

BUILDING THE NEXT GENERATION OF TOMATO FARMERS IN NORTHEASTERN THAILAND

Abstract

The Third Royal Factory of Doi Kham has invested in many knowledgeable projects to better develop the local farmers' skills; however, the farmers' application of the provided farming technology was not as expected. The goal of the project is to design an educational method for the farmers at The Third Royal Factory of Doi Kham, based on precision farming and a compromise between the farmers' lifestyles and Doi Kham's expectations to develop 'smart farmers'. Through onsite observation, interview, research and data evaluation, four objectives are proposed: to understand the current ways of farming of the farmers under the contract of Doi Kham's Third Royal Factory, to evaluate the farmers' cooperation and relationship towards Doi Kham based on farmers' way of living and traditions, to identify suitable practices for local farmers depending on Doi Kham's farmer management and the advancement in their agricultural technology and to advocate farmers' agricultural knowledge and skills as a guideline to develop Doi Kham's smart farmers.

After an investigation at The Third Royal Factory, the team discovered that the local farmers' reliance mainly on past experiences and lack of active learner skills were the key factors to overcome. This resulted in the application of the suitable pH testing method for the farmers to easily follow and effectively optimize their farming expenses as the first step to becoming a new generation of smart farmers, along with the recommendations to Doi Kham on the emphasis on improving agricultural factors, the use of suitable measures of educational activities and future implementation plan.

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SMART FARMERS: AN IDEAL CHARACTERISTIC FOR SUSTAINABLE-LIVING FARMERS

Tomato farming in Northeastern Thailand is one of the most popular crops aside from rice and corn cultivation. However, the season of tomato farming begins in late September and lasts until February, which makes the Thai tomato market small in comparison to other crops that can be harvested throughout the year, and farmers will thereby have fewer opportunities to sell their products. Therefore, King Bhumibol Adulyadej (King Rama IX) established his goal to eradicate poverty and improve the quality of life for the people who lived in the Northeastern part of Thailand by establishing The Third Royal Factory (Tao Ngoi) and encouraging the local farmers to cultivate tomatoes as an extra source of income during the dry period of the year in Northeastern Thailand.

Doi Kham has numerous advanced technologies, such as a greenhouse, a parabola dome, and a global positioning system (GPS). These advanced technologies have been used to identify new suitable breeds and techniques for farmers. The conditions for growing tomatoes, such as suitable tomato breeds and the soil adjustment, will be supplied to local farmers seasonally.

After Doi Kham passed the know how on to the local farmers, it resulted in the farmers managing their farms more efficiently in that they are now able to increase yields whilst also reducing the expenditure spent on the fields. Moreover, Doi Kham holds meetings and demonstrates to local farmers on the usage of those technologies. As a result, local farmers are capable of using their newfound knowledge and technology to improve their production line and field efficiency. Lastly, Doi Kham consistently provides educational activities for local farmers in order to develop 'smart farmers'. However, key aspects of the educational activity, such as practicality and critical thinking, are still missing. Once they succeed in mastering practicality and critical thinking, the local farmers will have gained a better understanding and be better prepared to deal with any obstacles on their own.

The goal of this project is to develop the next generation of tomato farmers in Northeastern Thailand, where farmers are able to be active learners, whereby they engage in educational activities rather than passive listening. To accomplish the goal, the team needs to understand the current farming methods used by the farmers under the contract of Doi Kham's Third Royal Factory. From this, the team will conduct research and investigate Doi Kham's Third Royal Factory and local farmers. Additionally, the team needs to evaluate the farmers' cooperation and relationship towards Doi Kham based on the farmers' way of living and traditions by interviewing the Doi Kham local farmers and Doi Kham staffs to ascertain their points of view. Thirdly, the team will identify suitable practices for local farmers, depending on Doi Kham's farmer management and the advancement in their agricultural technology by investigating Doi Kham's farming technology in the Third Royal Factory based on the data obtained. Lastly, the team aims to advocate the farmers' agricultural knowledge and skills as a guideline to build Doi Kham's smart farmers by designing the educational activity, evaluating the educational activity result, and proposing a future plan to Doi Kham.

HISTORY OF DOIKHAM

Poverty in Northern Thailand is likely to be on the rise. King Bhumibol Adulyadej (Rama IX) established his goal to eradicate poverty and improve the quality of life of people in the Northern part of Thailand. Doi Kham Co., Ltd. was first established in 1972, aiming to support local farmers by buying agricultural products and processing them into affordable and organic goods¹. The vision of Doi Kham² is "being a role model social enterprise that develops products from local communities with global quality for the goodness of the community." The mission of the company was to improve the people, the organization, the production chain, and payment, as well as develop the community and the people towards sustainable development under the Sufficiency Economy and the King's Philosophies. The main objective of the project is not aimed to merely benefit Doi Kham, but rather to enhance and develop the local community.

Nowadays, there are three Royal Factories operated by Dokham – The First Royal Factory (Fang, Chiang Mai), The Second Royal Factory (Mae Chan, Chiang Rai), and The Third Royal Factory (Tao Ngoi, Sakon Nakhon)². Over 220 products are produced by DoiKham through the operation of 36 retail shops and 13 franchise stores in Thailand. The Third Royal Factory (Tao Ngoi) was established, and King Bhumibol Adulyadej (Rama IX) encouraged the plantation of tomatoes as an extra source of income during the dry period of the year in Northeastern Thailand. The tomatoes grown by farmers in Tao Ngoi, Sakon Nakhon are now being bought by Doi Kham. Hence, by applying King Bhumibol's sustainability philosophy, the food processing factory is able to help increase the income of farmers, and develop the economy in the province significantly.

PREVIOUS RESEACH

The research conducted by Doydee et al. (2014) was carried out in Tao Ngoi district, Sakon Nakhon Province. The major goal was to investigate the attitude of the small-scale farmers towards tomato farming. A total of 52 farmers were interviewed and identified through key informant interviews as a part of the site-specific and expert choice sampling populations. The findings revealed that the majority of farmers (78.80%) agreed to grow the tomatoes after receiving advice from local agricultural experts. The Third Royal Factory provided another way for the farmers to add to their income instead of relying solely on rice production.

The research showed that the farmers preferred to plant P89, the tomato breed that is suitable for the cool season, which begins in November and lasts until February as the P89 breed was found to develop faster than other tomato breeds. It has been found that the majority of the farmers use their own funds for tomato cultivation, with an estimated cost of 5,800 Baht per rai (1,600 square meters). Therefore, the Third Royal Factory came to assist the local farmers in enhancing the quantity and quality of tomato production and paid them prices between 2.50 to 3.00 baht per kilogram.

THE RELATIONSHIP BETWEEN DOI KHAM AND THE LOCAL FARMERS



In order to elevate and improve the farmers, Doi Kham arranges annual agricultural training sessions. The Third Royal Factory has cooperated with their partners including Kasetsart University, Chalermphrakiat Sakon Nakhon Province, Chiangmai University, Siam University, and Roi Et Rajabhat University along with the officials from Sakon Nakorn. All of the partners have cooperated in organizing an activity that promotes Sakon Nakhon youth leadership. The activity follows King Rama IX's philosophy of sufficient economy which involves dying clothes and picture printing by organic colors. Additionally, the meetings between local farmers and the Third Royal Factory are arranged to exchange their opinions regarding the activities simultaneously with the visions of the factory. The farmers are free to provide any feedback regarding Doi Kham's actions ?

An equally significant aspect of 'smart farming' is the ecolabels on food production and consumption in Thai agriculture. Doi Kham applies GAP policies on the local farmers when growing tomatoes to maintain the quality of the products, control the amount of chemicals used and the income of the farmers . According to research , GAP, known as Good Agricultural Practice, is one of Thailand's national policies in food production under self-sdfficient economics and ofganic farming systems. The farmers are instructed to adjust the chemicals used to be maintained at an acceptable level and optimize their resources according to GAP while increasing their products' prices. The author also pointed out that it was important for the farmers to apply the policy, but currently, the consumers do not yet support the ecolabel products .

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CONDITIONS FOR GROWING TOMATOES

Tomato planting is a well-known crop in Northeastern Thailand. The weather in Northeastern Thailand has a mildly cold winter season from November to January, which allows for dry air which thereby minimizes the chance of tomatoes contracting a disease while also enhancing the growth of tomatoes.

The optimal temperature for the tomatoes to grow is around 15 - 30 degrees Celsius. Higher temperatures can influence the presence of diseases and discoloration in tomato planting, especially when the temperature exceeds 35 degrees Celsius whereby the tomato will stop producing red pigments causing the color to be pale orange.

Tomato plants need to be grown in well-aerated soil, otherwise, there will be a reduction in nutrient uptake, resulting in plants that are deficient in nutrients. Another important factor is the soil pH which is measured by the acidity and alkalinity in the soil. The ideal soil pH for tomato planting is between 6.0 to 7.0 for best nutrient uptake. Strongly acidic or alkaline soil will destroy micronutrients and observable amount is less than expected.

NPK stands for Nitrogen, Phosphorus, and Potassium. Nitrogen is responsible for producing leaf and green pigments; too little nitrogen will cause yellow leaves, too much nitrogen will stimulate the production of foliage but delay in flowering producing poor quality fruit. Phosphorus plays an important role in plant genetics and seed development. Potassium helps strengthen the stem, improves the color and flavor of fruits. Lack of potassium will result in poorly developed root systems. Soil pH has a direct relationship with the availability of nutrients uptake. Soil pH affects nutrient availability by changing the form of the nutrients in the soil. When the pH is too high or too low, NPK will be less available for the plants. However, lower pH will increase the solubility of aluminum and iron, which are toxic to plants if an excess is present.





FACTORS THAT AFFECT THE YIELD OF TOMATO

• Soil

Soil is a necessary factor for the planting of tomatoes. The soil will give support to the trunk of the plants. If the plants do not have soil, it will be difficult for the plants to get the nutrients that they need.

Soil pH is measured to determine the acidity and alkalinity in the soil. The pH value is one of the factors that make tomato planting successful. The ongoing crop production will tend to lower the pH of the soil because hydrogen ions are released and converted to nitrate by the soil microbes.

The optimal soil pH for tomatoes is found to be slightly acidic soil with a pH of 6.0 to 7.0. The nutrients that are less affected by the change of soil pH are Nitrogen(N), Potassium(K), and Sulfur(S). However, Phosphorus(P) is directly affected by the change of soil pH. In alkaline soil, the phosphate(P) ions will produce less soluble compounds by reacting with magnesium(Mg) and calcium(Ca). On the other hand, in acidic soil, the phosphate(P) ions will react with iron(Fe) and aluminum(Al) to form less soluble compounds that are hard for plants to break down. If the soil pH is above 7.5, most of the micronutrients will be less available. However, there is an exception for molybdenum(Mo) which is found to be more available under alkaline soil.

• Water

Water is an essential component in any life form on Earth, it is, therefore, naturally important to take the quality of water into consideration as one factor that will affect the growth and yield of tomatoes. There are many aspects of water that could affect the plant such as salinity, pH, hardness, alkalinity, electric conductivity (EC), and trace elements.

Salinity is used to describe the concentration of soluble salt within the water body. It creates water stress that affects the rate of absorption of water in the root system as the process of osmosis of water into plants can be reversed with the high salinity in water. This can lead to stunted growth in plants and the possibility of withering.

The pH of the water can indicate the type of ions present in the water and can lead to a change in solubility of some mineral ions in the water such as iron, phosphorus, or manganese. This means that the minerals added to the plant can be affected by the pH of water.

• Temperature

Temperature is one of the important factors that affect the growth of the plant. Some plants do not grow well in a hot climate, likewise, some are not good with a cold and dry climate. This means the temperature is the determining factor for the suitability of the crops in the area. This is because the pollination stage of a plant is sensitive to temperature, it can affect the growth and yield if the temperature is not within the range of growth and fruition.

Temperature also can affect the presence of disease. There are many types of plant disease, from bacteria, viruses, or mold. These pathogens also have specific environments that they optimally reproduce in. Therefore, crops can be expected to be infected with disease if the condition is favorable for the pathogens.

VARIETIES OF TOMATO

There are a few varieties of tomato in Thailand, which can be divided into main types:

1. Cherry Tomato

This type of tomato is small in size and sweet in taste. It has fewer seeds and is strong in taste. This type of tomato is considered to be higher in price compared to other types of tomato. The color of cherry tomatoes varies per breed and can be red, yellow or even brown.

2. Red tomato

This type of tomato is red in color and large in size. This type of tomato is commonly seen and heavily commercialized. It is usually used to make tomato paste and tomato sauce as it has a strong smell. It is considered juicy and fleshy.

3. Srida Pink Egg Tomato

This tomato is commonly seen in Thailand. It has a pinkish red color and is medium sized. It has a bland or sour taste, weak smell and hard flesh.

4. Wild Tomato

This type of tomato is similar to the cherry tomato, as it is small in size, and varies in color. It has a sour taste and soft flesh. It has a lot of seeds and is not juicy. This type of tomato is commonly cultivated in Northern and Northeastern Thailand.

The different varieties raise concerns regarding the tomato species' characteristics. Each of them have specific characteristics such as the Red tomato (Perfect 111, Figure 4) which is best for producing tomato juice but is not recommended for eating because of its hard texture and little flesh. The cherry tomato (Figure 5) is recommended to eat fresh due to its softness. However, it is not suitable for juice production because it produces less juice⁴.



SOIL PH TESTING METHODS

The soil pH is a factor that can affect the available nutrients in the soil. This factor can affect the yield and growth rate of the plant. Therefore, such an important factor must be monitored and controlled to maximize the effectiveness of the soil.

Soil pH can be found through several means, either through chemicals or electrical conductivity.

Chemical methods can be utilized by using the property of some chemical which change in color in different pH and the result is then correlated to find the exact pH of the chemical. This means that the chemical can be coated onto paper to be used as indicator paper.

The electrical conductivity of the liquid changes with its pH thus it can be correlated and this principle is used for the pH meter, both analog and digital.

The pH of the soil is determined by the mineral contained within the soil, as such, in practice, the soil is usually dissolved in the water to dissolve the mineral in water and determine the pH of the soil indirectly. Alternatively, a specialized device must be used to determine the pH of the soil through electrical conductivity with moisture in the soil.

SMART FARMING TECHNOLOGY IN THAILAND

Smart farming has been introduced to the farmers in order to utilize agricultural technology in a way that can optimize resources such as energy, water, manpower, and time management, resulting in the increase in the quality and the quantity of the products 5 . Smart farming mostly involves the Internet of Things (IoT), which is the use of the internet in controlling agricultural systems such as remote sensors and program controls that are connected to the internet⁶.

The research provided examples of Thailand's implementation of smart farming technology. In Kalasin province, the farmers grew pumpkins outdoors but the yield was not sufficient for the demands in the market. To solve this problem, they installed a greenhouse using the system of Internet of Technology (IoT) which includes automatic watering systems, automatic fertilizer systems, soil humidity censoring devices, and automatic temperature measuring devices for enhancing the yield and growth of the pumpkin.

Simultaneously, in Lopburi province, the farmers organically grew homegrown vegetables that were infested by pests and seasonal issues. Therefore, they started to use the greenhouse technology greenhouse that was powered by solar cells with an additional automatic watering system controlled by mobile phones. From this, the plantation could take place throughout the year with fewer pests, resulting in a better quality of the product and sustainable income for the farmers. This is possible since the environment within the greenhouse is confined enough that it can be regulated and carefully monitored at all times by the computer system to allow the optimal condition for plant growth and yield. Page 7

OBJECTIVE NUMBER 1: *TO UNDERSTAND THE CURRENT WAYS OF FARMING OF THE FARMERS UNDER THE CONTRACT OF DOI KHAM'S THIRD ROYAL FACTORY*

Research on Doi Kham's and the Third Royal Factory

Prior to the field trip, the team should have the fundamental knowledge to effectively proceed and achieve the project's objectives. The team has to study Doi Kham's past achievements in terms of technology development projects and research. Therefore the team divided the research areas into two groups: to study the vision and goals of the factory, and the possible adaptations to the local farmers after previously studying Doi Kham's goals and visions. The second group examined the factory's previous achievements and technology development in order to investigate their tomato planting techniques.

Investigate Doi Kham's local farmers and the tomato fields

The team decided to observe the tomato fields and visit the local farmers who lived around the Third Royal Factory in Tao Ngoi. The team observed the farms under the contract of the Doi Kham factory by interviews based on the variation in their production process. Interview questions are separated into 3 parts:

- 1. General information about the farm consisting of soil, water, locations, manpower, tomato breeds, bugs, plant diseases, and financial situation
- 2. The technology that the farmers obtained from Doi Kham
- 3. Farmers' knowledge of tomato-planting methods including the results after the cultivation, the production process, the difficulties during the farming.

Accordingly, the team aims to investigate the tomato fields located about 5 kilometers from the factory. The types of farms that the team selected were:

1.) The tomato fields that have a significantly high yield per rai (7 tons per rai is an average contracted amount with Doi Kham)

2.) The tomato fields that have less yield per rai than the contracted amount.

To analyze the entire information, the team has been assigned to identify the differences in the production process based on the farmer's ways of farming, after the other team had gathered the information from an on-site investigation. Page 8

OBJECTIVE NUMBER 2: TO EVALUATE THE FARMERS' COOPERATION AND RELATIONSHIP TOWARDS DOI KHAM BASED ON THE FARMERS' WAY OF LIFE AND TRADITIONS

terview Doi Kham's local farmers and staff

Before the trip, our team gathered and appointed each member to carry out fundamental research on different specific areas such as the Third Royal Factory farmers' lifestyle, their tomato productions, and the relationship between Doi Kham and the local farmers. After obtaining the information, we came up with a few survey questions for the local farmers from gathering key points toward the research on what the farmers think of Doi Kham and what they receive from the factory in terms of selling prices, insurance, and the farmer's perception towards Doi Kham.

After our team has conducted our fundamental research on the Doi Kham farmers, it is essential to do qualitative research. We will check Doi Kham's official Facebook and website, and have prepared 15 questions to gain an understanding on Doi Kham and the support that Doi Kham provided and the previous educational activities held by Doi Kham to the farmers. Our team planned to visit their greenhouses and carry out some fieldwork which will help the team gain more information on the cooperation that the farmers give to Doi Kham.

Evaluate the Data Obtained from The Field Trip

The information gathered from the interview with the Doi Kham's farmers and staff will be divided into two categories:

1. Sociology is categorized by data on the local farmers' way of life, feedback exchange with Doi Kham, and the relationship between Doi Kham and the farmers, relating to the commitment of the two parties which allowed the team to explore the possibility of Doi Kham's initiative and how it was considered by the farmers. Societal commitment can impact the results of the initiative. The relationship between the two parties can affect the enthusiasm of the farmers and their willingness to learn. Meanwhile, the farmer's way of life will determine the tendency of the initiative to be continued.

2. Resource is the capability of the farmers in selecting the initiative. The number of resources for the farmers will determine the adaptation of a new technique and technology initiated by Doi Kham including the data on the farmer's farm, Doi Kham's technology and workshop which can be related to the general conditions of the field, the financial situation, and their current technology. This category aims to show the viability of the initiative to be implemented in terms of resources to the farmers, such as budget, time, or technical knowledge to Page 9

OBJECTIVE NUMBER 3: *TO IDENTIFY SUITABLE PRACTICES FOR LOCAL FARMERS DEPENDING ON DOI KHAM'S FARMER MANAGEMENT AND HOW ADVANCED THEY ARE IN THEIR AGRICULTURAL TECHNOLOGY*

Finding potential areas for improvement

Tomato planting is a well-known crop in Northeastern Thailand. The weather in Northeastern Thailand has a mildly cold winter season from November to January, which allows for dry air which thereby minimizes the chance of tomatoes contracting a disease while also enhancing the growth of tomatoes (Martens, 2002).

The optimal temperature for the tomatoes to grow is around 15 - 30 degrees Celsius. Higher temperatures can influence the presence of diseases and discoloration in tomato planting, especially when the temperature exceeds 35 degrees Celsius whereby the tomato will stop producing red pigments causing the color to be pale orange (LODO, 2021).

Tomato plants need to be grown in well-aerated soil, otherwise, there will be a reduction in nutrient uptake, resulting in plants that are deficient in nutrients. Another important factor is the soil pH which is measured by the acidity and alkalinity in the soil. The ideal soil pH for tomato planting is between 6.0 to 7.0 for best nutrient uptake. Strongly acidic or alkaline soil will destroy micronutrients and observable amount is less than expected (PiaGrowtech Co., Ltd. 2016).

NPK stands for Nitrogen, Phosphorus, and Potassium. Nitrogen is responsible for producing leaf and green pigments; too little nitrogen will cause yellow leaves, too much nitrogen will stimulate the production of foliage but delay in flowering producing poor quality fruit. Phosphorus plays an important role in plant genetics and seed development. Potassium helps strengthen the stem, improves the color and flavor of fruits. Lack of potassium will result in poorly developed root systems. Soil pH has a direct relationship with the availability of nutrients uptake. Soil pH affects nutrient availability by changing the form of the nutrients in the soil. When the pH is too high or too low, NPK will be less available for the plants. However, lower pH will increase the solubility of aluminum and iron, which are toxic to plants if an excess is present.

OBJECTIVE NUMBER 4: *TO ADVOCATE THE FARMERS' AGRICULTURAL KNOWLEDGE AND SKILLS AS A GUIDELINE TO BUILD DOI KHAM'S SMART FARMERS.*

Suitable pH measuring methods

In order to find a suitable pH measuring method for farmers, the team has to research different methods of pH measurement. Afterwards, the team has selected the method based on the farmers' knowledge and the accessibility of the equipment. The team will compare the experimented results of Universal indicator with a digital pH meter, as the digital pH meter is the most accurate testing method. However, the parameters in choosing a suitable method will solely depend on accuracy, simplicity, and affordability.

Measurement of the farmers' understanding

From the 3 different groups of farmers that our team is testing, the farmers are required to take a post-quiz covering the information that they have learned from our group members and the video documentary. Additionally, farmers will be required to submit the pH test results with the soil sample from the fields to the team. The team will check the results by comparing the farmer's results with a pH digital meter which the team will use to to test the soils once again. The criterion for the practical test is the error bar with a standard deviation value. From there, our team can compare the differences and determine the best method to deliver information amongst farmers.

OBJECTIVE NUMBER 4: *TO ADVOCATE THE FARMERS' AGRICULTURAL KNOWLEDGE AND SKILLS AS A GUIDELINE TO BUILD DOI KHAM'S SMART FARMERS.*

Design an educational activity

Firstly, the team will provide knowledge to the farmers on the impact of soil pH on the ability of nutrient uptake so the farmers understand the importance of pH measurement. Secondly, the team will emphasize the relationship between the soil pH and the NPK value, as the pH value is related to nutrient availability and the health of the soil. After the farmers learn how to successfully measure the soil pH, it will help them to manage their costs of production such as the amount of fertilizer that will be needed prior to the cultivation seasons.

The team will randomly select 28 local farmers by focusing on the local farmers under contract with Doi Kham. The 28 local farmers will be divided into three subgroups: 16 local farmers for the Direct teaching method, 5 local farmers for the video learning method and 7 local farmers for the third-hand knowledge method.

The team has to choose a small sample size of farmers because this educational method works better in a controlled sample group, and it is essential for the team to mainly focus on these groups in order to get the most accurate result.

Each of the groups will be provided with the same information on the method of pH testing and soil mixing. To find the most effective educational activity for local farmers, the team has separated the local farmers into 3 groups:

1. Directly instructed by our research team

The first group will represent the farmers who directly learn from the instructor through the use of presentation slides and activity-based learning. The results from group 1 will determine how the local farmers have gained knowledge after being taught based on direct methods.

2. Learning from the video

The second group will represent the farmers who have been taught based on the use of video instructions. This video is designed as an instruction or manual for pH measuring methods. The video instructions will test the learning capability of the local farmers who are relying on the video as the medium for learning.

3. Third-hand knowledge

The third group will represent the farmers who have learned via third-hand knowledge. They will learn from the designated person, who has learned of the method from our team. This educational method stimulates the scenario that one farmer is imparting knowledge to another farmer after they have obtained the knowledge themselves. Page 12

THE CURRENT METHOD OF FARMING OF THE FARMERS UNDER CONTRACT WITH DOI KHAM'S THIRD ROYAL FACTORY

Research on Doi Kham's and The Third Royal Factory

Prior to the visit of The Third Royal Factory of Doi Kham, the team studied Doi Kham's visions, goals and past technological achievements in order to investigate Doi Kham's possible adaptations to the local farmers and their tomato planting techniques. The vision of DoiKham Co., Ltd. (2016), as quoted from their website, is "being a role model social enterprise that develops products from local communities with global quality for the goodness of the community". The vision here is illuminated in their company's business activities, thereby supporting the local economy by employment, community services, environmental efforts, and changes in society. These activities are within their vision of being a social enterprise that supports the people within the area and sustainable development. The King's Philosophies also help in shaping the activities of the company to provide self-sustainable development of the community by developing product quality or helping to develop industry in the area.

Doi Kham's missions as a social enterprise are to develop the community and its people toward sustainable development with the Sufficiency economy and the King's Philosophies. This is in line with the origin of DoiKham which is not profit oriented but is rather to benefit the local community.

The insights of Doi Kham's local farmers

Through observation during the visit of the Third Royal Factory at Tao Ngoi, our team obtained information about the current ways of farming from the local farmers, as well as the farmers' behaviors and characteristics on how to find sources on farming practices.

The investigation during the field trip concluded data from observing local farmer's farms and data from interviewing local farmers. Our team has investigated the farms of 9 local farms with different tomato productivity and techniques. This section will explain the result after the investigation in order to understand the current ways of farming.

THE CURRENT METHOD OF FARMING OF THE FARMERS UNDER CONTRACT WITH DOI KHAM'S THIRD ROYAL FACTORY

The insights of Doi Kham's local farmers (cont.)

The team investigated the tomato farm of the local farmer who was under contact with Doi Kham and based on our interview questions our team has gained the information which is categorized into 3 topics.

- 1. General information such as soil type, water type, location, and manpower. This result showed some factors such as soil type and water type which are likely to be the same since their locations are in a similar area.
- 2. The technology that they applied is different on each farm. The technique of using bamboo sticks to support the tomato is widely applied because it can prevent the tomato plant from becoming infected or rot, leading to higher tomato production.
- 3. The overall farmer's knowledge of tomato planting is very high when compared to their level of education because they have been in this field for a long time and have been trained by Doi Kham staff or have even obtained the knowhow from within their neighborhood.

As the farmers mentioned during the interview and observation from the farms, they mostly rely on their past experience as they are the ones who work daily on their own farms. They are independent from Doi Kham on their choice of equipment which is essential for their farms and the tomato yields and tend to pass on advice to other farmers if some of them encounter problems in planting such as plant diseases and drought. As they consider their experience in tomato planting more practical than that of Doi Kham, they tend to rely on how they themselves have managed their farms to provide them with higher yields and quality of the fruits, together with the suggestions by the neighbors since their conversations are based on actual on-field experiences and less on complicated technical explanations.





THE CURRENT METHOD OF FARMING OF THE FARMERS UNDER CONTRACT WITH DOI KHAM'S THIRD ROYAL FACTORY

A summary on the current ways of farming of the farmers under contract of with Doi Kham's Third Royal Factory

The farmers lack active learner skills, including being intrinsically motivated to learn and ask questions by themselves about tomato farming. In order to be an active learner, one must be enthusiastic about finding new ideas and knowledge along with solving problems and making decisions.

Therefore, our team came up with the term "Smart Farmers" in order to develop the local farmers' to become active learners, by which they are actively involved with the learning process rather than just listening. 'Smart farmers' should be capable of self-directed learning while engaging with the educational activities that were provided.



THE FARMERS' COOPERATION AND RELATIONSHIP TOWARDS DOI KHAM BASED ON THE FARMERS' WAY OF LIFE AND TRADITIONS

Information obtained from Doi Kham

According to the first field trip at the Third Royal Factory, we have observed that various advanced technologies are used for tomato cultivation. Furthermore, as we examined greenhouses, nurseries, and demonstration farms, we found that Doi Kham has constructed a greenhouse called "Phuhiran," which is smart farming as shown in **Figure 9**. The greenhouse demonstrates how to grow seeds using hydroponics. Phuhiran greenhouse is used for experimenting with new tomato species. We have also investigated technologies that Doi Kham uses, for example, controlling the pH in fertilizer, water control systems as shown in **Figure 10**, which is a developing vegetable plot. It is a demonstration vegetable plot that is used to grow different species of tomatoes to experiment on which methods are suitable for tomato cultivation, such as the splice grafting method that is used to graft red tomatoes with Solanum melongena (eggplant). This method helps increase the output and promote growth, including promoting disease resistance.

Additionally, there is another demonstration vegetable plot as shown in **Figure 11**, which is used to experiment with growing a variety of tomato species to examine and identify both the advantages and disadvantages of each tomato species. Any plot that does not provide satisfying products or is not resistant to the disease will be eliminated.

In conclusion, we have discovered that Doi Kham has been investigating and implementing various technologies, such as constructing greenhouses and demonstration farms in order to establish a model for smart farming.







THE FARMERS' COOPERATION AND RELATIONSHIP TOWARDS DOI KHAM BASED ON THE FARMERS' WAY OF LIFE AND TRADITIONS

Relationship between Doi Kham and local farmers

For this second objective, the collection of data was achieved by Research on Doi Kham's Third Royal Factory, by interviewing the local farmers' relationship toward Doi Kham and Interviewing the Doi Kham staff. As a result, the collaboration and relationship could be analyzed for further cooperation between Doi Kham and the local farmers using the exchange of knowledge method.

According to the methods of collecting data mentioned above, the team discovered that the farmers have a good relationship and cooperate well with Doi Kham. Subsequently, interviewing local farmers also pointed to the fact that the farmers under the contract of Doi Kham tend to follow the yield contract strictly and often participate in annual and monthly training sessions. The training sessions would either be conducted by Doi Kham staff or by inviting experts from universities such as Kasetsart University Chalermphrakiat Sakon Nakhon Province, Chiangmai University, Siam University, and Roi Et Rajabhat University. The farmers feel grateful to Doi Kham for arranging activities and they find them knowledgeable. The farmers also consider Doi Kham as a method to earn additional income from tomato farming.

Last but not least, the conversations with the Doi Kham staff also made it obvious that the local farmers are interested in Doi Kham's informative activities as evidenced by the scores the farmers received post-tests of each training session and applying the techniques taught by Doi Kham into their farms. Moreover, the staff also mentioned there would be contracts of annual yield and GAP that are applied to the farmers to work in accordance with the company and optimize their chemicals used in the farms to produce the best quality of the products.

In summary, according to the data obtained, the farmers have a good relationship and cooperate well with each other as they follow their contract policies strictly and attend Doi Kham's activities in order to develop their own tomato farms which would then be harvested and sent to Doi Kham. It is mutually beneficial for both Doi Kham and the farmers as Doi Kham is able to control the product quality by setting yield goals each year for the farmers, optimizing their chemicals, and educating them on how to improve their farms. Also, the farmers, by being under the contract, are able to receive a sustainable amount of income. With good quality tomatoes, the farmers would be able to increase the selling price of the tomatoes. Therefore, the relationship and cooperation between Doi Kham and the farmers are considered to be satisfactory.

THE FARMERS' COOPERATION AND RELATIONSHIP TOWARDS DOI KHAM BASED ON THE FARMERS' WAY OF LIFE AND TRADITIONS

The teaching methods are still not fully effective enough in passing knowledge on to farmers

According to an interview with farmers that have been working and have trained with Doi Kham, the results indicate that the majority of farmers are not able to understand and apply knowledge given by Doi Kham. Although Doi Kham has been trying to design new approaches and teaching methods, it has not tackled the core issues or transferred additional knowledge regarding tomato cultivation. As a result, farmers are not able to effectively apply the knowledge received from the training programs. For instance, farmers understand and are able to measure the pH level in the soil. They do acknowledge acidic soil and alkaline soil and are able to adjust soil pH, but they lack knowledge regarding the causes and effects of the pH level. Furthermore, many farmers lack the ability to measure and read the pH level accurately and correctly. They follow the basic suggestions from Doi Kham, which are to analyze issues that may arise but are then unable to find appropriate solutions to solve issues effectively. Accordingly, we are of the opinion that Doi Kham may need to redesign the training programs by providing more information and encouraging farmers to analyze the root causes of the problem as well as transfer agricultural knowledge and technologies in accordance with the concepts and goals of Doi Kham to create a smart farming system and 'smart farmers'.

Educational activity from Doi Kham

From 4.2.1, after investigating Doi Kham's technology, our team noticed that Doi Kham only held meetings with the local farmers once a year. In the annual meeting session, Doi Kham will present their new growing techniques on different types of tomatoes, the amount of fertilizer to apply, and instructions on how to dispose of the different types of chemical fertilizers. However, as mentioned in 4.2.3, farmers do not have the basic knowledge on planting, such as knowledge about the soil conditions before planting the seedlings. Moreover, the meeting is held in a room with over 100 farmers, which makes direct teaching seem less effective.

THE MOST SUITABLE PRACTICES FOR LOCAL FARMERS DEPENDING ON DOI KHAM'S AGRICULTURAL TECHNOLOGY AND FARMERS MANAGEMENT

The potential areas for improvement

After the team observed the Third Royal Factory, our team came up with research on potential areas for improvement of the farmers. This research aims to discover which areas the farmers still need improvement.

Research on Precision Farming

As mentioned, most farmers rely on past experience, which can cause misunderstandings in agricultural techniques. Additionally, following past experience could cost more for production when the farmers do not truly understand the concept of agriculture. Therefore, our team chose to focus on Precision Farming which will help farmers be more precise in agriculture while optimizing costs of production, as well as increasing productivity and quality of the product.

From the research⁸, it was stated that "Precision Farming will help reduce the need for input such as water and artificial fertilizers and pesticides, thus reducing the environmental footprint of farming." According to the research, precision farming will optimize the use of excess inputs. The Vibe Farm also mentioned the estimation from the World Economic Forum that if farmers adopted Precision Farming, the yield could possibly increase by 10-15%.

ON FARM TRIALS FOR PRECISION AGRICULTURE

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THE MOST SUITABLE PRACTICES FOR LOCAL FARMERS DEPENDING ON DOI KHAM'S AGRICULTURAL TECHNOLOGY AND FARMERS MANAGEMENT

Thus, our team carried out another research that focused on on-farm experimentation and has come upon research on on-farm trials for Precision Agriculture. This report experimented on Economically Optimum Nitrogen Rate (EONR) in several soil fields. The report concluded that these spatial patterns will be used as a variable for fertilizer management programs which can further be used to optimize fertilizer inputs in each field⁹.

Interview with ideal smart farmers

After investigating Doi Kham's local farmers, our team came across an example of someone fitting the profile of an ideal 'smart farmer' in our project. This interview was conducted to explore the concept of being a 'smart farmer'.

According to the interview, the interviewees had previously known about the pH testing method, where this method was already applied on the farm. One factor that the team recognized about the ideal smart farmer was her passion towards her career goals. Consequently, it motivated the interviewee to be eager on finding new technology in order to develop her tomato field. Additionally, our team asked about the production yield after she adapted the pH testing method with her farms. She stated that "In my point of view, it is better to use pH testing, as it can optimize the costs of production and fertilizer."¹⁰

It turned out that even though the tomatoes usually cannot grow well during this season of each year, the production yield from the interviewee's farm proves that she is capable of managing her farm by successfully utilizing the precision agriculture concept. Therefore, our team sees the potential in using precision farming, in this case where she had previously used the pH testing method. The team can see that managing the farm precisely, can help optimize the costs of production and other input used as mentioned above. All in all, this is due to her characteristics: she is an active learner, who actively seeks new knowledge and is able to rely on herself rather than others.



Figure 16. illustrates the timeline for building the next generation of "Smart Farmers" and explains the plans of our project. According to the summary of objective 1, farmers manage their tomato farms by relying on their past experiences and information gained from neighborhoods (step 0), which shows that they have limited knowledge of farming. In order to educate farmers, we suggest that Doi Kham chooses effective and suitable teaching methods, and teaches the techniques of "Precision Farming", which is an approach that picks the right variables, which is suitable soil pH, that is able to help farmers to produce a yield with their limited capital (steps 1-2). From there, farmers are motivated and are able to gather necessary data which affects the growth of tomatoes, and ask questions on how to use the data obtained to develop their tomato fields (steps 3-4). Consequently, farmers adapt to independence and seek new knowledge, making them active learners (step 5). Eventually, the next generation of "Smart Farmers" are created. Farmers can enthusiastically learn new techniques and are able to produce the maximum yields of tomatoes while lowering expenses and increasing profits (step 6).

Creating four educational activities

After investigating Doi Kham's educational activity, our team come up with 3 teaching methods which are:

1. Direct learning:

Direct Learning will be held in the factory in the same way as the monthly meeting that Doi Kham conducts with the local farmers

2. Video learning

Video learning is based on Direct learning but in the form of a video, This helps the local farmer access the content even though they are not at the factory. The video can be watched multiple times if the local farmer wants to and it will be shared online via Youtube.

3. Third-hand knowledge

This method is to choose the leader of the local farmers and provide that person with the knowledge. After that, when the leader understands the knowledge he can share this information to other local farmers. This is to mimic the real situation where local farmers tend to ask farmers on nearby farms for some advice.

Findings from data analysis of the test results

This topic explains the obtained data which was collected by the farmer and the soil sample that farmers got from their farm which will be presented in tables. The result of the pH data from the farmer is recorded in the data paper given and the collected soil sample is collected in a zip lock bag.

Data from the 1st Group Experiment (Direct teaching)

In group 1 there are 16 farmers and 16 soil samples. We also separated the group into 2 sub-groups.

- Group learning (Group teaching with 11 local farmers)
- Individual learners (Individual teaching in a 1 on 1 situation)

Data from the 2nd Group Experiment (Coaching video)

In group 2, there are 5 farmers and 5 soil samples.

Data from the 3rd Group Experiment (Third-hand knowledge)

In group 3, there are 7 farmers and 7 soil samples.



Figure 17. represents the mean error from the pH value measured by the local farmer compared to the pH value measured by the team's Digital pH meter. Y-axis is the absolute error mean. The graph with the error bar (or standard deviation) shows that the different methods that we use show no difference in statistics on the capability of delivering the knowledge.

Preference on methods used

As mentioned, our team has segmented the educational activities into 3 groups. First, the direct teaching methods in which our team directly demonstrates the use of pH testing devices. Second, the video learning, where the team provides videos for the farmers to learn by themselves. Third, the third-hand knowledge method, where the farmers learn from their peers. The survey results are classified based on the farmers' satisfaction towards the 3 educational activities. The total responses were collected from 28 Doi Kham farmers.



3. Third-hand knowledge: 7%

The results show that out of 3 educational activities, the farmers were most satisfied with the video learning, followed by the direct teaching and the third-hand knowledge.

Interview to discover the farmers' opinions on the three educational activities

Apart from the survey regarding the satisfaction of the farmers, an interview was conducted to obtain the opinion of the farmers to affirm the most suitable educational activities based on their lifestyles.

From the interviewees, the majority of the farmers are concerned about the time period of the educational activities. According to the farmers who were taught using Video learning, they stated that "It would be nice to learn through the video as it is quick, easy to understand, and fun."¹¹

The interview results show that most of the farmers mentioned that the video learning is quick and can save time. This results directly from their lifestyle that primarily focuses on farming. The results show that the farmers prefer to spend less time on studying in order to concentrate more on their production. However, some farmers still prefer the direct teaching activity, due to there being a real demonstration during the teaching activity. From this, it enables the farmers to understand easily, also providing them with the opportunity to ask questions directly to the specialist. On the other hand, there are a minor group of farmers who don't like the third-hand knowledge activities and their reasoning is that other farmers view the farmer passing on the knowledge as a boastful person, as they come to teach their peers without any evidence to support their knowledge.

The farmers' accessibility on using technology

Aside from obtaining the opinions from the interview, a survey was conducted to determine the accessibility of the farmers to using technology. As mentioned in 4.4.3 and 4.4.4, the results show that the farmers show the highest satisfaction with video-learning activities due to their limitation of time. From there, our team further surveyed the accessibility of using technologies, such as Line, Facebook, Youtube, etc. The total responses were collected from the same 28 Doi Kham's farmers.



Accessibility on technology 1. Unable to use technology: 70% 2. Able to use technology: 30%

By surveying the same sample group, our team discovered the difficulties of applying video learning through online media since most of the local farmers are unable to access technology. As shown in Figure 20, there is only a minor group of the local farmers who are able to use social media such as Line, Facebook, or Youtube.

The most suitable method for measuring the pH level

After collecting and analyzing data from the factory, including the results of the experiment on various methods to measure the pH level in soil, such as pH meter, Litmus paper, Universal pH paper, as well as DIY soil pH measurement methods, such as baking soda and red cabbage juice indicator and interviewing the farmers, we used three criteria to determine the most suitable method to measure the pH level in soil, including accuracy, simplicity, and affordability. We used a diagram in order to compare every method visually.

- 1. "Accuracy" We measured pH using five different methods and compared it with a pH meter digital device in order to identify the most accurate method.
- 2. "Simplicity" It should be simple and easy for farmers to understand.
- 3. "Affordability" Price is an important element to be considered. It should be affordable enough for farmers.

	pH meter				Litmus Paper			Res.						
	Accuracy	Simplicity	Affordability		Accuracy	Simplicity	Affordability		c	Gal. 9590 100 Tests	ι	Universal pH Indicator		
									pi pi no Dip	H-indicator strips H-indicator strips H 0 - 14 In bleeding In - read while still moist.		Accuracy	Simplicity	Affordability
19 - S /	Red Cabbage Juice Indicator				Baking So	dα				I 2 3 4 5 6 7		0	Ø	
	Accuracy	Simplicity	Affordability		Accuracy	Simplicity	Affordability	SODA						·
	×	×	0		×	0	0							

According to **Table 1.** above, the results demonstrate that reading the pH level from the pH meter can be difficult for farmers as it may require skills in order to read the results on a numerical scale from 1 to 14. Although the pH meter offers a high accuracy rate, it is expensive. Litmus paper is an easy and quick method to determine and measure the pH level in the soil. Although it is inexpensive, the accuracy rate is low compared to a pH meter because litmus paper is limited only to neutral colors; hence, it is not accurate for measuring pH level. However, we found that a Universal pH indicator is highly accurate because it has a range for a variety of colors. Moreover, this method does not require complex processes and is affordable, especially for farmers to afford. Baking soda is the easiest and most affordable methods to measure the pH level. However, it is not accurate as the results cannot be read numerically. Red cabbage juice indicator is among affordable methods. However, it requires many processes to prepare the juice indicator and furthermore, this method is not accurate either.

To conclude, we experimented with five methods and the results showed that a Universal pH indicator is the most accurate and suitable for measuring the pH level in the soil. Page 26

A summary on a guideline to build Doi Kham's 'smart farmers'

The response from local farmers toward each educational activity is very interesting. Local farmers in some areas are satisfied with Video learning while in other areas are more satisfied with Direct teaching.

As mentioned, farmers' accessibility to using technology such as the internet and smartphone was lower than our team expected. However, local farmers that are still unable to access the technology, are willing to learn these technologies in the future if they have a chance. After analyzing the pH data of local farmers and the opinion of 'ideal smart farmers', our team suggested that the success of the educational activity is the device, not the teaching methods. This device refers to the educational activity that our team has created using the appropriate tools, easy to understand and useful information. This will motivate the local farmers to participate in the educational activity.

DOI KHAM SHOULD EMPHASIZE IMPROVING AGRICULTURAL FACTORS

As Doi Kham aims to build 'smart farmers', it is crucial for them to encourage farmers to become active learners on the topics which affect the agricultural factors: soil. water. temperature, and weather. Using methods that test such factors, it can be used to emphasize the topic, which will stir the curiosity of the farmers in this topic and push them to become active learners. pH testing in the report can be used as an example to emphasize the quality of soil in the process of farming to the farmers.

02

USING ADDITIONAL EDUCATIONAL ACTIVITIES TO REACH THE TARGET GROUP MORE EFFICIENTLY

From interviews with the farmers, it has been ascertained that the farmers feel that DoiKham's teaching method is uninteresting and too technical to understand. The team therefore suggested additional methods to Doi Kham Third Royal Factory to teach the farmers, which are through video and third-hand knowledge.

As mentioned with the method used for the teaching, video and third-hand knowledge can be used in addition to the direct teaching method for variation and different target groups.

Method	Target group
Direct Teaching	Local farmers living "nearby" the factory
Video	Local farmers living "far away" from the factory
Third-Hand Knowledge	Local farmers who are "close to each other"

Table 2: Methods and Target Group

The table shown above shows the recommended target group with which each method could work effectively.

03

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PROVIDING A VIDEO LEARNING FOR THIRD-HAND KNOWLEDGE

After interviewing some local farmers, it came to light that third-hand knowledge is widely used throughout the area. Some of the local farmers are likely to ask local farms for some farming advice, while some like to learn this information by themselves. In some cases, local farmers who have knowledge and information of the farming techniques are willing to share useful information with their local friends. However, some local friends might not listen due to their mindset, as their peers may have the impression that knowledgeable farmers are boastful people. Thus, providing the video clip which is a trustworthy tool provided by the organization will make local farmers listen more to their friends, as there is evidence to support the knowledgeable farmers.

CHARACTERISTICS FOR SUITABLE TOOLS

Using suitable tools for the educational activity is important, because if the tool is not suitable enough, the results of the educational activity may differ. The characteristics of suitable tools consist of being affordable, easy to find, and easy to understand.

Affordable means local farmers can easily buy the tool themselves or the Doi Kham factory can provide the tools for the local farmer. The tool should be easy to find or commercially sold in the market, in as much as it is not necessary to buy the tool from a specific store. Easy to understand means the selected tool is not too technical or does not require extensive knowledge to use it.



IMPLEMENTATION PLAN



Figure 21: Timeline on building the next generation of tomato farmers

From **Figure 21**, the implementation plan of our project is created into a timeline of "Building the next generation of tomato farmers". This timeline will be used to guide tomato farmers to become the next generation of farmers. From step 0 where the tomato farmer relies on their experience only, Doi Kham has designed a new educational activity by selecting the suitable tool for the farmer (Step 1), teaching "precision farmer" is introduced (Step 2), the farmer has learned the new information and then adapts the knowledge to their work (Step 3), where the farmer becomes motivated to learn new knowledge by on their own (Step 4). Finally, farmers can determine what information they need and can seek out the information by themselves and thereby develop into becoming "Smart farmers". (Step 5). Even though it is a one-direction timeline, for steps 1,2 and 3 will need some time as it will need to be repeated in order to develop properly.



IMPLEMENTATION PLAN



Figure 22: Loop on building the next generation of tomato farmers

From **Figure 22**, the loop consists of (Step 1) Design educational activity and tool, (Step 2) Teaching precision farming and (Step 3) Developing method. Our team thinks it will take around 6 months to finish 1 loop of (Steps 1,2, and 3). The loop will need to be repeated approximately 2-3 times in order to make tomato farmers move on to (Step 4) where farmers are motivated to learn new knowledge by themselves. Finally, when tomato farmers reach (Step 5) they will adapt into active learners and simultaneously develop into smart farmers.

CONCLUSION

'Smart Farming' is a concept in which the farmers are active learners who can solve their own problems, constantly improve their knowledge on their own, and optimize productivity using precision farming. Through interviewing the farmer, the team has come to understand the farmers' current way of farming. It is found that the local farmers are not active in their learning and still rely on their own past experience, therefore not qualifying to be smart farmers.

Through the introduction of pH testing, the team aims to transform the farmers into active learners by stimulating curiosity and providing knowledge to the farmers on optimization of the factors of agriculture. After the process, it will lead the farmers to use the method of precision farming and therefore become 'smart farmers' at the end of the proces. Nonetheless, the farmers still need further help from Doi Kham to transform their system into 'smart farming' using additional activities and knowledge regarding the factors of productivity.

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