cooperation with the community and has the relevant departments, namely the BAAC.

2. Khao Chakan Agroforestry Bank, located at 175 Village No. 6, Khao Chakan Subdistrict, Khao Chakan District, Sa Kaeo Province, formerly was an area of cassava forest and sugar cane forest. In an area of approximately 50 rai of Dr. Krirk's family, Ming Krirk has planted 3 forests with 4 benefits. by mixed cultivation By focusing on more than 470 species of perennial plants in 35 rai of land, which currently have trees cut. Especially the acacia or acacia in the processing. Build a building for a dwelling only.Tree Bank Management Khao Chakan agroforestry. During the year 2016, there was a project for people who dare to return the land. Subsequently, it was changed to Training 3 B (Intensive Stage), which was later student study of the college of life The activities in the course consisted of making fertilizer from leaves. Pruning branches to burn charcoal get wood vinegar plant seedlings.

3. Ban Khlong Ruea Tree Bank Located at Village No. 9, Pak Song Subdistrict, Phato District, Chumphon Province, the original condition is a moist evergreen forest. With a lot of biodiversity in the year 2006 began to discuss tree banks and set up as Thailand's first tree bank

The more trees A forest-like agricultural area was created. There are served as food crops, energy crops, and useable trees. There were planted for seedlings, wild vegetables, and planting in their own areas. Expansion of wild plants with a project in 84 Tambon Rak Pa built the people towards a sufficiency economy which have jointed activities in communities and other provinces , There was a network with the community with the outside community and being a social network with communities and other provinces

The more people from outside has studied and visited in the tree banks. There have shown in four-tier agricultural plots, which following forms and methods of practice: Level 1, selected and supplemented with plants (economic crops) that are classified as the highest level, which was the upper floor according to their growth characteristics. with high speed, such as sata, betel nut, durian, neem, takhianthong. The second layer is selected and planted with economic plants. The middle tier was classified such as mangosteen, longkong, the 3rd layer selects economic plants at the lower level, such as single-season or multi-season types, such as peppers, eggplants, liang vegetables, wild vegetables, leafy vegetables etc. The 4th layer selected and grown plants with basement tubers such as galangal, turmeric, and wild yam to completed the weeds to be useful plants.

Diversity of perennials in tree bank activity in 1 Rai area by plotting

1. Khao Chakan Agroforestry Bank, Sa Kaeo Province according to the survey in 1 rai was approximately 400 perennial trees because they are planted with a size of 2 by 2 meters with a total of 50 tree species.

2. Ban Khlong Ruea Tree Bank, Chumphon Province according to the survey was approximately 100 perennial trees in 1 rai because they are planted with a size of 4 by 2 meters with a total of 45 tree species.

3. Ban Tham Suea Tree Bank, Phetchaburi Province according to the survey was approximately 150 perennial trees in 1 rai because they are planted with a size of 4 by 4 meters, with a total of 40 species of trees.

Determination of tree names for value determination by the Bank for Agriculture and Agricultural

Cooperatives, amounting to 4 groups Total 58 types

1. List of trees consisted of teak, rosewood, rosewood, sapling, buffalo sapling, Sathorn, Daeng, Praduo, Ban Pradu, Macha Mong, Makha Tae Kiam, Kiem Khanong, Teng, Rang, Payom, Takhian Thong, Takhian Hin, Takhianchan, Cat's eye, rubber tree (excluding rubber), neem, neem, neem, tiger, Taku. Nonsi Sattaban, sea trotters, pruek, peep, tabaekna, sela, inthaninnam, blood tabak, otter, champai (Champi Sirindhorn, Champi Pa, Champi Thai, Champi Dong, Champi Khaek, Champi Phet) Canada Kalapapruek, Ratchaphruek, Suphannika, Lueang Pridiyathorn, Mahad, Makhampom, Wah, Chamchuri, persimmon, Kankera, large leaf pan, pit, agarwood, fragrant wood, Thep Taro, Fang, all kinds of bamboo, mango trees. Durian and tamarind must be planted as the age of 1 year or more with a straight trunk of 2 meters or more. The valuation required at least 3 directors and bank members to participate in the valuation. Each tree was height of 1.30 meters with not less than 3 centimeters, and compared the measured circumference with the quantity and price table of wood.

2. The tree into 4 groups were divided to find the value of the trees. They were lend 50 % of the appraised value of that type of tree. The groups of wood were catagorized to be 1) Trees with a fast to medium growth rate. short tooth cut low value of wood, 2) Trees with medium growth rates, long cutting cycles, relatively high value of the wood, 3(Trees with medium growth rate, long cutting cycle, high value of wood, and 4) Trees

with slow growth rate, long cutting cycle, high value of wood which can apply for a loan at Bank for Agriculture and Agricultural Cooperatives or BAAC nationwide.

Activities in tree plots that affect the sustainable household economic environment to have activities and effects on the BCG model

1. Khao Chakan Agroforestry Bank, Sa Kaeo Province using its activities affected by cultivating seedlings for sale and for charcoal burning, wood vinegar making, production of soil or leaf fertilizer and organization as a training and learning center (Figure 3).

Figure 3. Charcoal burning Production of soil or leaf fertilizer in the field

2. Ban Klong Ruea Tree Bank, Chumphon Province. Using activities affected by carbon credit in charcoal burning, wood vinegar production. production of soil or leaf fertilizer and organization as a training and learning center for tourist attraction (Figure 4).

Figure 4. Charcoal burning Cultivation of seedlings in the field

3. Ban Tham Suea Tree Bank, Phetchaburi Province showed the activities and effects on carbon credit and charcoal burning, wood vinegar production. production of soil or leaf fertilizer and organization as a training and learning center (Figure 5).

Figure 5. Learning image attraction Homestay accommodation

Table 1. The related environmental tree bank management schemes and household economy of the three tree bank prototypes

	Tree bank		
Implementation of the master tree bank	Eastern region Tree Bank Khao Chakan Agroforestry Khao Chakan Subdistrict Khao Chakan District, Sa Kaeo Province	South region Tree bank Ban Khlong Ruea Phato District, Chumphon Province	Central region Tree bank Tiger Cave House Kaeng Krachan District, Phetchaburi Province
Number of years in operation of the tree bank	Started in 2008 - present, a total of 14 years	Started in 2007 - present, a total of 15 years	Started in 2007 - present, a total of 15 years
Environmental management in the area operates a tree bank	-Resource preservation management Environment in the dimensions of soil, water, and forest by planting 3 forests, 4 benefits, with demarcated areas. To take advantage of including collecting seeds. and then bring that seed to propagate -Rehabilitation and development of resources and the environment By changing from monoculture planting sugarcane and cassava to planting 3 forests with 4 benefits, making the soil fertile. and moisture There is a water source for regeneration from monoculture to organic or non-toxic agriculture. Including the restoration of lost forests by reforestation.	- Management of storage resources Environment in the dimensions of soil, water, forest by planting 3 forests, 4 benefits, 4-storey agricultural plots, utilization from the trees that grow in the plot including collecting seeds and take the seeds to propagate - Rehabilitation and development of water resources and the environment by modifying from monocultures grow coffee alone Come to plant 3 forests, 4 benefits, making the soil fertile. and moisture Because the area is the watershed in the rehabilitation, change from plants, chemical purification to organic or non-toxic agriculture. Including the restoration of lost forests by reforestation. - Utilizing the resources and environment in the tree bank by utilizing the resources within the 3 forest planting, 4 benefits, bringing fallen leaves to the forest floor. Bringing trees that can be utilized to make a building Removed replacement forests added.	- Management of storage resources Environment in the dimensions of soil, water, forest by planting 3 forests, 4 benefits, area management in accordance with the context because the area has the Phetchaburi River seed collection and take the seed Let's make a seed bullet. - Rehabilitation and development of resources and the environment by modifying from monocultures only fruit gardening Come to plant 3 forests, 4 benefits, making the soil fertile. and moisture There is only one source of water to rehabilitate and modify the production of fruit trees. use of chemicals Become an organic farming while restoring lost forests through reforestation. - Utilization of resources and environment in the tree bank by utilizing resources within 3 forest plantings, 4 benefits, using trees that can be utilized to make buildings. Removed replacement forests added.
Activities of the Tree Bank that affect the household economy according to the New Economic Principles (BCG Model)	-Bio economy breeding seedlings for sale -Circular economy Making soil, leaves / burning charcoal / collecting wood vinegar -Green economy Open a learning center (3 b) / open a sawmill / open a learning room of the institute for the people	-Bio economy Plant seedlings/carbon credits -Circular economy Making soil and leaves / burning charcoal / collecting wood vinegar / -Green economy It is a learning/homestay/tourist attraction.	-Bio economy Plant seedlings/carbon credits -Circular economy making soil and leaves/ burning charcoal/ collecting wood vinegar/ -Green economy It is a learning/homestay/tourist attraction.

	(University of Life)		
The number of species, the number of trees, and the abundance of perennial plants in the plot of the tree bank used to place the plant survey plot, size 20X20 wa = 400 square wa (1 rai).	50 / 400 (R2 = 2.5) -Number of 50 species of species -Number of 400 standing trees -Value of multiplicity 2.5	45 / 100 (R2 = 4.5) -Number of 45 species of species -Number of 100 standing trees -Value of multiplicity 4.5	40 / 144 (R2 = 3.33) -Number of 40 species of species -Number of 150 standing trees - many values 3.33
Amplification	From the tree bank in the village to the Khao Chakan sub-district, Khao Chakan district. to the whole of Sa Kaeo Province and is a training facility 3 b in Khao Chakan Agroforestry. where people from all over the country in 77 provinces come to train for a total of 58 generations	From the tree bank in the village to the Paksong sub-district / Phato district to the whole of Chumphon province.	From the tree bank in the village of Ban Tham Sua goes into Kaeng Krachan Subdistrict / Kaeng Krachan District to the whole of Phetchaburi Province.

Discussion

Research on tree bank management schemes for the environment and household economy showed three tree bank models which discussed as follows:

1. The results showed that the three ecological tree bank management schemes were similar in using organic fertilizers in their plots and combined tree plantings including planting 3 forests, 4 benefits, and reducing carbon emissions. This is in line with the research results of Dirk Sarath (2020) which found that soil and air moist improved the environment, increased biodiversity, become an important natural food source. The results of the study indicated that the cultivation of trees for the restoration of rural ecosystems would successful be consistent with the community context and meet the needs of the villagers. There are supported by agencies that appropriated and operated continuously.

2. The results showed that the three household economic tree bank management schemes had the same characteristics; charcoal burning/wood vinegar collection/tree seedling/carbon credit/leaf soil/learning/homestay/tourist attraction. It was found that trees became more important and potential for savings and safety for the poor and to use in emergency response, among other things, investing the poor in safe and complete ownership of trees with the right to harvest, cut and sell, similar to the withdrawal rights of depositors in the Government Savings Bank.

Acknowledgements

The author would like to thank Dr. Krirk Meemongkit, President of Khao Chakan Agroforestry Bank, Khao Chakan Subdistrict, Khao Chakan District, Sa Kaeo Province, Mr. Suthep Pimsiri, Chairman of the Ban Tham Suea Tree Bank, Kaeng Krachan Subdistrict, Kaeng Krachan District, Phetchaburi Province. and Mr. Chairat Wankaew, chairman of Ban Khlong Ruea Tree Bank, Pak Song Subdistrict, Phato District, Chumphon Province, who provided information on the study of the model tree bank. The research team would like to express their gratitude.

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