Hydroponic vegetable cultivation development for extension at Luk Phra Dabos Agricultural Training and Development Center, Samut Prakan province

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Abstract

Hydroponic vegetable production in Thailand has been expanding every year. Farmers have turned to this technique realizing that it is easier to manage than the soil-grown, especially for temperate lettuce and herbs that are normally imported, and some other popular local crops. Under controlled conditions, the products are cleaner, safer and get a better price, which means much higher income for farmers. At the initial stage, hydroponic technology and equipment were all imported resulting with high capital cost. In order to lower the production cost, much effort has been put to replace imported items with local material. The objective of this research is to find hydroponic vegetable production systems suitable for extension program at Luk Phra Dabos Agricultural Training and Development Center. The research revealed that: 1) suitable systems for lettuce: were Nutrient Film Techniques (NFT) > Dynamic Root Floating Techniques (DRFT) > Deep Flow Techniques (DFT) > Aeroponics, for western herbs: they were NFT > DRFT > DFT, for popular native vegetable were DRFT > NFT > DFT and the substrate cultures technique was more suitable for fruit vegetables, 2) key success factors of hydroponic were good varieties, suitable production site, contract market and good management and, 3) farmers were advised to use the hydroponic system modified by using local materials for lower production cost and simple maintenance easily done by themselves.

Keywords: hydroponic, soilless culture

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Introduction

Food security in Thailand started to be more important as witnessed by higher demand of hygienic food than production. Global warming and climate change like drought, gales, heavy rain, flood, high temperature, forests fires, pests etc. cause many impacts on plants. Determination of natural resource, soil fertility and quality of water induce hydroponic vegetable production more important than traditional soil grown. For certain crops such as temperate lettuce and herbs that are normally imported and for some other popular food crops, farmers prefers hydroponic technique to conventional cultivation method.

Since Thailand's economic crisis in 1997, hydroponic 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 (Mortri and Wattanapreechanon, 2006).

The number of hydroponic farmers at the commercial scale has rapidly increased from 188 registered in 2010 to 765 in 2016 (Department of Agriculture, 2010, 2016). In addition, several small hydroponic units were used in vegetables production for home consumption. Those commercial hydroponic vegetable farms were mostly in Bangkok and its surrounding areas as well as in tourist attraction provinces such as Phuket, Chiang Mai, Prachuap Khiri Khan and Surat Thani. However in some locations like Khoakho district, Petchaboon province which located on 700 meters above sea level with cool weather all year round, the productivity could double like 26 crops per year and all year round for lettuce (Senadee, 2015). They all used locally manufactured equipment, resulting with lower initial investment and capital cost. It was found that greater volume of hydroponic vegetables have gradually all filled the shelves of supermarkets over the country.

Resh (1993) said that, hydroponics was a valuable means of growing fresh vegetables not only for countries with minimal arable land but also for small countries with large population. It could also be particularly useful in small countries with tourism as main industry, where hotels and tourist facilities took over most arable areas of the country, forcing conventional agriculture out of existence. Hydroponics could be done on the remaining non arable land to provide sufficient fresh vegetables for the indigenous population as well as the tourists.

The soilless plant production in greenhouse was the most environment-friendly growing technique because it could reduce the use of chemical pesticides, and realize the efficient use of natural resources and is a low load cultural

system to the soil. In addition, a little amount but with frequent fertigation was the most advanced cultural technique, because it could reduce labor for management, improve the productivity, and realize the stable production (Ikeda, 2007).

Luk Phra Dabos Agricultural Training and Development Center was established in 1998 as one of the Royal Development Projects with the objective to offer long term and short term training courses in integrated agricultural activities, value added methods for agricultural products, and herbs and renewable energy for Luk Phra Dabos Agriculture curriculum students, farmers, interested students to study and train here. Such agricultural technology transfer was not limited to Thai people but also to interested foreigners as well.

This study was conducted during 2009-2015 with the identify appropriate hydroponic systems that could be used in Thailand for cash crops like temperate lettuces and herbs that were normally imported and for some other popular local crops.

Methodology

The research methodology consisted of 4 steps as follows:

1. Collecting soilless culture data. The data were obtained from various projects, namely The Royal Northern Project, H.M.'s Private Development Projects at Sapansung, Sai Jai Thai Foundation, Bangkok, and Luk Phra Dabos Agricultural Training and Development Centre, Samut Prakan province, Comparisons were made on the techniques used at those projects and at other farms in Thailand.

2. Conducting focus groups. A focus group discussion was conducted among 22 members from the Thai Soilless Culture Forum Committee, hydroponic system manufacturers, hydroponic 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 hydroponics for crop production.

3. Interviewing 58 hydroponics farmers chosen as representatives from each part of Thailand to collect information and follow up hydroponic technology transfer.

4. Measurement for checking and analyzing data obtained on qualifications, authenticity and trust.

Results and discussion

Vegetable growing in soil was still predominant in Thailand but Thai farmers had to face many serious problems such as drought, flood, pests, plant diseases, low quality products and misuse of insecticides causing risks for their income earning. New agricultural technologies

have been researched and developed by government agencies, research institutes, universities and importantly, The Royal Development Projects.

Problems of growing vegetables in soil were soil-borne diseases and high temperature, growing plant continuously without crop rotation or interruption in production in open field, leading to an excessive build-up of soil pathogens and high temperature causing low yield and low quality product. Moreover, heavy rain could pave way for secondary infection from fungi and bacteria.

In Thailand, there were five soilless culture or hydroponic systems currently practiced, namely, Nutrient Film Techniques (NFT), Dynamic Root Floating Techniques (DRFT), Deep Flow Techniques (DFT), aeroponics, and substrate culture. However, the existing information, data, and recommendations were still minimal and inadequate for interested persons to study and help them make decision before implementing this new technology.

Of the five soilless culture systems in use, 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. However, hydroponics was seen as an alternative means for farmers who would like to grow fresh and healthy vegetables to serve the high demand from markets.

Key success factors of soilless culture or hydroponics in Thailand

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

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, improved product quality, and increased the diversity of food to achieve national food security targets. Temperate lettuces and herbs were popular with tourists and well-to-do health-conscious Thai people. The consumption of local vegetables was in fact higher than for exotic vegetables.

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 were to be considered.

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 invested in buildings with evaporative cooling systems for better temperature and pest control, and could produce vegetables at an average of 16 crops per year. Contract market worked well for hydroponic products as growers could earn a stable income from consistent yields with continuous cultivation.

4. Good management

At the commercial scale, hydroponics management was both art and science. Growers had to know what kind of nutrients needed, how much to apply and under what conditions. They must understand 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 take care of 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.

Recently, the economic aspect became more important factor and research works have been conducted. Therefore, researchers have been working on how to reduce costs and improved the production of hygienic vegetables. The previous studies focused on identifying 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.

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 province were as follows (Table 1).

Table 1 Comparison between soil and soilless production of temperate lettuce varieties, herbs in NFT with PVC gullies in evaporative cooling house conducted at Luk Phra Dabos Agricultural Training and Development Center, Samut Prakan province during 2013.

vegetables / data concern	lettuce[1/] soil culture	green oak	red oak	red coral	butter head	cos	frillice iceberg	rocket young vegetable
1. plot size (m)	1.00×5.00	1.60×12.00	1.60×12.00	1.60×12.00	1.60×12.00	1.60×12.00	1.60×12.00	1.60×12.00
2. No. of plants (plants/m^2)	9	25	25	25	25	25	25	250
3. yield (kg/plot)	7.9	60	56	48	64	68	55	38
4. average yield (kg/m^2)	1.58	3.13	2.92	2.50	3.33	3.54	2.86	1.98
5. wholesale price (baht/kg)	20	65	65	65	65	65	65	100
6. income (baht/m^2)	31.60	203.45	189.80	162.50	216.45	230.10	185.90	198.00
7. annual crops	4	14	14	14	14	14	14	14

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

Table 2 Soilless outdoor production of temperate lettuce varieties, herb in NFT with PVC gullies under slan shading conducted at Luk Phra Dabos Agricultural Training and Development Center, Samut Prakan province during the cold season (December, 2013).

vegetables / related data	green oak	red oak	red coral	butter head	cos	frillice iceberg	rocket (young)
1. plot size (m)	1.60×6.00	1.60×6.00	1.60×6.00	1.60×6.00	1.60×6.00	1.60×6.00	1.60×6.00
2. average yield (kg/m^2)	3.77	3.58	3.17	4.00	4.08	3.67	2.10
3. wholesale price (baht/kg)	65	65	65	65	65	65	100
4. income (baht/m^2)	245.05	232.70	206.05	260.00	265.20	238.55	210.00
5. annual crops	14	14	14	14	14	14	14

Soilless culture was identified as a technique that could solve many problems in unsuitable environments. Plants could grow better, the growing season could be extended, and finally there was increase in crop yield and income would eventually increase (Table 2, 3, 4, and 5).

Table 3 Soilless production of temperate lettuce, some popular local crops conducted at H.M.'s Private Development Projects, Sapansung, Bangkok during the cold season (December, 2013).

vegetables / related data	green oak (NFT in evap)	red oak (NFT in evap)	butter head (NFt in evap)	cos (NFT in evap)	Chinese cabbage (DFT with plastic cover)	amaranthus (DFT with plastic cover)	Chinese celery (DFT with plastic cover)
1.plot size (m)	1.60×12.00	1.60×12.00	1.60×12.00	1.60×12.00	1.20×4.80	1.20×4.80	1.20×4.80
2.average yield (kg/m^2)	2.70	2.60	2.90	3.17	3.60	3.75	4.60
3.wholesale price (baht/kg)	65	65	65	65	50	50	50
4.income (baht/m^2)	175.50	169.00	188.50	206.05	180.00	187.50	230.00
5.annual crops	14	14	14	14	12	12	12

Table 4 Soilless indoor production of temperate lettuce varieties in DFT under plastic cover greenhouse conducted at Royal Northern Project, Inthanon Station, Chiang Mai province during the cold season (December, 2013).

vegetables / related data	green oak	red oak	butter head	cos	frillice iceberg
1. plot size (m)	12.00×6.00	12.00×6.00	12.00×6.00	12.00×6.00	12.00×6.00
2. average yield (kg/m^2)	4.16	3.75	5.27	5.41	4.72
3. wholesale price (baht/kg)	65	65	65	65	65
4. income (baht/m^2)	270.40	243.75	342.55	351.65	306.80
5. annual crops	12	12	12	12	12

Table 5 Average yield of temperate lettuce grown by various systems at different housing, and sites.

	Royal N. projects DFT in plastic house	Chitralada Palace NFT under slan shading	Sai Jai Thai NFT under slan shading	LukPhra Dabos NFT under slan shading	H.M.'s Dev. Projects NFT in EVAP	LukPhra Dabos NFT in EVAP
average yield (kg/m^2)	4.62	3.96	3.76	3.71	2.84	3.04

From the trial works, it was revealed that:

1. The average yield of temperate lettuce grown by NFT in PVC gullies in the evaporative cooling house was less than those grown under slan shading (Table 5) due to the lower quality and intensity of light for photosynthesis. However, the quality of vegetable produced harvested from evaporative cooling house was better because there was less damage from rain and fungus diseases in the rainy season and the temperature could be controlled in the summer.

2. The yield of temperate lettuce harvested in December was much higher than in October as the weather in December was much cooler.

3. It could be concluded that each individual varieties of lettuce yields differently as follows:

3.1 October: cos > butter head > green oak > red oak > frillice > red coral

3.2 December: cos > butter head > green oak > frillice > red oak > red coral

3.3 Frillice was particularly sensitive to hot temperature. If grown in cooler temperature, its productivity was much better.

4. For temperate lettuce if grown in different locations but not far apart, the yields were not different significantly. Luk Phra Dabos Agricultural Training and Development Center and Sai Jai Thai Garden could yield at the same level, which was higher than H.M.'s Private Development Projects, possibly because of the growers' experience. However, the Chitralada Palace and Royal Northern Projects could yield higher than those three mentions farms due to the higher efficiency of chillers for nutrient solution at Chitralada Palace and lower temperate at Royal Northern Project (Table 5).

Substrate culture was suitable for fruit vegetables as shown in (Table 6). However, yield of tomatoes grown by hill tribe farmers in Royal Northern Projects when compared with growers at Camelon High Land, Malaysia (30 kg/m^2) was nearly the same (Senadee, 2014).

Table 6 Soilless substrate culture of fruit vegetables under plastic cover greenhouses conducted at hill tribes farmers in Royal Northern Projects, Chiang Mai province during the cold season (December, 2013).

vegetables / data concern	tomatoes	cucumbers	sweet peppers
1. average yield (kg/m^2)	27.60	21.80	15.20
2. wholesale price (baht/kg)	30	25	75
3. income (baht/m^2)	828	545	1,140
4. annual crops	2	2	2

Research results showed that soilless culture had more advantages over soil culture as shown in (Table 6) which indicated that yield, income, and the number of crops per year of soilless culture were much higher than that of soil culture.

In the hydroponic system, replanting could be done immediately after harvesting, 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 met the most stringent catering specifications (Wilson, 2000). In Thailand, most hydroponic growers got good agricultural practice (GAP) certificates as a guarantee to buyers that the product was safe, hygienic and grown by using standard techniques. (Figure 1) showeds the yield and income of temperate lettuce grown by a hydroponic system in an area of high soil salinity, where temperate lettuce could not be normally grown.

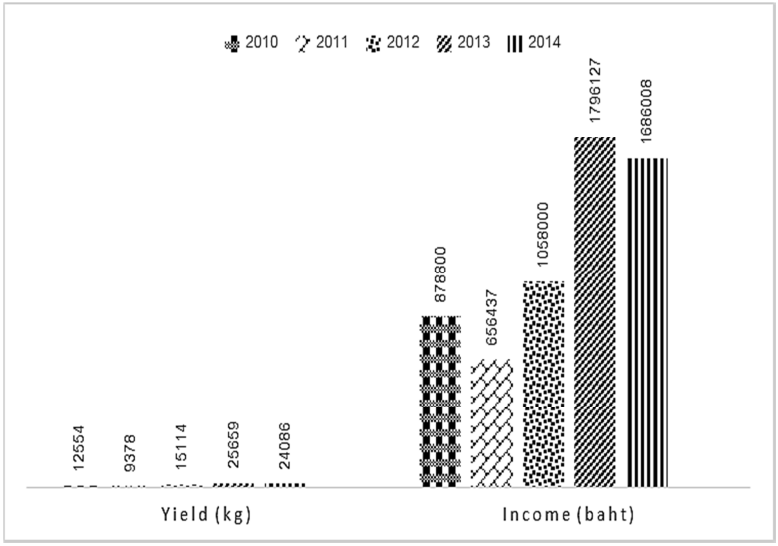

Figure 1 Total farm yield and income of hydroponic vegetable production conducted at Luk Phra Dabos Agricultural Training and Development Center, Samut Prakan province, with 90 plots (size 1.6×6.0 m) under slan shading and 24 plots (size 1.6×12.0 m) in evaporative cooling house, total area = 1,324.8 m^2. Source: Luk Phra Dabos Agricultural Training and Development Center (2014).

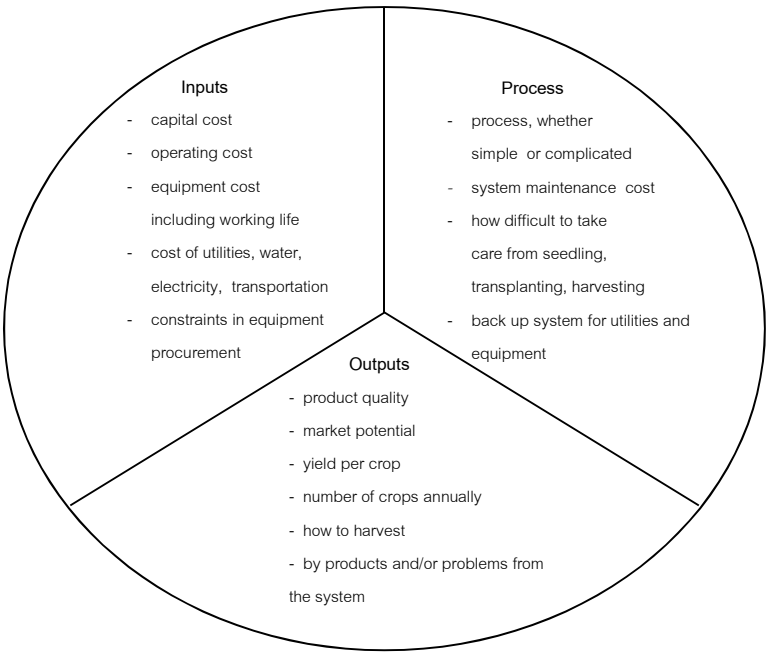

Figure 2 IPO model of hydroponic system.

In this study, the results revealed that in conducting a feasibility study and choosing suitable hydroponic systems, there were 3 dimensions to be considered called IPO model as shown in (Figure 2).

With the aim to identify and develop the hydroponic system suitable for growing crops, the focus group discussion and brainstorming sessions were conducted among research experts, hydroponic farmers, system manufacturers, involving SWOT analysis on the inputs, outputs, and process of soilless culture. It was concluded that only 5 main soilless culture systems were used - NFT, DRFT, DFT, aeroponics and substrate culture. The NFT, DRFT and DFT systems worked well for leafy vegetable production, but the substrate culture was proved to be suitable for fruit vegetable (sweet peppers, tomatoes, etc.) depending on the limitations of crop size, crop price, variety, climate, tropical environment and the cost of investment. The results were similar to those from a previous study (Montri and Wattanapreechanon, 2006) and confirmed by the study of Jongjairuk (2005) and Srinuanjun (2008). However, the volume of soilless crop production was still found to be lower than that in the developed countries. Although many species of vegetables including temperate lettuce and herbs could easily to be grown under all climates and in all locations using suitable processes and maintenance, many problems still remained to be solved.

The researchers worked on how to reduce costs and improve the production of hygienic vegetables. The research results could identify certain safe and cheap hydroponic systems suitable for growing each cash crop and some popular local crops (Table 7). So the researchers could synthesize data and select the systems suitable for potential crops as shown in (Table 7).

Table 7 Suitable systems for hydroponic crop production in Thailand.

crops	suitable system
temperate lettuces	NFT > DRFT > DFT > Aeroponics
temperate herbs (rocket, sweet basil)	NFT > DRFT > DFT
local vegetables (Chinese cabbage, Chinese celery, Chinese kale, water convolvulus etc.)	DRFT > NFT > DFT
fruit vegetables	substrate culture

In order to reduce production costs and improve product quality on hydroponic farms, it was necessary to develop equipment using local materials. The best hydroponic system using locally produceed equipment were conducted at Chitralada Palace, Bangkok, Sai Jai Thai Garden (Vocational Training Centre for the handicaps) Bangkok and Luk Phra Dabos Agricultural Training and Development Centre, Samut Prakan province. The results from experiments conducted at the Luk Phra Dabos Agricultural Training and Development Centre, Samut Prakan province, (Wattanapreechanon and Sukprasert, 2012).

Adoption of soilless culture technology

From the primary data collection and in-depth interviews with 58 hydroponic growers, the research revealed that:

Most hydroponic growers are male (69%). They preferred using NFT for leafy vegetable, and substrate culture for fruit vegetable. The NFT was used most at 48.3% (Table 8), because the investment cost of NFT (1,052 baht/m^2) was cheaper compared to DRFT (1,890 baht/m^2) (Sirinupong, 2013).

Most hydroponic growers get stable supply of quality products with stable price and high income, 56.9% could earn approximately 100,000 – 500,000 baht/year (Wattanapreechanon, 2014).

Table 8 Growers and their preference of soilless culture systems.

			soilless culture systems								total
			DRFT	NFT	DFT	substrate culture	NFT+ sub	DRFT NFT DFT	DRFT NFT	DRFT DFT	
sex	male	count	2	18	4	11	1	1	2	1	40
		expected count	3.4	19.3	4.1	7.6	0.7	1.4	2.8	0.7	40.0
		% of total	3.4%	31.0%	6.9%	19.0%	1.7%	1.7%	3.4%	1.7%	69.0%
	female	count	3	10	2	0	0	1	2	0	18
		expected count	1.6	8.7	1.9	3.4	0.3	0.6	1.2	0.3	18.0
		% of total	5.2%	17.2%	3.4%	0.0%	0.0%	1.7%	3.4%	0.0%	31.0%
total		count	5	28	6	11	1	2	4	1	58
		expected count	5.0	28.0	6.0	11.0	1.0	2.0	4.0	1.0	58.0
		% of total	8.6%	48.3%	10.3%	19.0%	1.7%	3.4%	6.9%	1.7%	100.0%

Hydroponic training programs at Luk Phra Dabos Agricultural Training and Development Centre, Samut Prakan province

Luk Phra Dabos Agricultural Training and Development Centre was the learning center as well as agricultural technology extension unit. Several one-day training courses have been offered since 2011 for farmers and interested people numbering 2,108 persons (Figure 3). In 2013, a 5-8 days training course for SME entrepreneurs has been added to help strengthen the communities. Moreover, many training curriculums on cooking with using vegetables as main ingredient like salad wrap, sushi with vegetable, salad and salad dressing, etc., which could draw attention of 366 interested people.

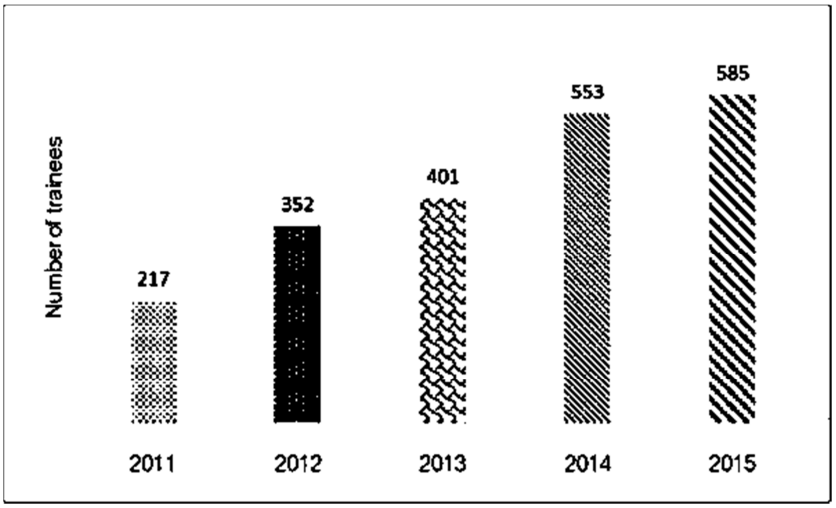

Figure 3 Number of trainees undergone 1-day training program on hydroponic culture conducted at Luk Phra Dabos Agricultural Training and Development Center, Samut Prakan province.

Conclusion

Hydroponic vegetable production in Thailand has been expanded rapidly due to growing demand for of hygienic vegetable by the incoming tourists and health conscious Thai people, creating important market for hydroponic vegetable production. There were more and more hydroponic farms throughout the country as the consumption volume was increasing every day. Temperate and some local varieties of vegetable were produced to serve the market demand both with the similar phenomenon as described by Resh (1993); Paul (2000). The advantages and impacts of hydroponic growing were nearly the same as in Japan (Ikeda, 2007). Those who decided to grow vegetable using hydroponic method had to do local market survey, field survey, to select crops and suitable system and to study the situation of hydroponic production and how to reduce the production costs especially by using local hydroponic equipment before starting their hydroponic farm.

From the research, it could be concluded that suitable systems for lettuce were NFT > DRFT > DFT > Aeroponic, for western herbs: they were NFT > DRFT > DFT, for popular local vegetable were DRFT > NFT > DFT, and the substrate culture technique was more suitable for fruit vegetables. All these are similar to farmers in Australia and New Zealand as most farmers concentrated on using NFT for leafey vegetable and substrate culture for fruit vegetable (Wattanapreechanon, 2011, 2012). To develop hydroponic production, many key factors should be taken into account. Farmers 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 to be sold at a reasonable price. In addition, farmers were advised to use the hydroponic system modified by using local material for lower production cost and simple maintenance easily done by themselves.

Acknowledgement

This research was kindly partly supported by Kasetsart University. The author would like to thank The Bureau of the Royal Household, Royal Project Foundation, The Phra Dabos Foundation and The Sai Jai Thai Foundation for providing information, facilities and areas to carry out experiments.

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