Strawberry History, Cultivation and Problems in the Northern Area of Thailand: A Review

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Abstract— **This review explores the history, cultivation practices, and challenges faced in strawberry production in the northern region of Thailand. Historically, strawberries were introduced to Thailand in the mid-20th century, with substantial development occurring in the 1960s through initiatives by His Majesty King Rama IX. These initiatives aimed to diversify agricultural outputs, replace opium cultivation, and improve the living standards of hill tribes in the northern area. The cultivation of strawberries in northern Thailand, particularly in provinces like Chiang Mai and Chiang Rai, has become significant due to the region's suitable temperate climate and elevation. The first strawberry varieties (Pharachatan numbers 13, 16, and 20) were successfully grown by 1972 and introduced to local growers as a replacement crop. Despite the favorable conditions, strawberry cultivation in northern Thailand encounters several challenges. These include pest infestations, diseases such as anthracnose, powdery mildew, botrytis, and issues related to soil fertility and water management. Furthermore, climate change poses a growing threat, with increasing temperatures and erratic weather patterns impacting production cycles. The Royal Project, Kasetsart University, and the private sector have introduced newer cultivars; Number 329 (Yael), Pharachatan numbers 50 (B5), 60 (Rosa Linda × Tochiotome), 70 (Toyonoka), 72 (Tochiotome), and 80 (hybrid) to replace the older varieties due to their many advantages. This study examines these challenges in detail and discusses potential strategies for mitigating their impact, emphasizing the importance of research, extension services, and sustainable agricultural practices in ensuring the future viability of strawberry farming in this region.**

***Index Terms*—Strawberry, Agriculture, Northern Thailand**

I. Introduction

Strawberry (*Fragaria* × *ananassa*) is a small plant of the genus *Fragaria* in the rose family. *Fragaria* comes from the word "Fragrance", meaning "great smell" which corresponds to the important characteristic of strawberry fruit. In the field of genetics, strawberry is an octoploid hybrid species with 56 chromosomes in nucleus of somatic cell which derives from accidentally crosses of two octoploid wild species (*fragaria virginiana* and *fragaria chiloesis*) in Brittany of France during the late 17th century [1]. Different varieties of strawberries were bred by other countries afterward, which were suitable for the local environment. Many varieties are constantly being bred and released to temperate and subtropical legions. Nowadays, this plant can be grown almost anywhere in the world except for the polar and desert regions. Strawberry plants are photoperiodic in flower induction and divided according to their response to daylight length into two groups: June-bearing and Ever-bearing. June-bearing strawberry is a group of short- day plants that have reproductive and vegetative states at different periods. Short-day length and low temperature in winter turn June-bearing strawberry to reproductive state by stimulating flower formation. The plant produces all their fruit in late winter to spring. After reproductive state, June-bearing strawberry divert their energy into growing and produce daughter plant. Ever-bearing or Day-neutral strawberry is a group of plants that have reproductive and vegetative at the same time. The plant is not seasonally sensitive. Fruit of ever-bearing is smaller than fruit of June-bearing as they expend energy into growing fruit far longer and do not offer as much energy towards producing runners and spreading. Although, photoperiodism is the main factor for flowering, strawberry flowering also requires other factors as well. Common factors such as temperature, fertility, and nutrient intake, including other environmental factors also affect the flowering of strawberries. The fruit of strawberry is widely appreciated for its unique flavor and has become one of the most popular fruits around the world due to its delicious taste, sweet aroma and high nutritional value. The production of strawberry is 8th in the rank of 2021 world gross production value of fruit. It is classified as one of the high-value agricultural products [2] and commonly consumed both as fresh fruit and as processed fruit [3]. The vitamins, minerals, and antioxidants in strawberry provide important health benefits [4]-[6]. Antioxidant compounds in strawberries protect cells and tissues in the body by neutralizing unstable molecules known as free radicals. Strawberries are low-glycemic foods. It has little effect on blood sugar. Furthermore, the polyphenols in strawberries enhance insulin sensitivity in non-diabetic adults. This is an option to control or lower glucose levels.

The fruit of the strawberry is also used in the food processing industry for products such as fruit juice, yogurt, sour milk, and jam. Moreover, strawberries are used in cosmetics. Strawberry-based cosmetic treatments protect the skin from harmful ultraviolet A radiation, especially when used in combination with coenzyme Q_{10} [7].

Strawberry cultivation in Thailand has a rich history that dates back to 1960 when His Majesty King Rama IX initiated the practice (Fig.1). The goal was to introduce strawberries cultivation to hill tribes in the northern region of the country [8].

Fig.1. His Majesty King Rama IX visited the people at Doi Ang Khang, Fang, Chiang Mai.
(Source; http://www.psproject.org/?page_id=9731 *The Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects*)

This initiative aimed to provide an alternative source of income for the hill tribes, who were often engaged in illegal activities like opium cultivation and drug trafficking. By introducing high-value crops such as strawberries, the government hoped to shift their focus towards legitimate and sustainable agricultural practices. However, despite the efforts to promote strawberry cultivation, the quality and quantity of the products fell short of cultivar standards. This could be due to inadequate cultivation methods or techniques. To address this issue, it is essential to combine traditional Thai farming knowledge of soil, water, and climate with advanced production technologies and improved crop management practices, as seen in the rapid growth of the strawberry industry in other countries like USA (Fig. 2), China (Fig. 3) or Japan (Fig. 4). Those countries have the advantage of being able to understand the plant, management and the use of labor-saving equipment because these countries have learned to cultivate strawberries for a long time.

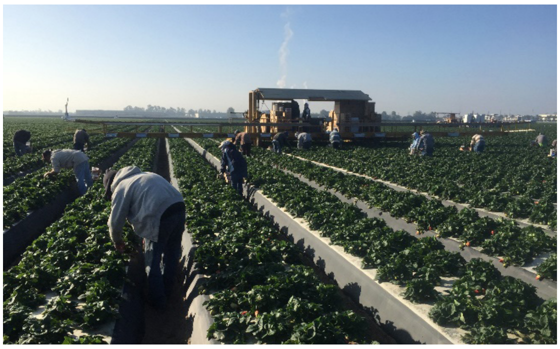

Fig. 2. Strawberry cultivation in California, USA

Fig. 3. Strawberry stereoscopic cultivation in Shandong, China (Source; http://www.xinhuanet.com/english/2018_12/10/c_137662200_4.htm)

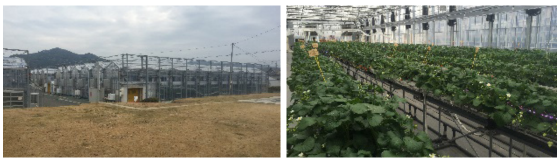

Fig. 4. Strawberry cultivation in Tokushima, Japan

Proper strawberry cultivation must come from integrating the traditional cultivation with foreign innovations. At present, the government, Universities and some companies have brought in foreign innovations without understanding, causing the cultivation to be inefficient or unworthy use of resources (not worth the yield). Linking Thai traditional cultivation with foreign innovation is an important development approach. Developing of cultivation systems for non-native crops such as strawberry or ice plant [9] can push these growers to become High-Value-Agricultural-Product (HVAP) producers faster because there are few competitors.

II. History of Strawberry in Thailand

There is no clear evidence of when Thai people first became aware of strawberries. The oldest historical evidence discovered is a royal letter from His Majesty King Rama V to the queen while he was traveling in Europe (Geneva, Switzerland) on 22 May 1897. Parts of the royal letter mention the fruit called strawberry, the same size of a lychee fruit and delicious [10]. However, there is no evidence that he brought it back to be planted in the country. Later, His Majesty King Rama IX was aware of the domestic problem of narcotics (opium), which is the main crop of the hill tribes in the north, and wanted to solve the problem. He sought out plants that were suitable for the cold weather and had high value for the hill tribes to plant instead. Early attempts at cultivation were largely experimental, but significant progress was made in the 1960s when the Thai government, in collaboration with private enterprises, launched initiatives to diversify agricultural production. King Rama IX had Luang Samanawakit to study their growth at the Chitralada Royal Villa, Dusit Palace [11]. Nine years later, the Royal Project Foundation was established to improve living standards of the hill tribe in the northern area of Thailand by using cash crops to replace opium cultivation. In 1972, first 3 cultivars (Cambridge Favorite, Tioga, and Sequoia) were successfully growth in northern part of Thailand and introduced to local grower in the name of Pharachatan number 13, 16, and 20 respectively. Pharachatan number 16 was the most adaptable and became the main cultivar until 1991.

During that, three cultivars of Aiko, Pajaro, and Douglas were introduced and trialed but were not successful. The Royal Project began to succeed in the next attempt (May 1986) for importing Japanese varieties such as Nyoho, Toyonoka, and Aiberry were a valid option [11]. After that, the Royal Project and Kasetsart University have brought in newer cultivars; Number 329 (Yael), Pharachatan number 50 (B5), 60 (Rosa Linda × Tochiotome), 70 (Toyonoka), 72 (Tochiotome), and 80 to replace the older due to their many advantages [12]. Pharachatan number 80 is the main variety of Thailand from 2007 and still in the great demand until now. This variety is June-bearing strawberry which requests short day condition with low temperature to initiated flower bud. Pipattanawong (2000) reported that the cultivation of strawberries in northern Thailand, particularly in provinces like Chiang Mai and Chiang Rai, has become significant due to the region’s suitable temperate climate and elevation. Over the decades, strawberries have evolved from a novel crop to a commercially viable product, gaining popularity among local farmers and consumers alike. At present, strawberries are the fruit with the highest price-per-unit of all economic fruits of Thailand [14].

III. Characteristics of Each Variety

A. *Pharachatan Number 13 or Cambridge Favorite*

A facultative short-day plant which is an early variety imported for testing by the Royal Project Foundation in 1969, which can adapt well to the environment of Chiang Mai province. It has small fruit sizes and soft in texture [15].

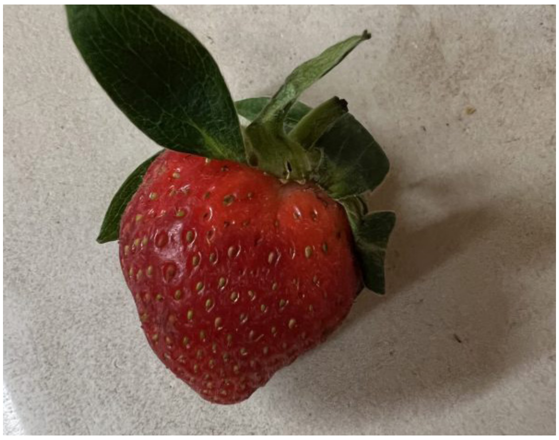

Fig. 5. Image of Pharachatan number 13
(Photo by Barry Proctor)

B. *Pharachatan Number 16 or Tioga*

This variety imported from America for experimental cultivation. A facultative short-day plant which adapts well with the environment of Chiang Mai province, full sun, very well drained soil. However, the harvesting period is short. The fruit is large (depending on the weather conditions). The flesh is quite hard, sour taste with light to dark red in color. Fruit is suitable for processed in the food industry because the pole comes off easily. [8].

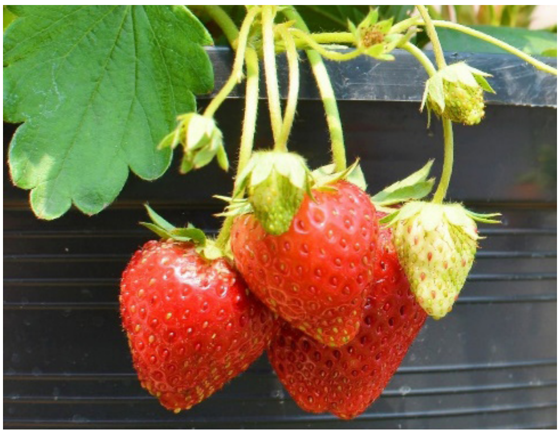

Fig. 6. Image of Pharachatan number 16
(Photo by the Seed Collection Pty. Ltd.)

C. *Pharachatan Number 20 or Sequoia*

A facultative short-day plant which has a sweet taste and is suitable for cultivation in highland areas. However, it is not very popular because the fruit’s flesh is very soft and the skin is thin, making it unsuitable for processing in the food industry [8].

Fig. 7. Image of Pharachatan number 20
(Photo by Putteringinthegarden)

D. Strawberry Number 329 or Yael

A short-day plant which was imported from Israel by Mr. Pramote Raksarat, Director-General of the Department of Agricultural Extension, in 2001. The skin and flesh inside are bright red and quite hard. The aroma and taste are quite sweet. When fully ripe, it can be stored for a long time. The fruit of this strawberry variety is very suitable for shipping and processing [8], [16], [17].

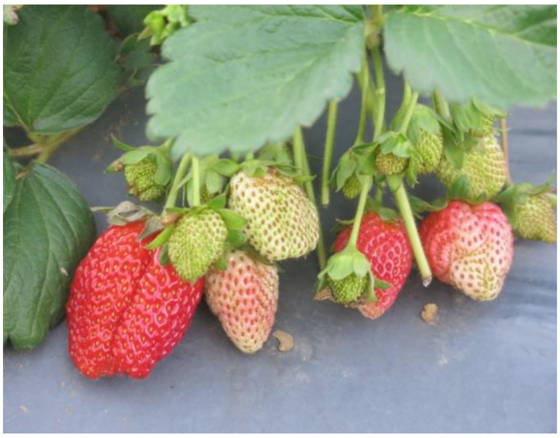

Fig. 8. Image of Strawberry number 329
(Photo by Phetchaburi Agricultural Research and Development Center)

E. Pharachatan Number 50 or B5

It is a variety that grows well in temperature conditions of 15-28 Celsius. Fruit is sweet, fragrant, and medium in size with dark red. The core of the fruit is mostly hollow. The texture is quite hard. Pharachatan number 50 is a variety that was created for His Majesty King Bhumibol Adulyadej in his 50 years celebrating of accession to the throne. [8].

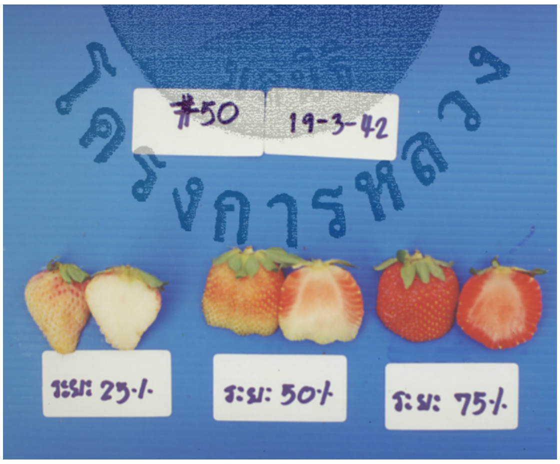

Fig. 9. Image of Pharachatan number 50
(Photo by The Royal Project Foundation)

F. Pharachatan Number 60

A facultative short-day plant which is the first hybrid variety to be successful, is a cross between Rosa Linda [18] and Tochiotome. The fruit is large, with an average weight of 10-15 grams. The taste is sweet. The skin and flesh inside are bright red [8].

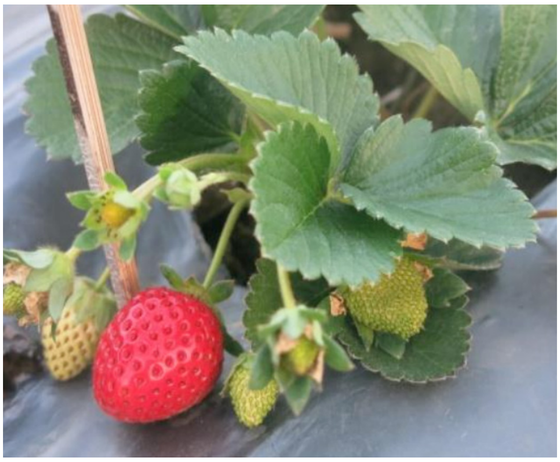

Fig. 10. Image of Pharachatan number 60
(Photo by Phetchaburi Agricultural Research and Development Center)

G. Pharachatan Number 70 or Toyonoka

A facultative short-day plant which is a variety imported from Japan. It's famous for its deep red color, sweet flavor, and juicy texture. It was first developed in the 1980s in Miyagi Prefecture and quickly became one of Japan's most popular strawberry varieties. In Thailand, this variety produces high yields. The fruit is large and has a spherical or conical shape, sweet taste. The skin and flesh are red with hard texture which makes it convenient for transportation and storage. Pharachatan number 70 is a variety that was created for His Majesty King Bhumibol Adulyadej in his 70 years celebrating of accession to the throne [8].

Fig. 11. Image of Pharachatan number 70
(Photo by Hanamankai)

H. Pharachatan Number 72 or Tochiotome

A facultative short-day plant which was brought from Japan by the Royal Project Foundation and given the number 72, which was named after the year His Majesty was 72 years old. The fruit has an average weight of 14 grams. The skin is dark red when ripe but the flesh is white. The flesh of Pharachatan number 72 is firmer than number 70, but less sweet [8].

Fig. 12. Image of Pharachatan number 72
(Photo by Phetchaburi Agricultural Research and Development Center)

I. Pharachatan Number 80

A facultative short-day plant which is a hybrid variety (code 01-16) from Japan that was planted and selected at Doi Pui Research Station, Chiang Mai, Thailand [19], [20]. It has the ability to adapt well to the Thai environment and is resistant to anthracnose. Healthy plants can produce high yields with average weight of 30 - 35 grams/fruit. The fruit is heart-shape, bright red skin with white flesh, juicy, and sour-sweet [8], [12], [13], [16], [19]-[22]. This variety was promoted to growers in 2007 and is popular to this day. However, the quantity and quality of their produce began to decline due to cell deterioration and unstable weather conditions.

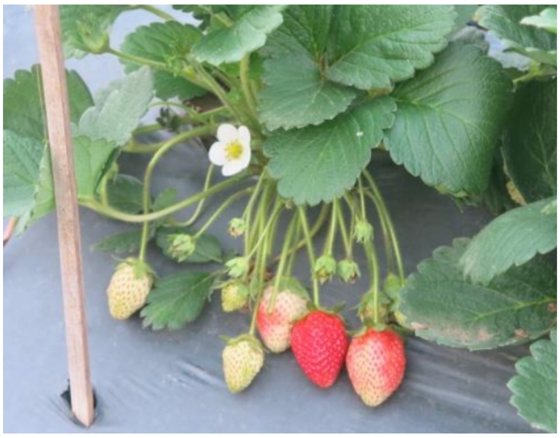

Fig. 13. Image of Pharachatan number 80
(Photo by Phetchaburi Agricultural Research and Development Center)

J. Pharachatan Number 88

A facultative short-day plant which is a hybrid strain between the number 80 and number 60. This variety was bred to solve the problem of incomplete flower development when exposed to fluctuating temperatures by adding genetics from number 60 that was able to flower even after receiving a short period of cold. The shape, firmness, aroma and taste are similar to those of number 88. However, this variety can produce flowers continuously and has a higher yield than number 80.

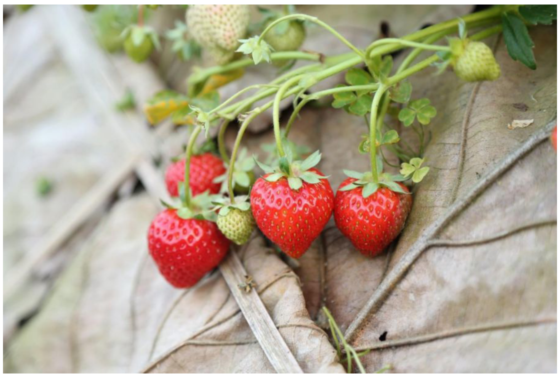

Fig. 14. Image of Pharachatan number 88

IV. Propagation

Strawberries, a winter fruit that has been cultivated in Thailand, have been able to adapt and create income for grower for a long time. It can propagate both sexually and asexually methods depend on objective [23].

A. Sexually Propagation

In general, the method of sexual propagation has been used in the field of breeding [24]. The Royal Project Foundation reports that strawberry breeding has been developed using the method of cross-pollination since 1997. The first variety obtained from the strawberry breeding program was Pharachatan number 60 and the Department of Agriculture issued a certificate of plant variety registration under the Plant Varieties Act of 1975 (R.P.2) No.276/2006 to the Royal Project Foundation on 16 September 2006 [25]. Later, the Angkhang Royal Project began a "Pharachatan number 80" breeding program by bringing hybrid seeds of "Royal Queen" from Japan to plant, test and select according to the program. This project was successful in the season of 2002 with variety code 01-16 selected. Strawberry breeding programs continue to be developed by royal projects, universities and private companies [8], [12], [13], and [21]. However, there is no strain that is more in demand than strain number 80.

B. Asexually Propagation

Field observations suggest that asexually method is suitable for commercial because it can be done quickly, at low cost, and produces new plant with the same genotype. Strawberry plants can develop stolon once they are fully grown. Stolon is an elongated, two-node, vegetative, axillary shoot, which supports the ramet (rooted rosette) until it is completely independent on its own roots [26]. In the northern area of Thailand, daughter plants in highland nurseries are propagate from April to October under the low night temperatures there induces flowering [27], [28]. Daughter plants must be planted in polyethylene bags in case production is required in lowlands. They are transplanted to extend the growing season at highland nurseries from June to October and to facilitate early December harvest. The mother plant much has approximately 4-5 branches and can produce up to 10 stolons in 60 days. Each stolon has approximately 7-10 daughter plants. Only 5 of the strongest plants should be selected for planting. Healthy mother plant can produce up to 50 daughter plants within a period [8]. In this duration, the mother plant sends energy to supply the daughter plant through the stolon and it is more susceptible to infection of microorganisms. During April to October, growers must prepare enough water for growth of strawberry because this is quite long and the water on the highlands is quite scarce. Insects such as thrip and spider mites are often infested during this period due to low-humidity and lack of rain. Using a sprinkler irrigation system along with the use of *Beauveria bassiana* can help reduce the rate of infestation. Insecticides should be used only when the infestations cannot be controlled by biological methods.

Although, currently variety (Pharachatan 80) is a hybrid cultivar that resists Anthracnose (*Colletotrichum* spp.). However, all types of plant pathogenic microorganisms have adapted to infect the plant all the time. *Colletotrichum* is also a type of fungus that is highly adaptable and can adapt to infect Pharachatan 80 in just a few years. Nowadays, *Colletotrichum* can be found on most of main planting areas (Samoneg and Fang districts) [29]. Watering should be completed early in the morning to prevent high humidity conditions during the night that suitable for fungal growth. Using *Trichoderma harzianum* is very necessary to control fungal plant diseases during this period. However, *T. harzianum* is not recommended to use when plant tissue must be taking in the tissue culture process in the aseptic technique. In this case, eliminating plant fungal diseases with fungicides is a more appropriate method.

Another big problem that is very common in growing areas is viral infections. However, the problem of virus outbreak can be resolved by removing infected plants from the area. Followed by the use of disease-free plants to replace. Currently, production sites such as the Royal Project or Doi Kham Food Products Co., Ltd. are continuously developing disease-free plant from using tissue culture (disease-free meristem). Moreover, Doi Kham Food Products Co., Ltd. has begun production and delivery to the growers who are in the promotion system of First Royal Factory as a pilot project. Another reason that limit yield of strawberry is regression. Using new-regenerate plant from meristem is the great way to eliminate this problem. Division of branch crowns is another method of propagation that can be can be used for strawberry propagation. However, it is a less popular method than daughter plants and only used in cases where the plant does not have a stolon.

V. Cultivation

A. Open Field Cultivation

Strawberries are grown as an annual crop. In Thailand, it should be planted between mid-august to mid-September for highlands, and between mid-Septembers to mid-October for lowlands [30]. Most plants cannot continue to grow when planted in conditions of excessively hot and dry weather. Choosing an appropriately area and improving the soil are the first factors that lead to success. The suitable soil for cultivation should be sandy loam and rich in organic matter [31], [32] It should be slightly acidic with pH=5.5 to 6.5 and able to retain moisture throughout the day but not become soggy because strawberry root is quite sensitive [11]-[13]. The strawberry planting bed must be approximately 30 centimeters above ground level and approximately 50 centimeters wide [8], [11]-[13]. Application of organic amendments such as leaf compost or manure with *T. harzianum* maybe use as an alternative to cover crops [8]. Planting have consistently demonstrated that the optimum is late August achieves a high yield in most cases. The planting spacing of each plant much be 25 to 30 centimeters apart [8], [11]-[13]. The stolon side must always be turned towards the inside of the plot. This planting direction will cause the flowers and fruits to grow outward, which is the right direction for harvesting. All roots must be under the soil. Surrounding area must be firmly pressed down and careful not to create puddles as this may cause the plant to sink into the plant material after watering (Fig. 15).

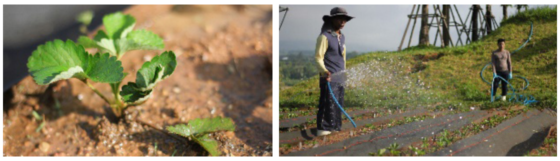

Fig. 15. Strawberry plant after transplant in the field.

Covering the plot with rice straw is an option for weed control called "Mulching". The hill tribe growers cover the raised beds with dry leaves of *D. tuberculatus* before planting [27], [28]. In the first 60 days, watering should be done using a sprinkler system and started early in the morning to remove dew from the leaves. A second watering can be done if the soil is dry, but this should be completed before noon [8]. Approximately 20 days after planting, add chemical fertilizer formula 12-24-12 at a rate of 10 grams/plant. [8]. Old leaves and those with signs of disease infestation must be removed as soon as they are found because it is a habitat for plant pathogens. Removing the leaves from the plant must be done carefully and always from the outermost leaves. At least 3 leaves must be left if the plant is still small. Also, stolon must be removed to help reduce energy consumption. All plant debris must be removed from the cultivation area and water sources. Ten days after, apply chemical fertilizer formula 13-13-21 approximately 10 grams/plant and repeat 4 times, 7-10 days apart [30]. The drip irrigation system must be replaced with the sprinkler irrigation system as soon as flowers are observed. The fertilizer that is high in phosphorus and potassium (18-24-24) much apply to the plant when most of the plants have bloomed. However, fertilizers that are high in nitrogen and potassium (12-6-18) replacement must be done as soon as the plant is found to quite worn out. Foliar spraying of micronutrients such as calcium, magnesium, and boron is very important during fruit development [8]. It also helps the plants to be more resistant to adverse environmental conditions. Fertigation can be used to add nutrients to plants. However, providing fertilizer with a high concentration will cause over-vegetative growth and inhibit flower production [33].

Flowering response of Pharachatan 80, particularly their temperature-photoperiod interaction, is a complex response and relatively unknown. Daughter plants must be exposed to low temperatures to stimulate the process of flower bud formation. It requires a low temperature, 10-15 °C, for 20-30 days to induce flower budding [8], [12], [13], [16], [19]-[22]. Suitable conditions for planting strawberry is the late fall or rainy season in the northern area of Thailand. This processes called strawberry vernalization [34]-[36]. The first inflorescences can be found immediately after the plant received enough chilling unit during vernalization and the blooming usually begins from November every year (Fig. 16).

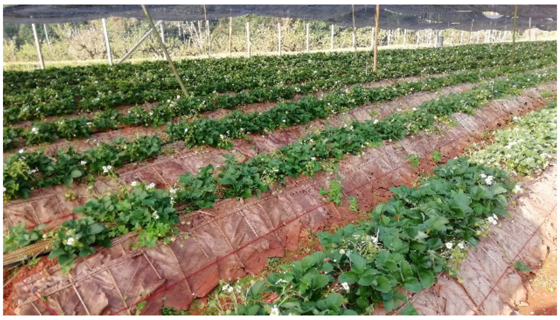

Fig. 16. Pharachatan number 80 grown at the Angkhang Royal Project Research Center While the first set of flowers is blooming.

Receptacle of strawberries will begin to significantly expand within 3-5 days after pollination has occurred. Strawberries are not berries in the botanical sense. The flesh is the tissue that develops from receptacle which soft, juicy, delicate and easily bruised [8]. The developing fruit can be seen from the central part of the flower that becomes raised and light (Fig. 17).

Fig. 17. The shape of strawberry flowers after being pollinated.

On the contrary, flowers that turn dark green to brown are those that cannot continue to develop. Postharvest pathogenic microorganisms often outbreaks during this time. The flower that have turned brown should be removed as soon as they are seen to reduce the habitat of pathogenic microorganisms. Pharachatan 80 usually have no more than 20 fruits per inflorescence with 12-20 grams per fruit [8], [12], [13], [16], [19]-[22]. Trimming the inflorescence is something that should be used in cases where there are too many flowers per inflorescence. Too many fruits per inflorescence causes the plant to not supply enough nutrients and makes all the fruits small. Moreover, too many fruits may have a negative effect on the plant and the next inflorescence.

Pharachatan 80 can provide 4-5 inflorescences during harvesting period (December to March). However, strawberry growers face the problem of drought in March every year. This problem limits the duration of reproductive with only 3 inflorescences. Irrigation management and soil improvement are good options to solve this problem.

B. Greenhouse Cultivation

The use of greenhouses for strawberry cultivation is still not popular. This is because building a greenhouse takes a lot of investment and has relatively high production costs. The payback period may exceed a specified number of years. Strawberry greenhouses are generally found only on farms that are open for tourism. In fact, growing strawberries in greenhouses can solve problems related to environmental fluctuations, disease and insect outbreaks, lack of water, nutrient deficiency and also increase productivity. One of the projects that encourage strawberry growers to learn and practice using greenhouses is a project of the Chiang Mai Provincial Agricultural Extension Office (in Thai; โครงการยกระดับการแข่งขันในระบบธุรกิจเกษตร). This project was created through the cooperation of government agencies, private companies, and educational institutions with the objective of developing strawberry production by supported the budget for the construction of 40 greenhouses with temperature control systems to 5 groups of grower in 2019. Each greenhouse in the project is equipped with temperature, humidity and lighting controls, as well as an automatic fertilizer dispensing system. These greenhouses can be used for both seedling and fruit production in all seasons. The strawberry plants grown inside are well protected from pests and adverse environmental conditions. The Chiang Mai Provincial Agricultural Extension Office focuses on Pharachatan 80 to supply for high-end market.

The group with the highest use of greenhouses is in Fang District, where greenhouses are mainly used for seedling (daughter plant) production. This project is under the royal initiative of Her Royal Highness Princess Maha Chakri Sirindhorn (Fig. 18). The advantage of using seedlings produced in a greenhouse system is uniformity in plant size, cleanliness and vigor. The seedlings produced can be used to alleviate the problem of a shortage of seedlings in the area, where growers mostly have to wait for remaining seedlings from production sites in Samoeng District. Most important point is the cleanliness of the seedlings because it reduces the mortality rate from disease outbreaks. It also helps growers reduce the use of dangerous chemicals. However, growers are still unable to produce strawberries according to the variety's characteristics because this variety was not selected for growing in greenhouses, combined with the relatively high humidity conditions inside the greenhouse, causing incomplete pollination.

Fig. 18. Disease-free strawberry plant production site. (Uper-left; Greenhouse, Uper-right; mother plants, lower-left; the production officer gave a report to Her Royal Highness Princess Maha Chakri Sirindhorn., lower-right; Daughter plants)

The group that is most successful in strawberry producing is the Khun Chang Khian with 5 greenhouses. The growers in this group have experience in growing and selecting appropriate varieties from Korea (Seolhyang). This strawberry variety was selected in greenhouses and is able to grow well under this environment. Moreover, the growers have a deep understanding of the growth and crop requirement of this variety. Both of these reasons allow growers to use their greenhouses to their full potential. However, Growers are still not successful in this business because sales income is still lower than annual production costs. Moreover, Seolhyang fruits are not in demand of the market, causing growers to have a lot of overdue products in storage.

VI. Harvest

Fruit of Pharachatan 80 is a kind of perishable fruit and often found fungal decay [37]-[40]. This character is similar to Japanese strawberry and requires intensive pre-harvest to post-harvest management. Some of the crop losses are caused by harvesting strawberries that are too ripe. Damage can be reduced by selecting maturity stages or using appropriate harvesting indices [34]. Most strawberry farms harvest their crop when 50-75 percent of the fruit is red. The major strawberry producing region of the United States, California, has a Harvest Index of 66 percent [41]. The harvest index that the Royal Project recommends to growers is 60-80 percent [42]. However, Doi Kham Food Products Co., Ltd. has set criteria that growers who want to sale in the premium category must harvest at 90 percent [22]. This chosen maturity stage is used as a selling point with the idea that consumers will receive high quality fruit which similar to that in the field. Packaging designed to accommodate the shape of the fruit is used along with maintaining temperatures from farm to store. The damage found was considerable even though various management systems had been put in place to help. Various techniques are applied to produce such as coating the surface of produce with edible solutions. However, coating fruit that is eaten fresh without peeling is quite risky in terms of taste. A technique that seems more likely to be applied to strawberries is plasma treatments and low temperature, as in the experiment with figs [43] or pre- and post-harvest salicylic acid treatment [44].

VII. Problem and Mitigation

Strategies

A. Pest Infestations

Common pests such as aphids, spider mites, and thrips can significantly damage strawberry crops. Effective pest management requires continuous monitoring and timely interventions.

Mitigating pest infestations in strawberry cultivation requires an integrated approach combining several strategies to effectively manage and reduce pest populations while minimizing the impact on the environment and human health. Integrated Pest Management (IPM) is a holistic approach that combines biological, cultural, mechanical, and chemical methods to manage pests sustainably. This involves using natural predators or parasites to control pest populations. For instance, introducing ladybugs to control aphids or using nematodes to target soil-dwelling larvae. Moreover, crop rotation and intercropping can disrupt pest life cycles. Selecting pest-resistant strawberry varieties and practicing proper sanitation by removing plant debris can also help reduce pest habitats. The chemical pesticides should be used as a last resort, they are sometimes necessary for managing severe infestations.

B. Diseases

Strawberries are susceptible to various diseases, including anthracnose, powdery mildew, botrytis (grey mold), and verticillium wilt. These diseases can reduce yield and fruit quality if not properly managed. Mitigating diseases in strawberry cultivation requires a comprehensive approach that incorporates cultural practices, biological controls, resistant varieties, and responsible use of chemicals.

1) Cultural Practices

Crop Rotation: Rotating strawberries with non-host crops can help break the life cycle of soil-borne pathogens. Avoid planting strawberries in the same field more than once every three to four years.

Sanitation: Removing plant debris and infected plants can reduce the sources of inoculum. Keeping the field clean and free from old plant material helps minimize the spread of pathogens.

Proper Spacing and Pruning: Adequate spacing between plants improves air circulation, reducing the humidity that favors disease development. Regular pruning of excess foliage can also help. minimize the spread of pathogens.

2) Resistant Varieties

Disease-Resistant Cultivars: Planting disease-resistant strawberry varieties can significantly reduce the incidence of certain diseases.

3) Biological Control

Beneficial Microorganisms: Introducing beneficial bacteria and fungi into the soil can suppress harmful pathogens. For instance, Trichoderma spp. can be used to control root diseases, while Bacillus subtilis is effective against foliar pathogens.

Natural Predators and Parasites: Encouraging natural enemies of disease vectors (such as mites and insects that spread viruses) can help manage disease indirectly.

4) Chemical Control

Fungicides: When necessary, fungicides can be used to control fungal diseases. It’s important to use them judiciously to avoid resistance development. Rotating fungicides with different modes of action can help prevent resistance.

Biorational Pesticides: Using softer chemicals like neem oil or potassium bicarbonate can be effective against diseases with minimal impact on the environment and non-target organisms.

C. Soil Fertility

Maintaining soil health is crucial for strawberry production. Issues such as soil compaction, nutrient depletion, and poor drainage can adversely affect plant growth.

Ensuring soil fertility is crucial for the successful cultivation of strawberries. Planting cover crops like legumes (e.g., clover or vetch) can fix nitrogen in the soil and improve its organic matter content. These crops can be tilled into the soil before planting strawberries to boost fertility. Before crop, inoculating soil with beneficial microbes like mycorrhizal fungi and nitrogen-fixing bacteria can enhance nutrient uptake and improve plant health. These microbes form symbiotic relationships with plant roots, aiding in nutrient absorption and disease resistance. During crop, combining organic and inorganic fertilizers can provide immediate nutrient availability while enhancing soil health in the long term. Balanced fertilization with nitrogen, phosphorus, and potassium, along with trace elements like calcium and magnesium, is crucial for optimal growth. Regular monitoring and adapting practices based on specific soil conditions and plant needs are essential for sustained soil health and fertility.

D. Climate Change

Increasing temperatures and erratic weather patterns pose a significant threat to strawberry cultivation. Changes in climate can disrupt the growing season, affect fruit quality, and increase the incidence of pests and diseases. The most common obstacle is water shortages at the end of the growing season.

Mitigating the effects of climate change on strawberry cultivation in Thailand involves a combination of adaptive agricultural practices, technological innovations, and sustainable management strategies. Collecting and storing rainwater can provide an additional water source during dry periods. This practice helps maintain soil moisture levels and supports irrigation needs. Implementing drip irrigation and other water-saving technologies ensures that water is used efficiently and reduces the stress on water resources during droughts.

E. Incompletely Vernalization

This problem often happens due to warm air moving in the growing area. It increased the percentage of aborted flowers plus malformed fruits, resulting in a significant decrease in total marketable yield. Chiang Mai University has conducted an experiment using chilling to stimulate strawberries to bloom off-season. The results of the experiment show that artificial vernalization with the temperature lower than 10 that might show earlier flowering [31]. The plants which vernalized for 1 and 2 weeks at 2 °C showed earlier flowering (21.4 and 23.1 days, respectively) than did those vernalized at 4 °C (24.9 and 25.7 days, respectively). This technique can be further developed to solve the problem of plants not flowering in winter. Moreover, it was found that the use of MSG residue solution was sprayed to create flower inflorescences in Fang district. It was found that the strawberry plants had regular flower inflorescences after spraying this solution for approximately 3-4 days. This is consistent with subjection of Chiang Mai provincial agriculture and cooperatives office [45]. Also, supported by the study on a peanut legume which shows the highest yields when treated with MSG compared to the peanut treated with pig manure, chicken manure or cattle manure [46]. Research on the effect of MSG specifically on plant flowering appears to be limited or nonexistent in scientific literature. MSG is commonly known as a flavor enhancer used in food, but its potential impact on plant physiology, including flowering, hasn't been extensively studied. The next problem encountered after the plants show their inflorescences is incomplete pollination. Strawberries already have natural pollination factors such as insect, wind and gravity. However, there are some areas where poor pollination of strawberry flowers occurs results in small and malformed berries pollination or abnormal fruit shapes [47]. The use of plant growth regulators in the Gibberellin group can increase productivity. It has been widely found in Samoeng and Fang plantations. This is consistent with reports of using 75 ppm GA3 to increase strawberry fruit weight and the number of yields per plant [48]-[51]. Another plant growth regulator that promotes complete development of strawberry fruits is auxin [52]. However, the concentration of auxin is specific to the strawberry variety and something that must be taken seriously. Problems with incomplete fertilization can be common in greenhouse. The use of pollinators can increase the fertilization rate and allow the fruit shape to develop normally. Keeping bees to raise in strawberry greenhouses is a normal procedure in Japan (Fig. 19).

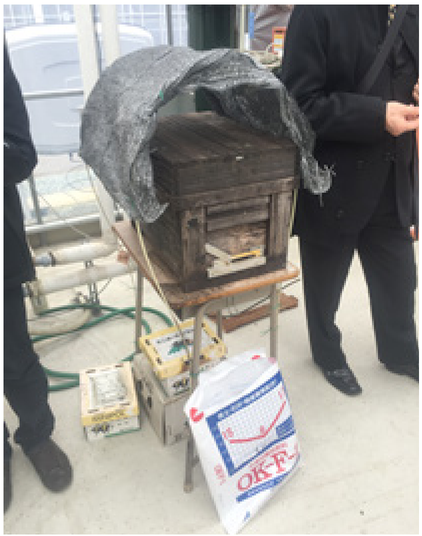

Fig. 19. Example of beekeeping in a strawberry production greenhouse for use in pollination

Some strawberry growers in Thailand have brought bees into their greenhouses to help with pollination and have had success in reducing malformed berries. A survey of the plantation area revealed that Maejo University is another source of strawberry cultivation under greenhouses that use bees for pollination and are successful (Fig. 20).

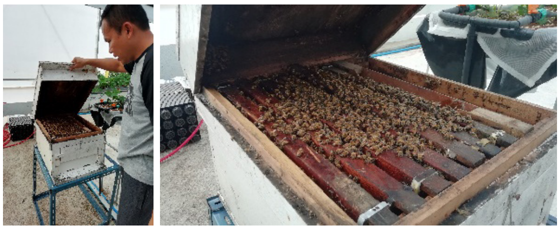

Fig. 20. Experiment with raising bees in strawberry production greenhouses at Maejo University, Chiang Mai

VIII. Conclusion

Strawberries are appreciated worldwide for their unique flavor, high nutritional value, and health benefits. Thailand has a rich history of strawberry cultivation dating back to the 1960s, aiming to provide hill tribes with an alternative source of income and combat illegal activities. However, challenges such as inadequate cultivation methods hinder optimal production.

Integrating traditional Thai farming with advanced technologies is vital for improving cultivation practices. Proper soil management, pest and disease control, and adaptation to climate change are crucial for successful strawberry cultivation. Strategies like IPM, using disease-resistant cultivars, and maintaining soil fertility play a key role in mitigating challenges. Harvesting and post-harvest management are critical to ensuring fruit quality and reducing losses. Addressing issues like incomplete vernalization, climate change impacts, and pollination challenges are important for sustainable strawberry cultivation. Adopting innovative techniques such as artificial vernalization, monitoring flower development, and enhancing pollination through growth regulators or pollinators can improve yields and minimize fruit abnormalities.

Overall, a holistic approach combining traditional knowledge with modern technologies, along with effective pest and disease management, proper soil fertility practices, and adaptation to climate challenges, is essential for successful and sustainable strawberry cultivation in the northern region of Thailand.

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