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Student Progress Report

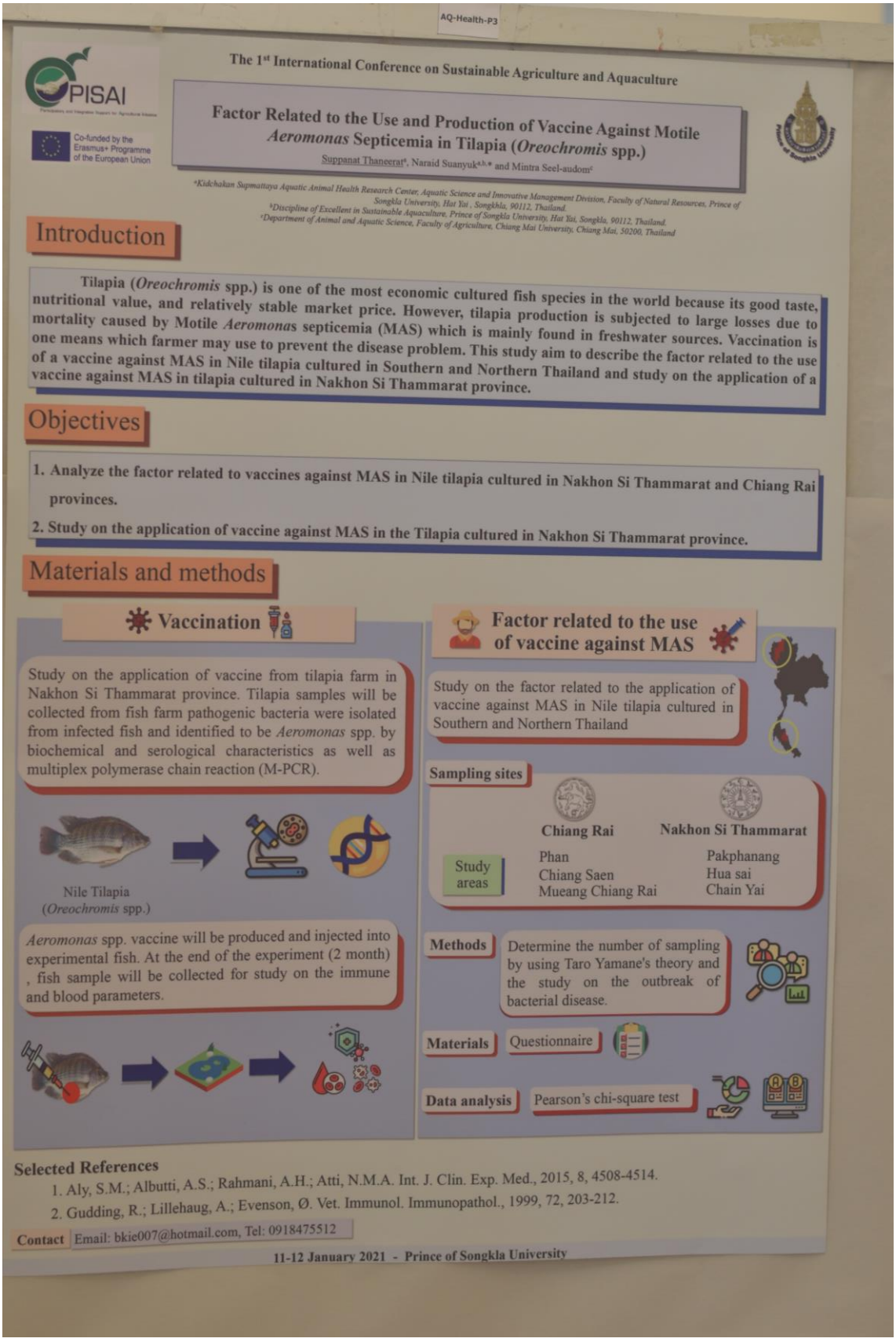
PISAI Project - Academic Year 2019

Prince of Songkla University

1. Mr. Suppanat Thaneerat

Home University: Prince of Songkla University

Host University: Chiang Mai University



2. Miss Sudarat Chantakam

Home University: Prince of Songkla University

Host University: Chiang Mai University

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The 1st International Conference on Sustainable Agriculture and Aquaculture

Uses of para-rubber seed kernel protein in feed on growth performance and feed utilization in red claw crayfish (*Cherax quadricarinatus*)

Sudarat Chantakam [1*], Chutima Tantikitti [1] and Suppasil Maneerat [2]

[1] *Aquatic Science and Innovative Management Division, Faculty of Natural Resources, Prince of Songkla University, Songkla 90112, Thailand.*

[2] *Department of Industrial Biotechnology, Faculty of Agro-Industry, Prince of Songkla University, Songkla 90112, Thailand.*

Introduction

Para-rubber is an important economic crop in Thailand having a yield of about 675 million kilograms of its seeds per year. However, only 25% of the yield is being utilized and the rest will be left to spoil. Alternatively, the para-rubber seed kernel can be used as an ingredient in animal feed such as in *Labeo rohita* (Sharma *et al.* 2014), *Cyprinus carpio* and *Pangasius pangasius* feed.

Red claw crayfish (*C. quadricarinatus*) is a new economic animal that is seriously lacking in important knowledge, especially nutritional aspect. In natural habitat, red claw crayfish feeds on a variety of items both plant and animal origin. Therefore, it is possible that it can utilize protein in the rubber kernel for growth.

This study aims to explore the utilization of para-rubber seed kernel in red claw crayfish feed by three-step processing to remove the toxin and improve nutritional quality before incorporating into the diet.

Table 1 The nutritional composition of para-rubber seed kernel

Composition (% Dry Weight)	UPRSK[1]	BPRSK	BOPRSK	FPRSK
Moisture	7.23	3.79	4.90	5.60
Protein	20.11	20.47	25.50	34.48
Lipid	34.10	44.19	39.61	20.35
Fiber	-	-	-	3.81
Ash	3.51	0.93	1.91	5.12
Cyanide (mg/kg)	649.16	86.98	-	62.34

Source: (1) Sample analysis data (2) Aguihe *et al.* (2017)

***URSK: Unprocessed para-rubber seed kernel

BRSK: Boiled para-rubber seed kernel

BORSK: Boiled and oil press para-rubber seed kernel

FRAK: Fermented para-rubber seed kernel

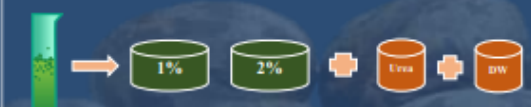
Materials and Methods

Step 1: Boiled and oil-pressed preparation

Para-rubber seed → Para-rubber Seed kernel → Boiled seed kernel → Oil-pressed seed kernel

Separating the para-rubber seed kernel, boiling for 30 min and drying with hot air to remove moisture , then oil-pressing and keeping at -20° C

Step 2 : Fermentation with *Aspergillus oryzae*



A. oryzae → Boiled and oil-pressed kernel (BORSK)

Adding *A. oryzae* solution 1% and 2% (w/v), then adding 0.75 % urea (calculated form BORSK weight) and 200 mL distilled water (DW), fermented for 4 days at room temperature.

The proximate composition is analyzed and the best sample treatments will be further fermented with yeast.

Step 3 : Fermentation with *Saccharomyces cerevisiae*

Testing suitable yeast concentration for fermentation 2, 3, 4 and 5 g

Testing suitable sugar concentration for fermentation 0.2, 0.3, 0.4 and 0.5 g

Testing suitable distilled water level for fermentation 40, 50, 60 and 70 mL

Testing suitable fermentation time 24, 48 and 72 h.

Feeding trial in red claw crayfish

The processed seed kernel will then be applied as an ingredient for fish meal replacement at 0, 25, 50, 75 and 100% in feed

Feed → 9 shrimps / tank

The experiment consists of 11 treatments, 5 replications (total of 55 units).

Evaluating effects on growth and feed utilization: including growth performance, feed utilization, chemical composition, pathological tissue changes, hematological changes, digestibility, digestive enzyme activity, water quality. Cost and economic return index will be determined at the end of growth trial.

Expected Benefits

The results of the study can be applied for development of red claw crayfish feed, value added para-rubber seed products and helping increase a good return for the farmers.

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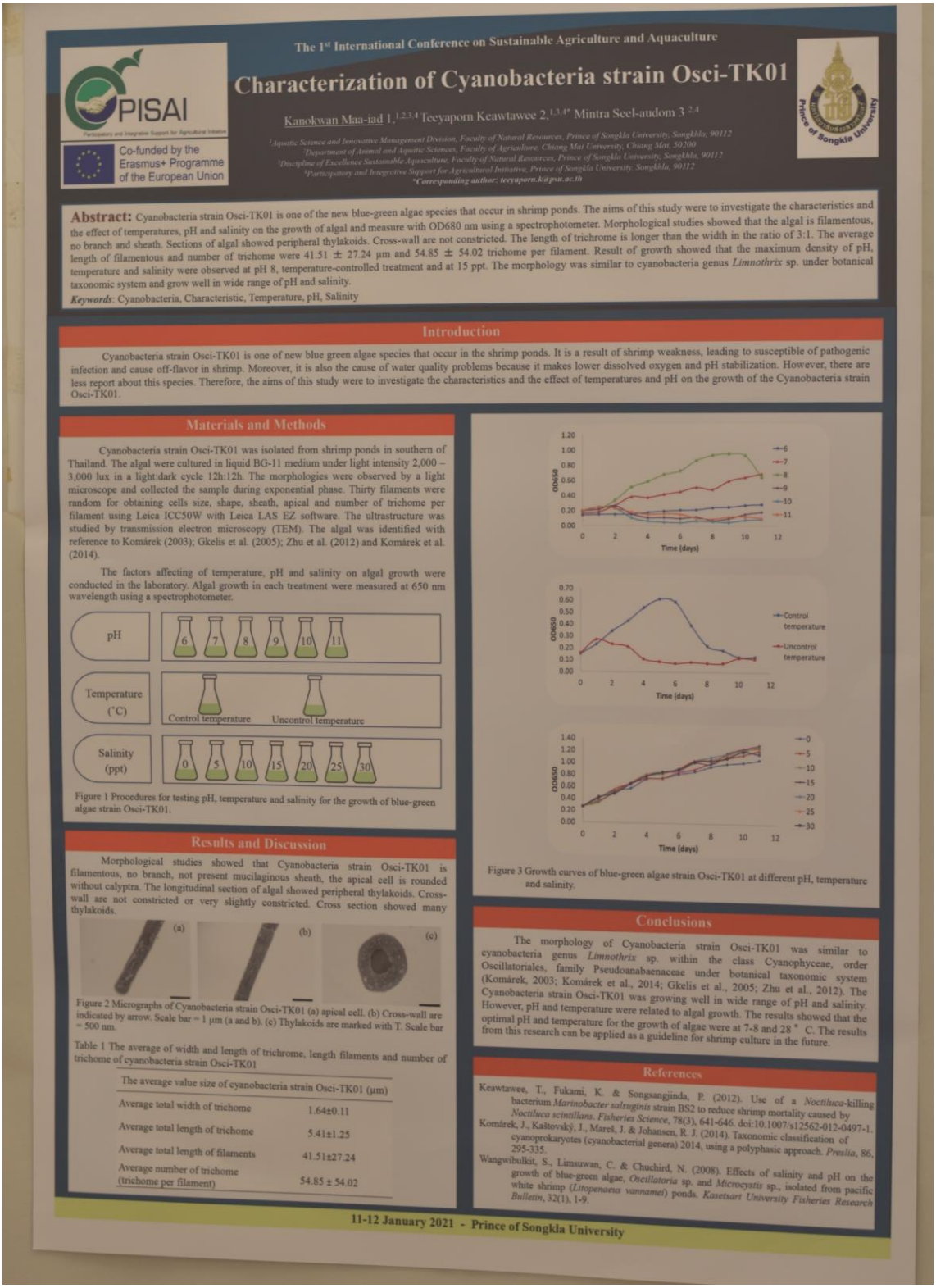
Contact e-mail address : Chantakam.S@gmail.com

3. Miss Kanokwan Maaiad

Home University: Prince of Songkla University

Host University: Chiang Mai University



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Characterization of Cyanobacteria strain Osci-TK01

Kanokwan Maa-iad 1,[1,2,3,4] Teeyaporn Keawtawee 2,[1,3,4*] Mintra Seel-audom 3 [2,4]

[1]Aquatic Science and Innovative Management Division, Faculty of Natural Resources, Prince of Songkla University, Songkhla, 90112
[2]Department of Animal and Aquatic Sciences, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200
[3]Discipline of Excellence Sustainable Aquaculture, Faculty of Natural Resources, Prince of Songkla University, Songkhla, 90112
[4]Participatory and Integrative Support for Agricultural Initiative, Prince of Songkla University, Songkhla, 90112
*Corresponding author: teeyaporn.k@psu.ac.th

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Abstract: Cyanobacteria strain Osci-TK01 is one of the new blue-green algae species that occur in shrimp ponds. The aims of this study were to investigate the characteristics and the effect of temperatures, pH and salinity on the growth of algal and measure with OD680 nm using a spectrophotometer. Morphological studies showed that the algal is filamentous, no branch and sheath. Sections of algal showed peripheral thylakoids. Cross-wall are not constricted. The length of trichrome is longer than the width in the ratio of 3:1. The average length of filamentous and number of trichome were 41.51 ± 27.24 µm and 54.85 ± 54.02 trichome per filament. Result of growth showed that the maximum density of pH, temperature and salinity were observed at pH 8, temperature-controlled treatment and at 15 ppt. The morphology was similar to cyanobacteria genus *Limnothrix* sp. under botanical taxonomic system and grow well in wide range of pH and salinity.

Keywords: Cyanobacteria, Characteristic, Temperature, pH, Salinity

Introduction

Cyanobacteria strain Osci-TK01 is one of new blue green algae species that occur in the shrimp ponds. It is a result of shrimp weakness, leading to susceptible of pathogenic infection and cause off-flavor in shrimp. Moreover, it is also the cause of water quality problems because it makes lower dissolved oxygen and pH stabilization. However, there are less report about this species. Therefore, the aims of this study were to investigate the characteristics and the effect of temperatures and pH on the growth of the Cyanobacteria strain Osci-TK01.

Materials and Methods

Cyanobacteria strain Osci-TK01 was isolated from shrimp ponds in southern of Thailand. The algal were cultured in liquid BG-11 medium under light intensity 2,000 – 3,000 lux in a light:dark cycle 12h:12h. The morphologies were observed by a light microscope and collected the sample during exponential phase. Thirty filaments were random for obtaining cells size, shape, sheath, apical and number of trichome per filament using Leica ICC50W with Leica LAS EZ software. The ultrastructure was studied by transmission electron microscopy (TEM). The algal was identified with reference to Komárek (2003); Gkelis et al. (2005); Zhu et al. (2012) and Komárek et al. (2014).

The factors affecting of temperature, pH and salinity on algal growth were conducted in the laboratory. Algal growth in each treatment were measured at 650 nm wavelength using a spectrophotometer.

Figure 1 Procedures for testing pH, temperature and salinity for the growth of blue-green algae strain Osci-TK01.

Results and Discussion

Morphological studies showed that Cyanobacteria strain Osci-TK01 is filamentous, no branch, not present mucilaginous sheath, the apical cell is rounded without calyptra. The longitudinal section of algal showed peripheral thylakoids. Cross-wall are not constricted or very slightly constricted. Cross section showed many thylakoids.

Figure 2 Micrographs of Cyanobacteria strain Osci-TK01 (a) apical cell. (b) Cross-wall are indicated by arrow. Scale bar = 1 µm (a and b). (c) Thylakoids are marked with T. Scale bar = 500 nm.

Table 1 The average of width and length of trichrome, length filaments and number of trichome of cyanobacteria strain Osci-TK01

The average value size of cyanobacteria strain Osci-TK01 (µm)	
Average total width of trichome	1.64±0.11
Average total length of trichome	5.41±1.25
Average total length of filaments	41.51±27.24
Average number of trichome (trichome per filament)	54.85 ± 54.02

Figure 3 Growth curves of blue-green algae strain Osci-TK01 at different pH, temperature and salinity.

Conclusions

The morphology of Cyanobacteria strain Osci-TK01 was similar to cyanobacteria genus *Limnothrix* sp. within the class Cyanophyceae, order Oscillatoriales, family Pseudoanabaenaceae under botanical taxonomic system (Komárek, 2003; Komárek et al., 2014; Gkelis et al., 2005; Zhu et al., 2012). The Cyanobacteria strain Osci-TK01 was growing well in wide range of pH and salinity. However, pH and temperature were related to algal growth. The results showed that the optimal pH and temperature for the growth of algae were at 7-8 and 28 ° C. The results from this research can be applied as a guideline for shrimp culture in the future.

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Kasetsart University

4. Miss Phornthawon Phanbut

Home University: Kasetsart University

Host University: Prince of Songkla University

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Surveys and Characterization of Plant-parasitic Nematodes Associated with Medicinal Plants

Phornthawon Phanbut,[1] Buncha Chinnasri,[1*] Anongnuch Sasnarukkit,[1] Thanunchanok Chairin [2]

[1]*Department of Plant Pathology, Faculty of Agriculture, Kasetsart University, Bangkok, 10900, Thailand. E-mail: phornthawon.ph@ku.th*

[2]*Department of Pest Management, Faculty of Natural Resource, Prince of Songkla University, Hat Yai, 90110, Thailand. *Corresponding Author*

Introduction

Millions of people around the world depend on medicinal plants for their well-being. In the tropics, medicinal plants are often used on a regular basis, especially in rural communities where modern pharmaceuticals are hard to obtain or even unavailable. Medicinal plants are important for people, not only as a primary source of medicines but also as phytochemical building blocks for development of new drugs (Fabricant and Farnsworth, 2001). Thailand is rich in medicinal plants in nature and has a long history of utilization of these valuable crops in various ways; for example as traditional medicines or in culinary purposes. Plant-parasitic nematodes are one of the most significant threats to the growth and the quality of medicinal plants. Turaganivalu *et al*. (2013) reported that plant-parasitic nematodes such as *Meloidogyne* spp., *Radopholus* spp.,*Pratylenchus* spp. and *Helicotylenchus* spp. were found associated with medicinal plants. Therefore, in this current research project, focuses have been placed on determining the impact and the characterization of plant-parasitic nematodes in Thai medicinal plants.

Materials and Methods

Study area and soil sampling

Surveys were conducted in Phu Phan district of Sakon Nakorn province during February 2020. Soil samples were randomly collected from the rhizosphere of *Curcuma longa* L., *Curcuma mangga* Valeton & Zijp, *Kaempferia parviflora*, *Boesenbergia rotunda* (L.) Mansf, *Centella asiatica*, *Zingiber montanum*, *Persicaria odorata*, *Morinda citrifolia* L., *Indigofera tinctoria* and *Melientha suavis*.

Nematode extraction

Nematodes were extracted from 200 g soil using the Cobb's Sieving and Decantation and the Modified Baermann's Funnel technique (Tomar *et al*., 2006). Nematodes were retrieved from the funnels after 48 hours.

3. Morphological analyses

All the plant-parasitic nematodes from each extracted sample were counted and identified to their genus level, based on stoma and pharyngeal morphology (Baniyamuddin *et al*., 2007), under a stereo-microscope, SZ-PT, Olympus, Japan with a cannon digital camera 750D.

4. Statistical analysis

Nematode data collected from different medicinal crops were compared and statistically analysed using the analysis of variance (ANOVA) technique (Cochran *et al*., 1965).

Table 1 Plant-parasitic nematodes extracted from soil samples (200 g) collected from medicinal plants in Phu Phan district of Sakon Nakhon province.

Medicinal plants	*Meloidogyne*	*Helicotylenchus*	*Tylenchorhynchus*
Curcuma longa	3^{a}	0^{a}	2^{a}
Curcuma mangga Valeton & Zijp	1^{a}	0^{a}	14^{b}
Centella asiatica	12^{b}	0^{a}	0^{a}
Zingiber montanum	2^{a}	0^{a}	0^{a}
Kaempferia parviflora	0^{a}	1^{a}	3^{a}
Boesenbergia rotunda	0^{a}	0^{a}	2^{a}
Persicaria odorata	5^{ab}	22^{b}	0^{a}
Morinda citrifolia	1^{a}	0^{a}	0^{a}
Indigofera tinctoria	1^{a}	0^{a}	0^{a}
Melientha suavis	0^{a}	1^{a}	0^{a}

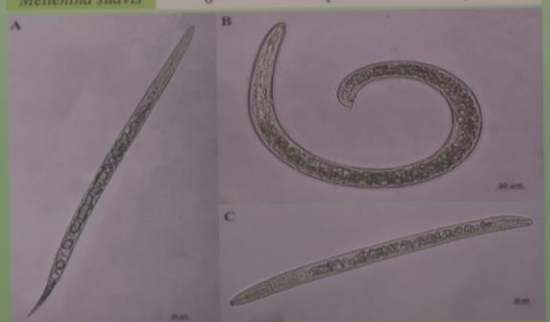

Figure 1 Photographs of *Meloidogyne* (A), *Helicotylenchus* (B) and *Tylenchorhynchus* (C) extracted from 200 g soil.

Results and Discussion

Three nematode genera including *Meloidogyne (Fig.1A)*, *Helicotylenchus (Fig.1B)* and *Tylenchorhynchus (Fig.1C)* were found associated with these medicinal plants (Table 1). *Meloidogyne* spp. was the most prevalent and observed at high densities in soil collected from *Centella asiatica*. Furthermore, the medicinal plant *Persicaria odorata* was shown to harbour highest number of plant-parasitic nematodes, followed by *Curcuma mangga* Valeton & Zijp, and *Centella asiatica*, respectively. These results were similar to Mohanta *et al*. (2015) which reported *Meloidogyne incognita* infecting in medicinal plants.

Conclusions

Plant-parasitic nematodes found in medicinal plants from these surveys included *Meloidogyne*, *Helicotylenchus* and *Tylenchorhynchus*. Further studies are needed to determine the effects of plant-parasitic nematodes on the yield and the pharmaceutical properties of some medicinal plants.

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Chiang Mai University

5. Miss Jirattikan Yontawong

Home University: Chiang Mai University

Host University: Prince of Songkla University

The 1st International Conference on Sustainable Agriculture and Aquaculture

Supply chain management of rice cultivars in Chiang Mai and Phatthalung Provinces

Jirattikan Yontawong[1*], Pornsiri Suebpongsung[1] and Ayut Nissapa[2]

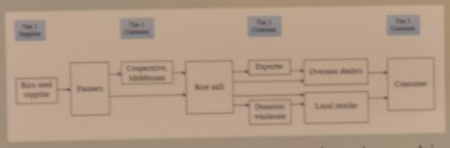
[1] Department of Agricultural Economy and Development, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200, Thailand.

[2] Department of Agricultural Development, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200, Thailand.

* Corresponding author, Email address: jirattikan.np@gmail.com

Introduction

Rice has been the main economic crop of Thailand and it has been the staple food crop of Thai people for a long time. Thailand has approximately 10 million tons of rice exported annually. On average, Thailand can produce about 28-32 million tons of rice per year. The Rice Department (2020) said that in the rice supply chain of Thailand there is still a problem with rice prices in the market that fluctuates, lack of planning and control of raw materials for rice production, trade barriers and natural disaster etc. The Thai rice supply chain is shown in Figure 1.

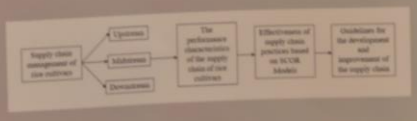


Recent research studies on the rice cultivars supply chain have found many problems such as operations under the supply chain are not very good, the quantity of products in each level is insufficient to meet the demand and the product is damaged during storage. Rice cultivars are a variety of rice that is cultivated either native or local. Rice cultivars are characterized by its resistance to diseases and pests, can adapt well to the environment.

The researcher is therefore interested to study the current situation of the linkage of indigenous rice varieties from the production process to the consumers in the supply chain. The main objective of this paper is to study the management processes of the local rice supply chain to compare between Chiang Mai and Phatthalung Provinces.

Conceptual framework

This study conducted interviews with the sample community enterprise groups on general characteristics of farmers. Process of farmers' production and marketing, including problems and obstacles that arise.



Methodology

Population and sample

The demographic groups are local rice-producing community enterprises in Chiang Mai and Phatthalung provinces. There is a Purposive Selection method selected from a group of farmers with support agencies to develop marketing potential. Divided into 2 areas: 8 community enterprises of rice cultivars in Chiang Mai province and 28 community enterprises of rice cultivars in Phatthalung.

For those with other supply chain stakeholders, including aggregators/middlemen and relevant government agencies, the snowball sampling method is used.

Tools for data collection

Quantitative Research: The Semi-Structure Interview was used to interview the sample farmers. It consists of a set of questions to choose from (Close-Ended Question) and question for respondents to express their opinions (Open-Ended question).

Qualitative Research: Open-ended questions are used as themes for In-depth Interview and Focus Group for key Informants.

Data collection

Primary data: Collect information from representatives, community enterprises and stakeholders.

Secondary Data: Information obtained from studying documents related to research.

Data analysis

Step 1: Study the general characteristics of farmers, production, marketing, problems and barrier by using descriptive statistics

Step 2: Study the activities that occur in the supply chain according to the principle of the SCOR Model.

Step 3: To propose the development and improvement of the supply chain

Conclusions

The analysis of the supply chain management of rice cultivars with the SCOR Model demonstrates the continuity of operations from planning, sourcing, making, delivering, returning and enabling from the upstream, middle and downstream levels.

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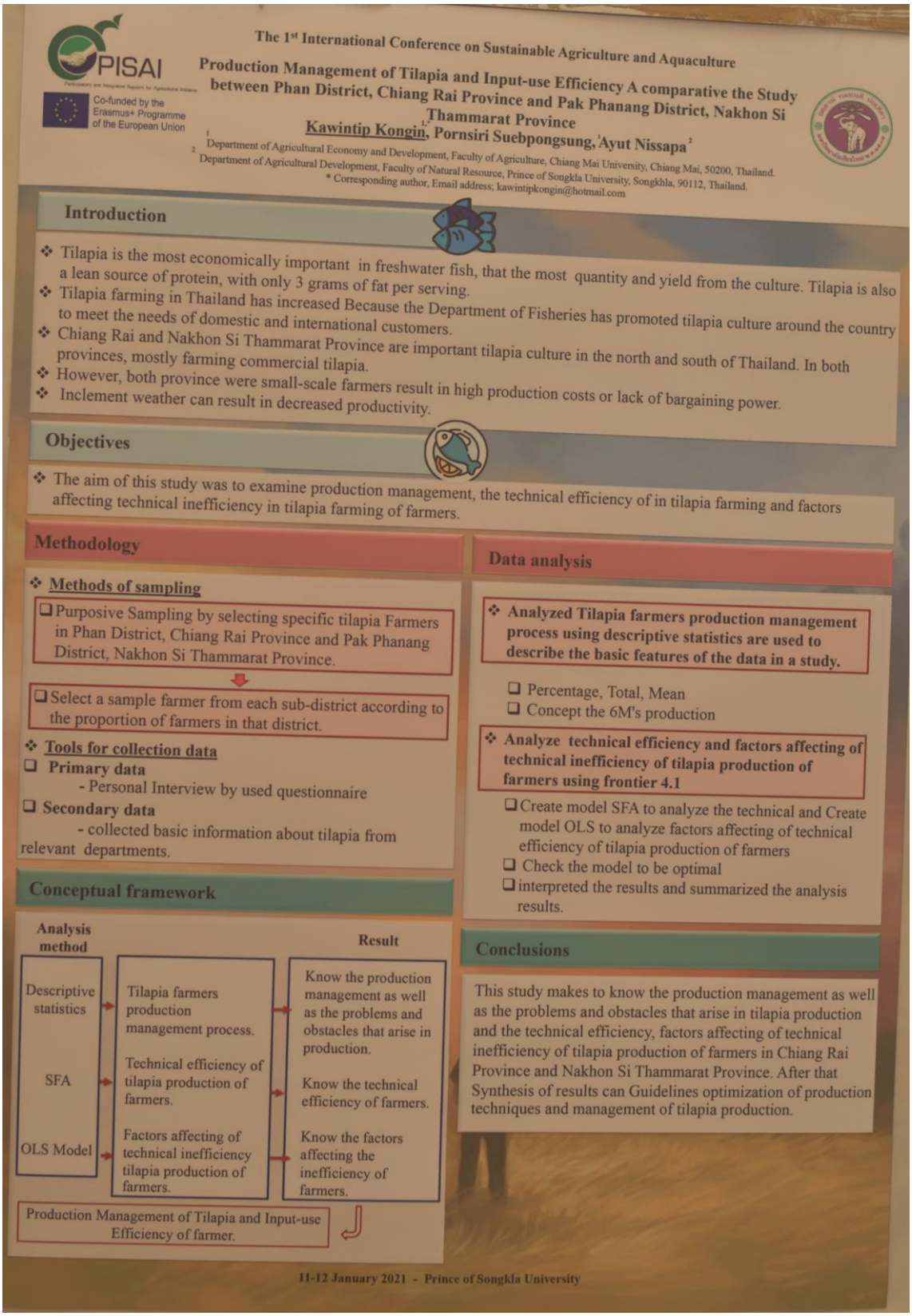
6. Miss Kawintip Kongin

Home University: Chiang Mai University

Host University: Prince of Songkla University



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Production Management of Tilapia and Input-use Efficiency A comparative the Study between Phan District, Chiang Rai Province and Pak Phanang District, Nakhon Si Thammarat Province

Kawintip Kongin[1,*], Pornsiri Suebpongsung,[1] Ayut Nissapa[2]

[1] Department of Agricultural Economy and Development, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200, Thailand.

[2] Department of Agricultural Development, Faculty of Natural Resource, Prince of Songkla University, Songkhla, 90112, Thailand.

* Corresponding author, Email address; kawintipkongin@hotmail.com

Introduction

- Tilapia is the most economically important in freshwater fish, that the most quantity and yield from the culture. Tilapia is also a lean source of protein, with only 3 grams of fat per serving.
- Tilapia farming in Thailand has increased Because the Department of Fisheries has promoted tilapia culture around the country to meet the needs of domestic and international customers.
- Chiang Rai and Nakhon Si Thammarat Province are important tilapia culture in the north and south of Thailand. In both provinces, mostly farming commercial tilapia.
- However, both province were small-scale farmers result in high production costs or lack of bargaining power.
- Inclement weather can result in decreased productivity.

Objectives

- The aim of this study was to examine production management, the technical efficiency of in tilapia farming and factors affecting technical inefficiency in tilapia farming of farmers.

Methodology

- **Methods of sampling**
  - Purposive Sampling by selecting specific tilapia Farmers in Phan District, Chiang Rai Province and Pak Phanang District, Nakhon Si Thammarat Province.
  - Select a sample farmer from each sub-district according to the proportion of farmers in that district.
- **Tools for collection data**
  - **Primary data**
    - Personal Interview by used questionnaire
  - **Secondary data**
    - collected basic information about tilapia from relevant departments.

Data analysis

- **Analyzed Tilapia farmers production management process using descriptive statistics are used to describe the basic features of the data in a study.**
  - Percentage, Total, Mean
  - Concept the 6M's production
- **Analyze technical efficiency and factors affecting of technical inefficiency of tilapia production of farmers using frontier 4.1**
  - Create model SFA to analyze the technical and Create model OLS to analyze factors affecting of technical efficiency of tilapia production of farmers
  - Check the model to be optimal
  - interpreted the results and summarized the analysis results.

Conceptual framework

Analysis method		Result
Descriptive statistics	Tilapia farmers production management process.	Know the production management as well as the problems and obstacles that arise in production.
SFA	Technical efficiency of tilapia production of farmers.	Know the technical efficiency of farmers.
OLS Model	Factors affecting of technical inefficiency tilapia production of farmers.	Know the factors affecting the inefficiency of farmers.

Production Management of Tilapia and Input-use Efficiency of farmer.

Conclusions

This study makes to know the production management as well as the problems and obstacles that arise in tilapia production and the technical efficiency, factors affecting of technical inefficiency of tilapia production of farmers in Chiang Rai Province and Nakhon Si Thammarat Province. After that Synthesis of results can Guidelines optimization of production techniques and management of tilapia production.

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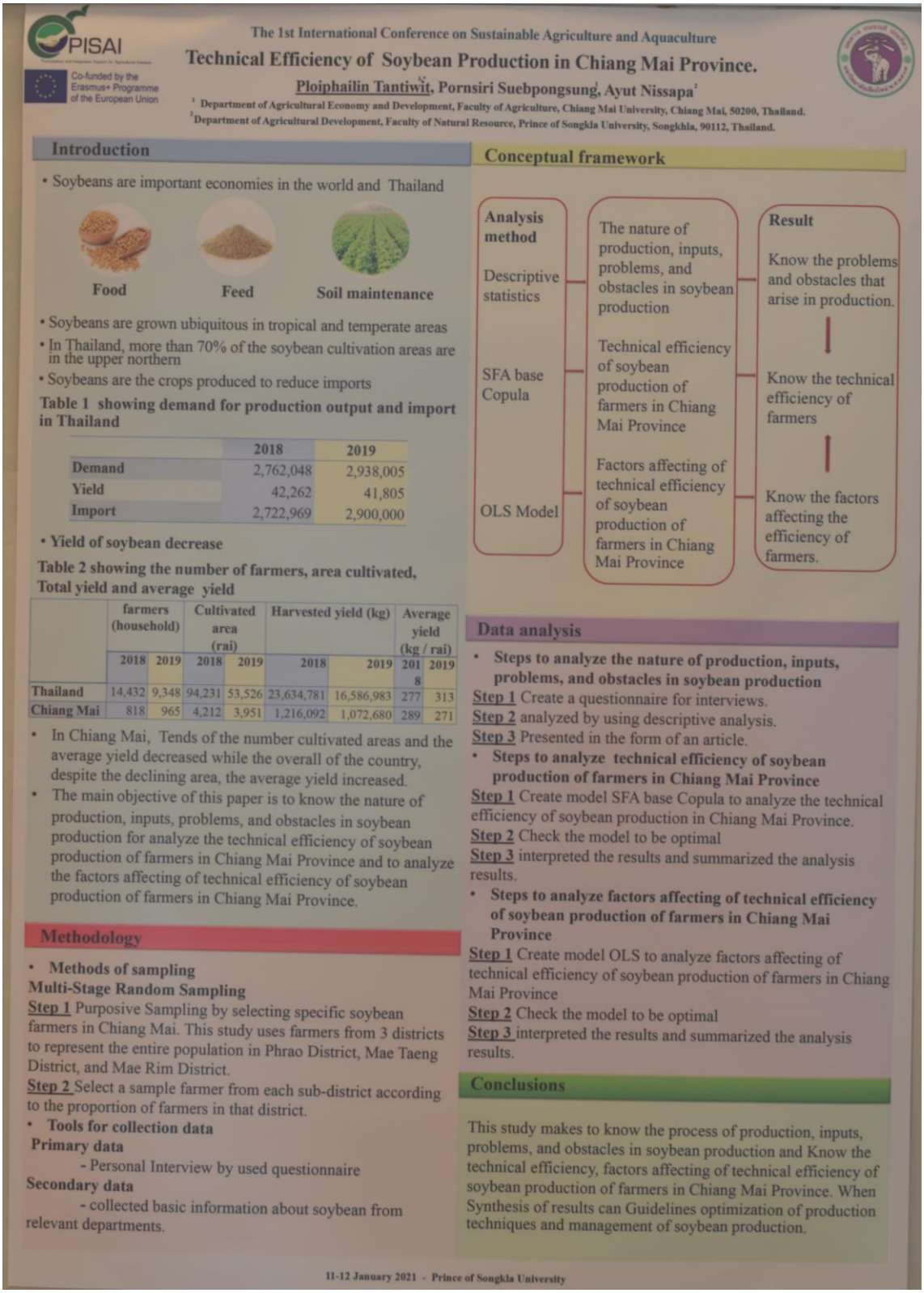
7. Miss Ploiphailin Tantiwit

Home University: Chiang Mai University

Host University: Prince of Songkla University



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The 1st International Conference on Sustainable Agriculture and Aquaculture

Technical Efficiency of Soybean Production in Chiang Mai Province.

Ploiphailin Tantiwit[1*], Pornsiri Suebpongsung[1], Ayut Nissapa[2]

[1] Department of Agricultural Economy and Development, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200, Thailand.

[2] Department of Agricultural Development, Faculty of Natural Resource, Prince of Songkla University, Songkhla, 90112, Thailand.

Introduction

- Soybeans are important economies in the world and Thailand

Food | Feed | Soil maintenance

- Soybeans are grown ubiquitous in tropical and temperate areas
- In Thailand, more than 70% of the soybean cultivation areas are in the upper northern
- Soybeans are the crops produced to reduce imports

Table 1 showing demand for production output and import in Thailand

	2018	2019
Demand	2,762,048	2,938,005
Yield	42,262	41,805
Import	2,722,969	2,900,000

- **Yield of soybean decrease**

Table 2 showing the number of farmers, area cultivated, Total yield and average yield

	farmers (household)		Cultivated area (rai)		Harvested yield (kg)		Average yield (kg / rai)	
	2018	2019	2018	2019	2018	2019	2018	2019
Thailand	14,432	9,348	94,231	53,526	23,634,781	16,586,983	277	313
Chiang Mai	818	965	4,212	3,951	1,216,092	1,072,680	289	271

- In Chiang Mai, Tends of the number cultivated areas and the average yield decreased while the overall of the country, despite the declining area, the average yield increased.
- The main objective of this paper is to know the nature of production, inputs, problems, and obstacles in soybean production for analyze the technical efficiency of soybean production of farmers in Chiang Mai Province and to analyze the factors affecting of technical efficiency of soybean production of farmers in Chiang Mai Province.

Methodology

- **Methods of sampling**

Multi-Stage Random Sampling

Step 1 Purposive Sampling by selecting specific soybean farmers in Chiang Mai. This study uses farmers from 3 districts to represent the entire population in Phrao District, Mae Taeng District, and Mae Rim District.

Step 2 Select a sample farmer from each sub-district according to the proportion of farmers in that district.

- **Tools for collection data**

Primary data

- Personal Interview by used questionnaire

Secondary data

- collected basic information about soybean from relevant departments.

Conceptual framework

Data analysis

- **Steps to analyze the nature of production, inputs, problems, and obstacles in soybean production**

Step 1 Create a questionnaire for interviews.
Step 2 analyzed by using descriptive analysis.
Step 3 Presented in the form of an article.

- **Steps to analyze technical efficiency of soybean production of farmers in Chiang Mai Province**

Step 1 Create model SFA base Copula to analyze the technical efficiency of soybean production in Chiang Mai Province.
Step 2 Check the model to be optimal
Step 3 interpreted the results and summarized the analysis results.

- **Steps to analyze factors affecting of technical efficiency of soybean production of farmers in Chiang Mai Province**

Step 1 Create model OLS to analyze factors affecting of technical efficiency of soybean production of farmers in Chiang Mai Province
Step 2 Check the model to be optimal
Step 3 interpreted the results and summarized the analysis results.

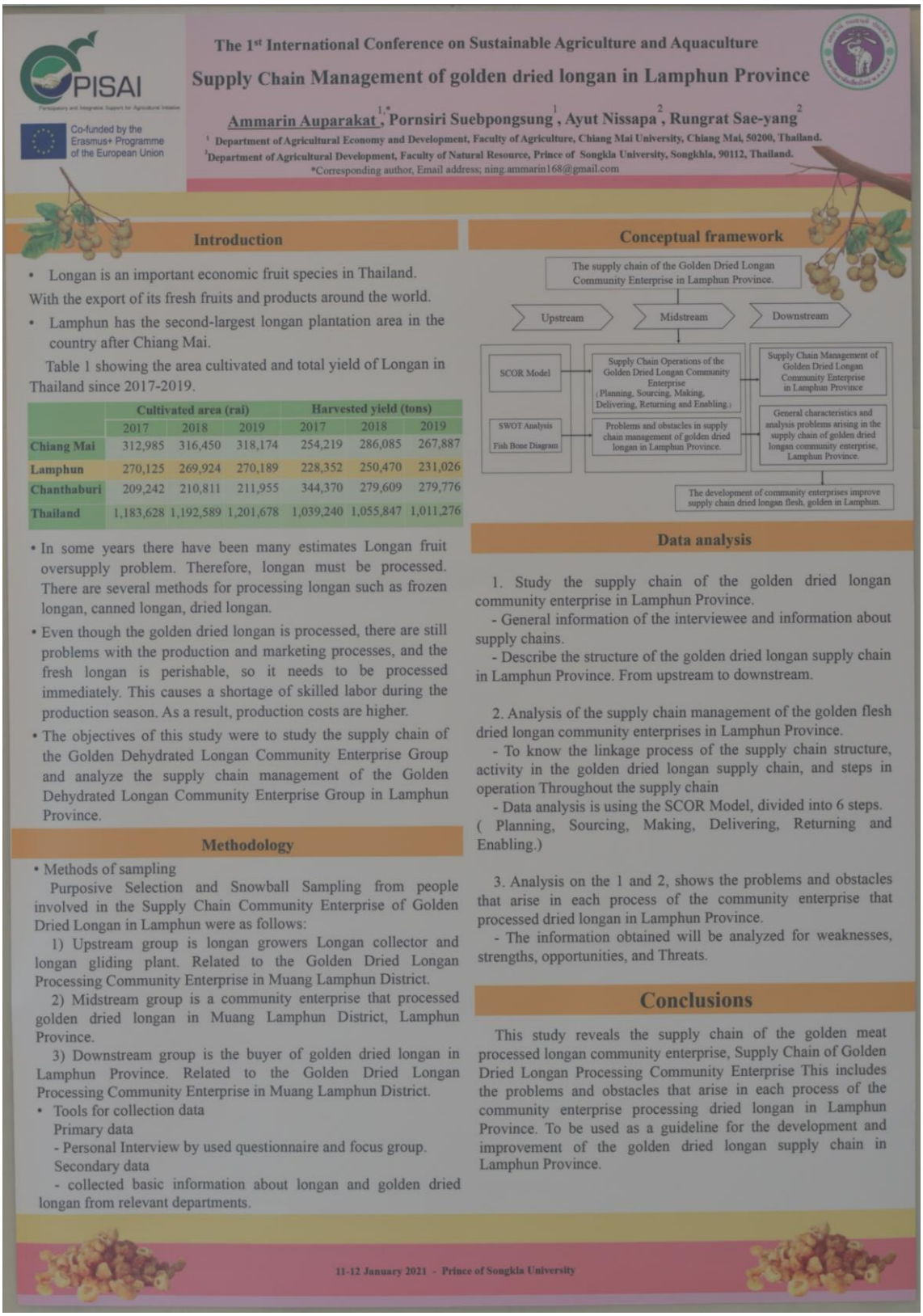
Conclusions

This study makes to know the process of production, inputs, problems, and obstacles in soybean production and Know the technical efficiency, factors affecting of technical efficiency of soybean production of farmers in Chiang Mai Province. When Synthesis of results can Guidelines optimization of production techniques and management of soybean production.

8. Miss Ammarin Auparakan

Home University: Chiang Mai University

Host University: Prince of Songkla University



The 1st International Conference on Sustainable Agriculture and Aquaculture

Supply Chain Management of golden dried longan in Lamphun Province

Ammarin Auparakat[1,*], Pornsiri Suebpongsung[1], Ayut Nissapa[2], Rungrat Sae-yang[2]

[1] Department of Agricultural Economy and Development, Faculty of Agriculture, Chiang Mai University, Chiang Mai, 50200, Thailand.

[2]Department of Agricultural Development, Faculty of Natural Resource, Prince of Songkla University, Songkhla, 90112, Thailand.

*Corresponding author, Email address; ning.ammarin168@gmail.com

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Introduction

- Longan is an important economic fruit species in Thailand.

With the export of its fresh fruits and products around the world.

- Lamphun has the second-largest longan plantation area in the country after Chiang Mai.

Table 1 showing the area cultivated and total yield of Longan in Thailand since 2017-2019.

	Cultivated area (rai)			Harvested yield (tons)		
	2017	2018	2019	2017	2018	2019
Chiang Mai	312,985	316,450	318,174	254,219	286,085	267,887
Lamphun	270,125	269,924	270,189	228,352	250,470	231,026
Chanthaburi	209,242	210,811	211,955	344,370	279,609	279,776
Thailand	1,183,628	1,192,589	1,201,678	1,039,240	1,055,847	1,011,276

- In some years there have been many estimates Longan fruit oversupply problem. Therefore, longan must be processed. There are several methods for processing longan such as frozen longan, canned longan, dried longan.
- Even though the golden dried longan is processed, there are still problems with the production and marketing processes, and the fresh longan is perishable, so it needs to be processed immediately. This causes a shortage of skilled labor during the production season. As a result, production costs are higher.
- The objectives of this study were to study the supply chain of the Golden Dehydrated Longan Community Enterprise Group and analyze the supply chain management of the Golden Dehydrated Longan Community Enterprise Group in Lamphun Province.

Methodology

- Methods of sampling

Purposive Selection and Snowball Sampling from people involved in the Supply Chain Community Enterprise of Golden Dried Longan in Lamphun were as follows:

1) Upstream group is longan growers Longan collector and longan gliding plant. Related to the Golden Dried Longan Processing Community Enterprise in Muang Lamphun District.

2) Midstream group is a community enterprise that processed golden dried longan in Muang Lamphun District, Lamphun Province.

3) Downstream group is the buyer of golden dried longan in Lamphun Province. Related to the Golden Dried Longan Processing Community Enterprise in Muang Lamphun District.

- Tools for collection data

Primary data

- Personal Interview by used questionnaire and focus group.

Secondary data

- collected basic information about longan and golden dried longan from relevant departments.

Conceptual framework

Data analysis

1. Study the supply chain of the golden dried longan community enterprise in Lamphun Province.

- General information of the interviewee and information about supply chains.
- Describe the structure of the golden dried longan supply chain in Lamphun Province. From upstream to downstream.

2. Analysis of the supply chain management of the golden flesh dried longan community enterprises in Lamphun Province.

- To know the linkage process of the supply chain structure, activity in the golden dried longan supply chain, and steps in operation Throughout the supply chain
- Data analysis is using the SCOR Model, divided into 6 steps. (Planning, Sourcing, Making, Delivering, Returning and Enabling.)

3. Analysis on the 1 and 2, shows the problems and obstacles that arise in each process of the community enterprise that processed dried longan in Lamphun Province.

- The information obtained will be analyzed for weaknesses, strengths, opportunities, and Threats.

Conclusions

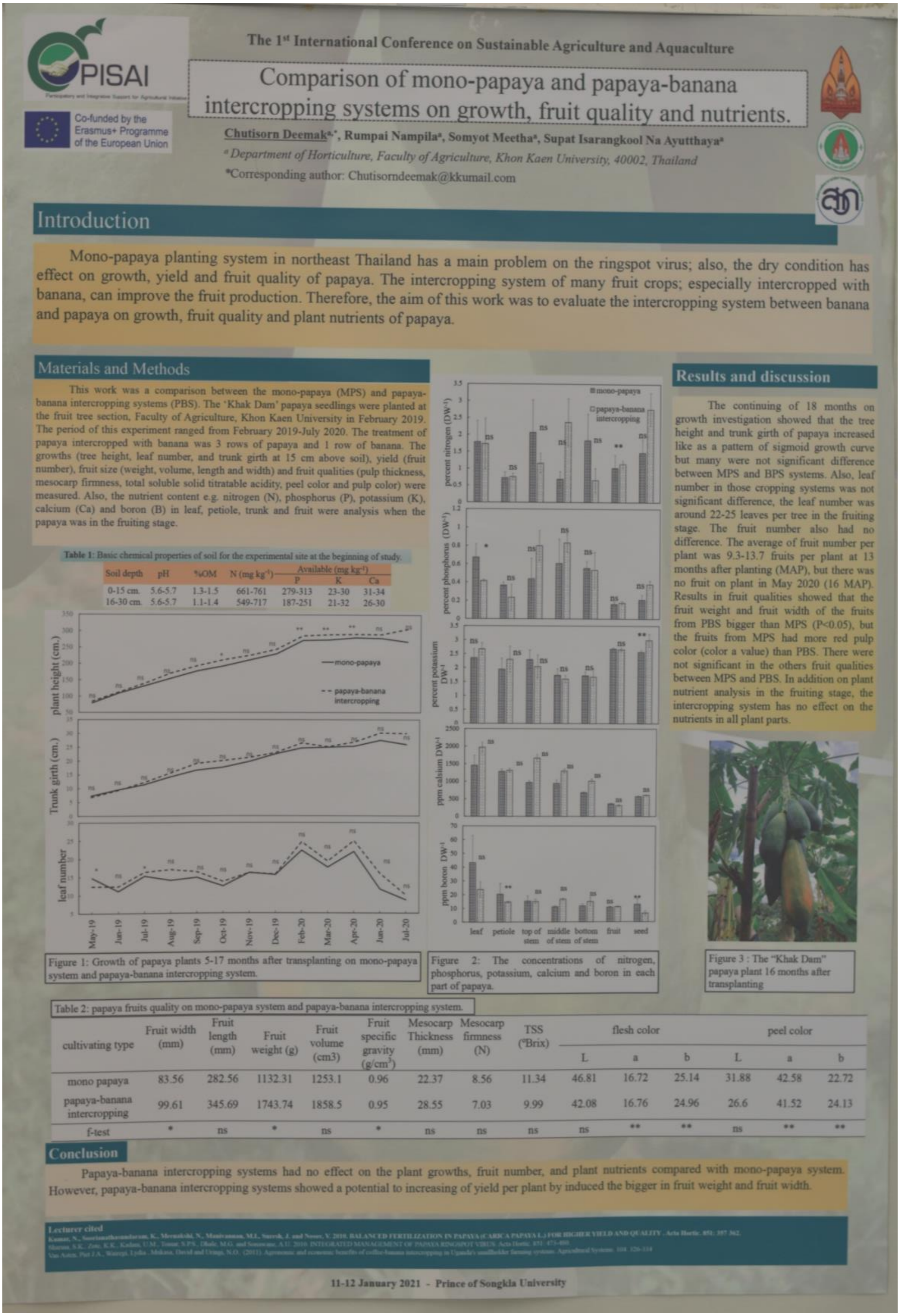
This study reveals the supply chain of the golden meat processed longan community enterprise, Supply Chain of Golden Dried Longan Processing Community Enterprise This includes the problems and obstacles that arise in each process of the community enterprise processing dried longan in Lamphun Province. To be used as a guideline for the development and improvement of the golden dried longan supply chain in Lamphun Province.

Khon Kaen University

9. Mr. Chutisorn Deemak

Home University: Khon Kaen University

Host University: Prince of Songkla University



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Comparison of mono-papaya and papaya-banana intercropping systems on growth, fruit quality and nutrients.

Chutisorn Deemak[a,*], Rumpai Nampila[a], Somyot Meetha[a], Supat Isarangkool Na Ayutthaya[a]

[a] Department of Horticulture, Faculty of Agriculture, Khon Kaen University, 40002, Thailand

*Corresponding author: Chutisorndeemak@kkumail.com

Introduction

Mono-papaya planting system in northeast Thailand has a main problem on the ringspot virus; also, the dry condition has effect on growth, yield and fruit quality of papaya. The intercropping system of many fruit crops; especially intercropped with banana, can improve the fruit production. Therefore, the aim of this work was to evaluate the intercropping system between banana and papaya on growth, fruit quality and plant nutrients of papaya.

Materials and Methods

This work was a comparison between the mono-papaya (MPS) and papaya-banana intercropping systems (PBS). The 'Khak Dam' papaya seedlings were planted at the fruit tree section, Faculty of Agriculture, Khon Kaen University in February 2019. The period of this experiment ranged from February 2019-July 2020. The treatment of papaya intercropped with banana was 3 rows of papaya and 1 row of banana. The growths (tree height, leaf number, and trunk girth at 15 cm above soil), yield (fruit number), fruit size (weight, volume, length and width) and fruit qualities (pulp thickness, mesocarp firmness, total soluble solid titratable acidity, peel color and pulp color) were measured. Also, the nutrient content e.g. nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and boron (B) in leaf, petiole, trunk and fruit were analysis when the papaya was in the fruiting stage.

Table 1: Basic chemical properties of soil for the experimental site at the beginning of study.

Soil depth	pH	%OM	N (mg kg^{-1})	Available (mg kg^{-1})		
				P	K	Ca
0-15 cm.	5.6-5.7	1.3-1.5	661-761	279-313	23-30	31-34
16-30 cm.	5.6-5.7	1.1-1.4	549-717	187-251	21-32	26-30

Figure 1: Growth of papaya plants 5-17 months after transplanting on mono-papaya system and papaya-banana intercropping system.

Figure 2: The concentrations of nitrogen, phosphorus, potassium, calcium and boron in each part of papaya.

Results and discussion

The continuing of 18 months on growth investigation showed that the tree height and trunk girth of papaya increased like as a pattern of sigmoid growth curve but many were not significant difference between MPS and BPS systems. Also, leaf number in those cropping systems was not significant difference, the leaf number was around 22-25 leaves per tree in the fruiting stage. The fruit number also had no difference. The average of fruit number per plant was 9.3-13.7 fruits per plant at 13 months after planting (MAP), but there was no fruit on plant in May 2020 (16 MAP). Results in fruit qualities showed that the fruit weight and fruit width of the fruits from PBS bigger than MPS (P<0.05), but the fruits from MPS had more red pulp color (color a value) than PBS. There were not significant in the others fruit qualities between MPS and PBS. In addition on plant nutrient analysis in the fruiting stage, the intercropping system has no effect on the nutrients in all plant parts.

Figure 3 : The "Khak Dam" papaya plant 16 months after transplanting

Table 2: papaya fruits quality on mono-papaya system and papaya-banana intercropping system.

cultivating type	Fruit width (mm)	Fruit length (mm)	Fruit weight (g)	Fruit volume (cm3)	Fruit specific gravity (g/cm^3)	Mesocarp Thickness (mm)	Mesocarp firmness (N)	TSS (°Brix)	flesh color			peel color		
									L	a	b	L	a	b
mono papaya	83.56	282.56	1132.31	1253.1	0.96	22.37	8.56	11.34	46.81	16.72	25.14	31.88	42.58	22.72
papaya-banana intercropping	99.61	345.69	1743.74	1858.5	0.95	28.55	7.03	9.99	42.08	16.76	24.96	26.6	41.52	24.13
f-test	*	ns	*	ns	*	ns	ns	ns	ns	**	**	ns	**	**

Conclusion

Papaya-banana intercropping systems had no effect on the plant growths, fruit number, and plant nutrients compared with mono-papaya system. However, papaya-banana intercropping systems showed a potential to increasing of yield per plant by induced the bigger in fruit weight and fruit width.

Lecturer cited

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