Development of Soilless Culture for Crop Production in Thailand

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ABSTRACT

In Thailand and many other countries alike, hygienic crops are in great demand especially among the growing number of tourists and health conscious people. Considering the problem of arable land shortage, soilless culture or hydroponics is a promising alternative crop production system. The objective of this research was to identify appropriate soilless culture systems for cash crops, like temperate lettuce and herbs that are normally imported, and for some other popular local crops.

The research procedure consisted of two main steps: 1) collection of data from His Majesty the King's projects for agricultural development in Thailand; 2) documentary reviews from seminar sessions in Thailand, Taiwan, Swaziland and the Maldives, and focus group discussions with experts. Data were collected by quantitative methods and analyzed by both quantitative and qualitative methods.

The research revealed that: 1) soilless culture systems for crop production used in Thailand were: dynamic root floating techniques (DRFT), nutrient film techniques (NFT), substrate culture, deep flow techniques (DFT), and aeroponics; and 2) DRFT, NFT and DFT were appropriate for vegetable production, but substrate culture was appropriate for fruit vegetables.

Thailand is a tropical country, but by using hydroponic technology, good quality and hygienic temperate vegetables and other crops can be produced. At present, people can buy temperate lettuce at a much cheaper price because local supply can replace imported products. Such endeavors could also be undertaken by many other countries with limited arable land and water resources in Oceania and Africa for example.

Keywords: soilless culture, hydroponic

บทคัดย่อ

ความต้องการผักอนามัยของประเทศไทยมีเพิ่มสูงขึ้น เนื่องจากการเพิ่มขึ้นของจำนวนนักท่องเที่ยวชาวต่างประเทศ และผู้บริโภคชาวไทยที่มีความห่วงใยในเรื่องสุขภาพ การปลูกพืชไม่ใช้ดินเป็นอีกทางเลือกหนึ่งของระบบการผลิตพืช การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อบ่งชี้ถึงระบบการปลูกพืชไม่ใช้ดินที่เหมาะสมกับการปลูกผักราคาสูง เช่น ผักสลัด สมุนไพรที่มีการนำเข้าจากต่างประเทศ และผักพื้นเมืองซึ่งได้รับความนิยม

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การวิจัยครั้งนี้ประกอบด้วย 1) การรวบรวมข้อมูลที่ได้จากการทดลองของโครงการตามพระราชดำริในด้านการพัฒนาการเกษตรของประเทศไทย 2) การตรวจเอกสารและการสัมมนาในประเทศไทย ไต้หวัน สวาซิแลนด์ และมัลดีฟส์ รวมทั้งการประชุมกลุ่มย่อยร่วมกับผู้เชี่ยวชาญด้านการปลูกพืชไม่ใช้ดิน ทำการวิเคราะห์ข้อมูลโดยใช้วิธีการในเชิงปริมาณร่วมกับในเชิงคุณภาพ

ผลการวิจัยพบว่า 1) ระบบการปลูกพืชไม่ใช้ดินในประเทศไทยมีอยู่ 5 ระบบ คือ ระบบ Dynamic Root Floating Techniques (DRFT), Nutrient Film Techniques (NFT), Substrate Culture, Deep Flow Techniques (DFT) และAeroponics และ 2) DRFT, NFT และ DFT เป็นระบบการปลูกพืชไม่ใช้ดินที่มีความเหมาะสมกับการผลิตผักโดยทั่วไป ส่วนระบบ Substrate Culture มีความเหมาะสมกับการผลิตผักที่ให้ผล

ประเทศไทยอยู่ในเขตร้อน แต่ด้วยการใช้เทคโนโลยีการปลูกพืชไม่ใช้ดินทำให้สามารถผลิตพืชเขตอบอุ่นและพืชอื่นๆ ที่มีคุณภาพดี ซึ่งในปัจจุบันได้มีการผลิตเพื่อทดแทนการนำเข้า โดยที่ประเทศอื่นๆ ที่มีข้อจำกัดในเรื่องที่ดินและแหล่งน้ำ เช่น หมู่เกาะต่างๆ และอาฟริกา ก็สามารถนำไปทดลองปฏิบัติได้

คำสำคัญ: การปลูกพืชไม่ใช่ดิน ไฮโดรพอนิกส์

INTRODUCTION

Academic and research work on soilless culture or hydroponics was started in 1957 at the Botany Department, Kasetsart University (Satiensawas, 2003). However, it was taken more seriously when HRH Princess Mahachakri visited Israel in 1977 and Japan in 1983 where agricultural development, including hydroponic systems at a commercial scale, attracted her attention. Upon her return, she graciously suggested that soilless culture techniques should be seriously studied and developed in Thailand. In 1987, the Food and Agriculture Organization (FAO), in order to mark the celebration of the King's 60th birthday granted financial support for research and development of soilless culture for crop production in Thailand to be jointly conducted by Kasetsart University and the Royal Development projects, Bureau of the Royal Household. The purpose of this project was to study the possible use of soilless substrates for crop production in Thailand. It also concentrated on finding alternative means of crop production for small farmers in the areas with soil problems (e.g. sandy, saline or acid-sulfate soils) which covered about 30 percent of arable land. Another aspect of the project was to identify which of the demanding techniques of hydroponics could be easily adopted by farmers.

Other research work on soilless culture was carried by Kasetsart University in collaboration with the Japan Society for Promotion of Science (JSPS) through the National Research Council of Thailand from 1990 to 1992 (Wattanapreechanon, 2007). In 1997, research on dynamic root floating hydroponic techniques as a means of growing vegetables in the Highlands all year-round was conducted under the technical cooperation program between the Royal Project Foundation and the Republic of China (Kao, 1997). Since Thailand's economic crisis in 1997, soilless culture or hydroponics has expanded throughout the country as the private sector has obtained the technology from developed countries and can produce up to 16 crops of leafy vegetable with consistently superior quality, high yield, and rapid growth all year-round (Montri & Wattanapreechanon, 2006).

In 2010, over 188 hydroponics growers were registered for commercial vegetable production in Thailand (Department of Agriculture (DOA), 2010). In addition, several small hydroponic units were used for producing vegetables for home consumption. Those commercial hydroponic vegetable farms are located in Bangkok and its surrounding areas as well as in tourist attraction provinces such as Phuket, Chiang Mai, Prachuap Khiri Khan and Surat Thani. All equipment is locally manufactured, reducing the

initial investment and capital cost required by the growers.

At present, the arable land in many countries is decreasing everyday, replaced by buildings and industries. Hydroponic technology is the answer to this problem, especially for crop production to serve the needs of health-conscious groups and tourists alike. Moreover, with good marketing strategies, hydroponic farming can generate a satisfactory income. It is recommended that other countries with similar problem, like those in Africa and Oceania should learn from Thailand's experience.

The objective of this study was to identify appropriate soilless culture systems that could be adopted in Thailand for cash crops like temperate lettuce and herbs that are normally imported, and for some other popular local crops.

LITERATURE REVIEW

Soilless culture is a technique to grow plants without soil, while hydroponics originally meant nutrient solution culture with no supporting medium. However, growing plants using solid media for anchorage and using a nutrient solution is also called hydroponics. Hydroponic systems of cultivation can be classified according to the techniques employed. A hydroponic technique refers to the method of applying nutrient solution to the plant roots (Ikeda, 2007).

Hydroponics is a valuable means to supply fresh vegetables in countries with limited arable land as well as in small countries with large populations. It could also be particularly useful in some other countries where tourism plays a vital role in their economy. Hydroponics could be used on the remaining non-arable land to provide sufficient fresh vegetables for the indigenous population as well as the tourists. Typical examples of such regions are the West Indies and Hawaii, which each have a large tourist industry and very little farmland for vegetable production (Resh, 1993).

SWOT analysis.

The overall evaluation of a company's strengths, weaknesses, opportunities and threats is called SWOT analysis; it is a way of monitoring the external and internal marketing environment (Kotler, 2009). This can be applicable to soilless culture in determining suitable crops for each system and vice versa taking into account the inputs, outputs, and process of crop growing.

Boston's model

This model is widely used and involves experts analyzing data and information obtained from SWOT analysis to identify the most appropriate soilless culture system for each crop (Sukprasert, 2008).

METHODOLOGY

The research procedure consisted of two main steps as follows:

1. Collecting soilless culture data. Data were obtained from various projects, namely His Majesty the King's Project for agricultural development in the North, H.M.'s Private Development Projects at Sapansung, Bangkok, and the Luk Phra Dabos Agricultural Training and Development Centre, Samutprakarn. Comparisons were made on the techniques (NFT, DRFT, and DFT) used at those projects and at other farms in Thailand.

Data were also obtained from various research reports presented at seminars on "Development of Soilless Culture for Crop Production" at Kasetsart University, Thailand, National Chung Hsing University, Taiwan, University of Swaziland, Swaziland, and the Ministry of Fisheries and Agriculture, Maldives. The data were used to assess the inputs, outputs, and the process of growing soilless culture as part of the SWOT analysis.

2. Conducting focus groups. A focus group discussion was conducted with 22 members from the Thai Soilless Culture Forum Committee, soilless culture farmers, and experts from Kasetsart University, to gather their experiences, problems, and comments which were analyzed using Boston's model to

identify the most appropriate system of soilless culture for crop production.

RESULTS AND DISCUSSION

Since 1997, soilless culture or hydroponics has expanded throughout Thailand after the country's economic crisis. There are five soilless culture systems currently practiced, namely, NFT, DRFT, DFT, areoponics, and substrate culture. However, the existing information, data, and recommendations were considered to still be minimal and inadequate for the interested persons to study and help them make decision before implementing this new technology.

In this study, it was necessary to obtain data from previous works: in 1987, from Kasetsart University and the Chitralada Palace; and in 1997, from the Royal Northern Project, from H.M.'s Private Development Projects in Sapansung, in Bangkok, and from the Luk Phra Dabos Agricultural Training and Development Centre, Samutprakarn and from the Sai Jai Thai Foundation, Bangkok. Some findings and practices on soilless culture from those projects were presented at both local and international seminars.

Of the five soilless culture systems in use in Thailand, growers chose a system depending on their conditions taking the following factors into account: crop size, crop price, varieties, climate, tropical environment, and cost of investment.

In the future, it has been anticipated that hydroponics should play a much greater role in food production in developing countries. Food products from hydroponic techniques have a high potential to help improve dietary standards as they are of superior quality and rich in nutrients. Maybe, hydroponics could also become an important tool to eradicate malnutrition problems and certain diseases commonly associated with extreme poverty conditions (Paul, 2000).

Hydroponics is usually claimed to involve a high initial capital cost and complicated operational procedures. However, these problems could be resolved by using new simplified hydroponic methods and simple equipment. In Japan, farmers simply built their own equipment using local materials which were much cheaper than purchasing the same thing (Ratanakosol, 1997).

Thailand, like any other country in the tropics, is influenced by the monsoon season. During the rainy season, various crops could be damaged to varying extents due to the heavy rainfall (334 mm in September) followed by severe plant diseases. Chemicals used in controlling pests and diseases are very expensive and could leave residues in plant products, while there is growing demand for high quality with minimal or no pesticide residues in vegetables, both for local consumers and for export. Therefore, it became necessary to study alternative methods of plant growing (Wattanapreechanon & Wattanapreechanon, 1997).

Soilless culture was seen as an alternative means for farmers who would like to grow fresh and healthy vegetables to serve the high demand from markets. However, there were still many problems to be solved.

1. Advantages of soilless culture

Research results have proved that soilless culture has more advantages over soil culture as shown in Table 1, which indicates that yield, income, profit, and the number of crops per year of soilless culture were much higher than for soil culture.

Soilless culture was identified as a technique that can solve many problems in unsuitable environments, since growers could control both the aerial and root environments of plants. Plants could grow better, the growing season could be extended, and finally there was an increase in crop yields and income. Advantages can be classified as follows:

1.1 Economic aspects

1.1.1 Time saving. A hydroponic system could drastically reduce the amount of time needed to produce good plants, crops, and fruit. Any vegetables, flowers, shrubs, and even trees could be

grown without the need to eradicate weeds and mulch, while watering and fertilizing can be taken care of by automatic systems. Hydroponic gardens can be established anywhere, irrespective of the soil or climate (Dalton & Smith, 2003). In Bangkok, farmers can harvest up to 16 crops of temperate lettuce per year using NFT (Montri & Wattanapreechanon, 2006), which is not possible in soil cultivation. For native vegetables, it is possible to have as many as 12 crops per year using DRFT.

1.1.2 Cost saving. Under a partially controlled environment, a smaller number of seedlings was required while losses from pests and diseases could be greatly reduced, especially if plants are in a greenhouse or some other protected structure. For commercial growers, hydroponic systems were considered ideal. They were highly efficient and required a low capital cost while they could produce maximum yields with less labor inputs.

Table 1 Comparison between soil and soilless production on investment and profit of temperate lettuce, some popular local crops and herbs conducted at Luk Phra Dabos Agricultural Training and Development Centre, Samutprakarn Province

Parameter \ Vegetable	Lettuce[1] (Soil culture)	Lettuce (NFT Outdoor)	Lettuce (NFT Evaporative cooling house)	Chinese cabbage[2] (DFT)	Chinese cabbage (DRFT)	Rocket Young vegetable (NFT outdoors)	Rocket Young vegetable (DRFT)
1. Plot size (m)	1.00×5.00	1.60×6.00	1.60×12.00	1.20×4.80	1.00×3.80	1.60×6.00	1.00×3.80
2. No. of plants (plants/m^2)	9.00	25.00	25.00	70.00	79.00	94 (pots)	79 (pots)
3. Yield (kg/plot)	7.90	28.00	60.00	25.00	18.00	20.00	12.00
4. Average yield (kg/m^2)	1.58	2.92	3.13	4.34	4. 74	2.08	3.16
5. Wholesale price (baht/kg)	20.00	60.00	60.00	40.00	40.00	100.00	100.00
6. Income (baht/m^2)	31.60	175.00	187.80	173.61	189.60	208.00	316.00
7. Average investment (baht/kg)	6.10	40.00	45.00	25.00	20.00	60.00	55.00
8. Investment (baht/m^2)	9.64	116.80	140.85	108.50	94.80	124.80	173.80
9. Profit (baht/m^2)	21.96	58.20	46.95	65.11	94.80	83.20	142.20
10. Annual crops	4.00	14.00	14.00	10.00	12.00	16.00	14.50

NFT = Nutrient film techniques, DRFT = Dynamic root floating techniques, DFT = Deep flow techniques

[1] Collected from The Royal Northern Project because most temperate lettuces and herbs cannot grow in Bangkok.

[2] Collected from H.M. Private Development Projects Sapansung, Bangkok

Source: Phra Dabos Foudation (2009)

1.1.3 Better quality and quantity. Fruit and vegetables produced hydroponically had a superb flavor and texture, because they could absorb all kind of necessary nutrients that the growers could provide. Plants grew faster and healthier with more resistance to diseases than plants grown in the soil. Growth could also be sped up by using techniques such as heating or cooling the nutrient solution to the optimum temperature suitable for the plants roots, so that greater yields and better quality could be anticipated. In a hydroponic system, replanting could be done immediately after harvest, as farmers did not have to sterilize the soil, making it possible to have continuous production (Figure 1). Hydroponic vegetables had no toxic substances, no pesticides and no harmful microorganisms, which meets the most stringent catering specifications (Wilson, 2000). In Thailand, most hydroponic growers get Good Agricultural Practice (GAP) certificates as a guarantee to buyers that the product is safe, hygienic and grown using standard techniques. Figure 1 shows the yield and income of temperate lettuce grown by a hydroponic technique in an area of high soil salinity, where temperate lettuce could not normally be grown.

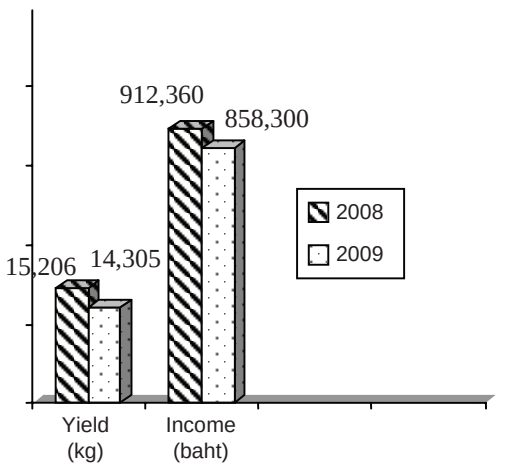

Figure 1 Yield and income of hydroponic vegetable production conducted at Luk Phra Dabos Agricultural Training and Development Centre, Samutprakarn, with 60 plots (size 1.6 × 6.0 m), total area = 576 m^2.

Source: Luk Phra Dabos Agricultural Training and Development Centre (2009)

1.2 Social aspects

A hydroponic system was considered to require less labor. Women, children, senior citizens, or disabled people could do the tasks without additional help. As there was no dirt in the system, it was easy to keep everything clean and minimize any problems usually caused by soil-borne diseases. Home-grown-quality fruit and vegetables could be produced almost all year-round. It could also be a challenging and exciting family hobby or a means of earning some supplementary income. Where there was a lack of labor, the younger generation could serve as competent growers.

1.3 Environmental aspects

Soilless plant production in a greenhouse was identified as the growing technique with the most friendly environment because it could reduce the use of chemical pesticides and encourage awareness of the efficient use of natural resources. For hydroponic systems such as NFT, DRFT, DFT, and aeroponics, the surplus nutrient solution could be easily recovered and recycled. Moreover, a closed system is highly cost-effective resulting in a low cost of nutrients, efficient use of water, and environmental friendliness.

Soilless culture or hydroponics was no longer seen as a subject of science fiction or a mysterious form of growing plants in the laboratory. It was considered a well established and fast growing part of modern commercial agriculture. However, growers had to choose the technique suitable for their conditions—climate, plant species, markets, management skills, local material and supplies for the system. The soilless culture techniques used in various countries are different according to their grower's conditions (Table 2).

The standard method for growing vegetables throughout Thailand was in the soil. Before 1995, following their introduction by the Royal Project

Table 2 Soilless culture systems for crop production in Thailand and in some other countries

Countries	NFT	DRFT	DFT	Aeroponic	Substrate culture
Thailand	✓	✓	✓	✓	✓
Singapore	✓	✓	-	✓	✓
China	✓	-	✓	✓	✓
Korea	✓	-	✓	✓	✓
Japan	✓	-	✓	✓	✓
New Zealand	✓	-	-	-	✓
Australia	✓	-	-	-	✓

NFT = Nutrient film techniques, DRFT = Dynamic root floating techniques, DFT = Deep flow techniques.
Source: Data obtained from personal visits to and surveys in these countries.

Foundation as substitute crops for opium, crisp iceberg lettuce, cos lettuce and red leaf lettuce were grown in soil in the Highlands by hill tribes. However, the produce was not sufficient to meet demand, especially in the summer and rainy seasons. Moreover, these products could not be grown in other parts of the country because it was too hot there. The fact that Thailand had a high demand for such crops, especially to serve the influx of over 13 million tourists in 2007, meant that substantial amounts had to imported from other countries. Growing numbers of tourists and health-conscious Thai people were an important market for soilless cultural vegetable production. For hydroponic culture, farmers can grow temperate lettuce all year-round and all over Thailand because the environment required for successful crop production, especially the temperature, could be controlled.

2. Development of soilless culture or hydroponics in Thailand

In Thailand, soilless culture was developed more than two decades ago but the product volume was still much lower than the demand. Many problems still remain to be solved. Much attention has been paid to developing a soilless cultivation technique for each crop and to standardize cultivation methods. This effort included careful selection of varieties and the selection of hydroponic equipment using local materials, e.g., seeds, growing substrate, water improvement techniques, cooling systems, automatic controlled water sprayers, and nutrient solution controllers.

The five main growing systems in Thailand are listed in Table 3.

The focus group discussion, consisting of 22 members from the Thai Soilless Culture Forum Committee, experts from Kasetsart University, and soilless culture farmers was held in November 2010. From the brainstorming sessions involving SWOT analysis on the inputs, outputs, and processes of soilless culture, it was evident that only 5 main soilless culture systems are used—DRFT, NFT, substrate culture, DFT and aeroponics. The DRFT, NFT, and DFT systems worked well for vegetable production, but substrate culture was suitable for fruit vegetables (sweet peppers, tomatoes, etc.) due to the limitations of crop size, crop price, variety, climate, tropical environment and the cost of investment (Figure 2). These results were similar to a previous study by Montri and Wattanapreechanon (2006), as shown in Table 3. However the high initial capital cost and mechanical complexity could be reduced by using newly simplified local materials and simple equipment as recommended by Ratanakosal (1997).

Figure 2 shows that only 4 soilless culture systems work well for vegetable production, being DRFT, NFT, substrate culture, and DFT.

Table 3 Classification and estimated area of soilless culture growing in Thailand

System	Crops	Area (ha)
NFT	Temperate lettuces	25
DRFT	Temperate lettuces, local vegetables	32
	(Chinese cabbage, Chinese celery,	
	Chinese kale, Water convolvulus etc.	
DFT	Temperate lettuces, musk melon	13
	Aquatic plants	3
Aeroponics	Temperate lettuces	1
Substrate: e.g. coconut fiber	Sweet peppers, tomatoes	
and coir	Musk melon	50
Substrate: e.g. coconut husk	Orchids	3,100
	Total	3,224

NFT = Nutrient film techniques, DRFT = Dynamic root floating techniques, DFT = Deep flow techniques
Source: Montri and Wattanapreechanon (2006)

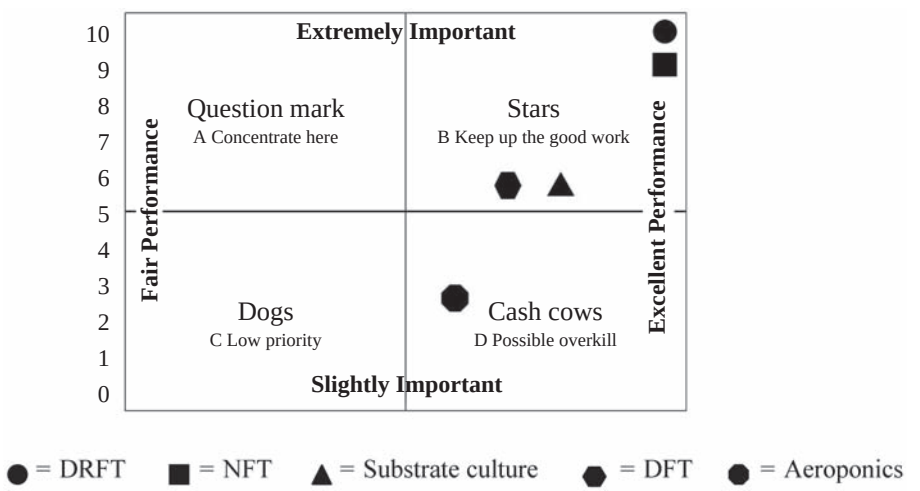

Figure 2 Analysis of a hydroponic system suitable for vegetable production in Thailand using Boston's Model

3. Key success factors of soilless culture or hydroponics in Thailand.

Commercial soilless culture or hydroponics production of fresh vegetables in Thailand has been growing steadily. In order to succeed, growers had to take many key factors into account as shown in Figure 3.

3.1 Good varieties

The soilless culture for vegetable production became more popular as Thai people consumed more fresh vegetables than before. Soilless culture has paved the way for growing new species and varieties. Technology combined with new species could increase food production and income, improve product quality, and increase the diversity of food to

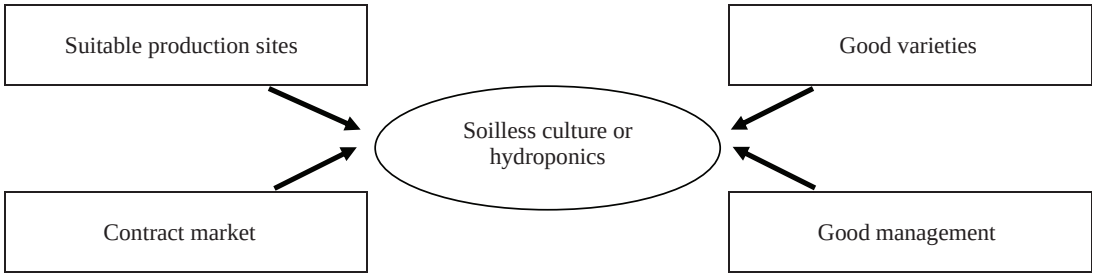

Figure 3 Key factors of soilless culture or hydroponics production

achieve national food security targets. Temperate lettuces and herbs were popular with tourists and rich, health-conscious Thai people but not amongst low income groups. The consumption of local vegetables was in fact higher than for exotic vegetables.

3.2 Suitable production site

Soilless culture or hydroponics was one of the means of growing fresh vegetables and flowers for tourists and city residents who needed high quality products. Some of these soilless vegetables were exported to foreign countries. However, in choosing an appropriate location for a soilless farm, the availability of water supply, electricity, communications, transportation systems, and markets needed to be considered.

3.3 Contract market

Although the market for perishable commodities was one of the most challenging problems, appropriate modern post-harvest technologies could be an effective solution. In order to maintain stable production, some farms have invested in buildings with evaporative cooling systems for better temperature and pest control, and can produce vegetables at an average of 16 crops per year. Contract marketing was working well for hydroponic products as growers could earn a stable income from consistent yields with continuous cultivation.

3.4 Good management

At the commercial scale, hydroponics management was both an art and a science. Growers had to know what kinds of nutrients and how much to apply and under what conditions, as well as understanding the plant-acquired nutrients from the environment and how they affected plant growth and development. Trained personnel were required to supervise the growing operations and the growers had to inspect their plants every day. In addition, a soilless culture system needed a steady power supply for equipment, good quality water, sufficient light, good ventilation, and good growing media.

4. Conditions for future development

In the past, research work on soilless culture or hydroponics was undertaken for its scientific knowledge only. Recently, the economic aspect has become more important. Therefore, researchers have been working on how to reduce costs and improve the production of hygienic vegetables. The past research could identify which hydroponic systems were suitable for growing each cash crop and some popular local crops with the appropriate food safety techniques at a reasonable price (Table 4).

In order to reduce production costs and improve product quality on hydroponic farms, it was necessary to develop equipment using local materials. The results from experiments conducted at the Luk Phra Dabos Agricultural Training and Development Centre, Samut Prakarn, are shown in Table 5.

CONCLUSION

In Thailand, soilless culture has developed steadily over the last two decades. Many commercial hydroponic farm have been set up in Bangkok and

Table 4 Suitable systems for crop production in Thailand

Crops	Suitable system
Temperate lettuces	NFT, DRFT, DFT (Highlands), aeroponics.
Temperate herbs (rocket, sweet basil)	NFT, DRFT, DFT (Highlands)
Local vegetables (Chinese cabbage, Chinese celery, Chinese kale, water convolvulus etc.)	NFT, DRFT, DFT
Fruit vegetables	Substrate culture

Table 5 Comparison of imported and locally made hydroponic equipment

	Imported	Locally made	Advantage of locally made
Substrate	Perlite + vermiculite	Urethane foam	Cheaper
Cooling system	Cooling set	Local assembly	Cheaper and good after-sales service
Automatic controlled water sprayed	Set	Local assembly	Cheaper and good after-sales service
Automatic nutrient solution controller	Set	Reused saline solution plastic bags	Very cheap and environmentally friendly
pH meter	Set	Local pH test kit	Cheaper

in the provinces with tourist attractions as described by Resh (1993). Plants grown by hydroponics had consistently superior quality, high yield, rapid harvest, and high nutrient content. Soilless culture could be applied to growing some popular local crops with the application of food safety standards and at a reasonable price (Paul, 2000). The advantages and impacts of soilless culture or hydroponic growing are nearly the same as in Japan (Ikeda, 2007). However, it was necessary to gather more knowledge and gain experience of soilless culture systems. From the focus-group technique, it could be concluded that there were only 5 main soilless culture systems in use, namely DRFT, NFT, substrate culture, DFT, and aeroponics. While the DRFT, NFT, and DFT systems were appropriate for vegetable production, substrate culture was appropriate for fruit vegetables due to the limitations of crop size, crop price, varieties, climate, the tropical environment, and the cost of investment. The results were similar to those from a previous study (Montri & Wattanapreechanon, 2006). However, the volume of soilless crop production was still found to be lower than that in developed countries. Although many species of vegetables including temperate lettuce and herbs could easily be grown under all climates and in all locations using suitable processes and maintenance, many problems still remained to be solved. Soilless culture production in Thailand first originated from orchid production, one of its major agricultural export items. In order to develop hydroponic production, many key factors should be taken into account. For example, growers need to better understand the technology, good management practices, good varieties, choose suitable production sites, and have contract markets. Production should not be limited only to temperate lettuce and herbs but should also cover some popular local crops for sale at a reasonable price. To expand the hydroponic industry in Thailand, it is necessary to develop hydroponic equipment using local materials

for commercial hydroponic farms, and to effectively disseminate the technology, as has been accomplished in Japan (Ratanakosol, 1997).

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