VAGETABLES SOILLESS CULTURE IN TAIWAN

by

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SUMMARY

The earliest recorded scientific approach to soilless culture in Taiwan was in 1969 in the form of gravel culture. Commercial-oriented water culture researches started in 1984 with rockwool culture initiatied in 1988. The total acreage of soilless culture in Taiwan is estimated to be about 35 hectares in 1990. Among the 35 hectares, 20 hectares are water-cultured water convolvulus, leaf lettuce, pei-tsai, chinese kale and amaranthus etc.; 13 hectares are rice-hull-cultured pea sprout; 1.2 hectares rockwool carnation and 0.5 hectare gravel cultured daylily.

Soilless culture systems used includes : water level regulating system and forced circulating system (deep water type); improved NFT system; root-floating system and rockwool culture.

Yamasaki's n/w formula developed in 1976 for calculating solution composition was adopted or slightly modified to fit for each culture system. The optimum nutrient composition in culture solution for some tropical vegetables are shown below:

	NO_3-N	P	K	Ca	Mg(me/l)
Leaf lettuce	7	1.5	4.5	2.5	1
Water convolvulus	10	4	7	3	2
Muskmelon (spring)	13	4	5.5	7.5	4
(summer)	14	4	7	7	4

Researches needed to be taken into account in the future are :

1.To develop suitable soilless culture systems for fruit vegetables.

2.To establish nutrient compositions and concentrations for the tropic areas.

3.To develop adequate techniques for controlling root diseases, such as *phytophthora, pythium* and *fusarium* spp.

4.To create low cost equipments and installations.

INTRODUCTION

Horticultural crops under structure in Taiwan was established mainly to prevent damage from heavy rainfall in summer and to protect from low temperatures in winter. Consequently, unlike the northern countries where glasshouses and heating systems are standard equipments, less complicated facilities, e.g., tunnel plastic structures or net houses are widely used in Taiwan. Using these structures, high quality and stable yielding horticultural crops have been produced on a total area of 1,560 hectares in 1989. However, the lands under structure tend to have soil problems due to continuous cropping year after year. Soilless culture under these structures was thus developed. The total acreage of soilless culture in Taiwan is estimated to be about 35 hectares in 1990 (Fig. 1). The acreage is expected to increase in the future years.

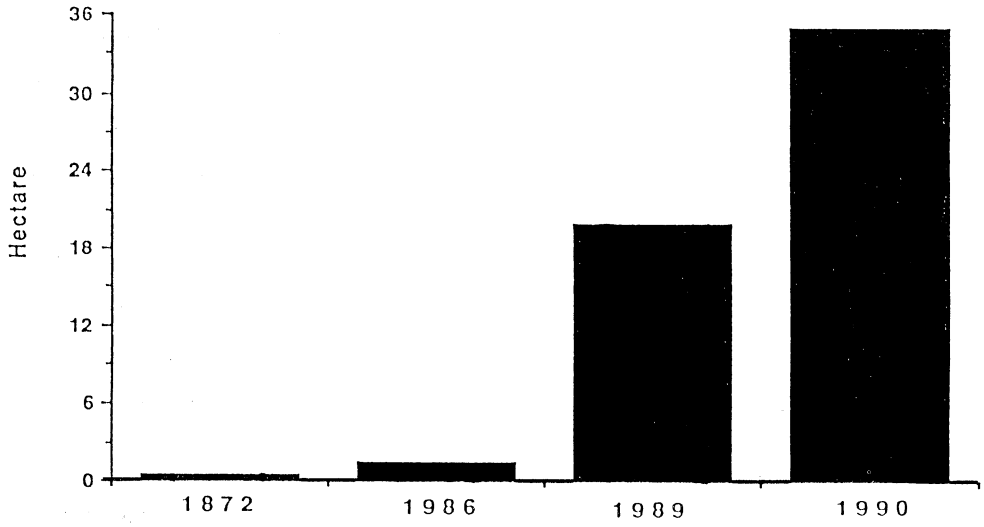


Fig. 1. Chronological change of soilless culture acreage in Taiwan.

COMMERCIAL SOILLESS CULTURE SYSTEMS

Soilless culture in Taiwan can be classified into three major groups, designated as water culture, aeroponics and medium culture, according to the culture medium and application systems (Fig. 2). The primary water culture systems used presently are deep water and NFT cultures. However, there are drawbacks for thses two systems. For deep water culture system. despite the additional pumps applied in the system, the dissolved oxygen can not meet the high oxygen demand of plants in summer. For NFT system, the relatively high variation of solution temperature makes

it difficult to manage, although the cost of this system is relatively low. An alternative system, the capillary-circulating system (Fig. 3), which possess both the advantages of NFT and root-floating systems, is energy-saving and gives good root system, deserves to be paid more attention to. Aeroponics is used only in part of the pea sprout production industry. Gravel culture, the prototype of soilless culture in Taiwan, is now still being used on daylily culture. The majority of the pea sprout producers use milled rice hull and sawdust as growing media. Rockwool, a popular culture system in Europe and Japan, is emerging in Taiwan.

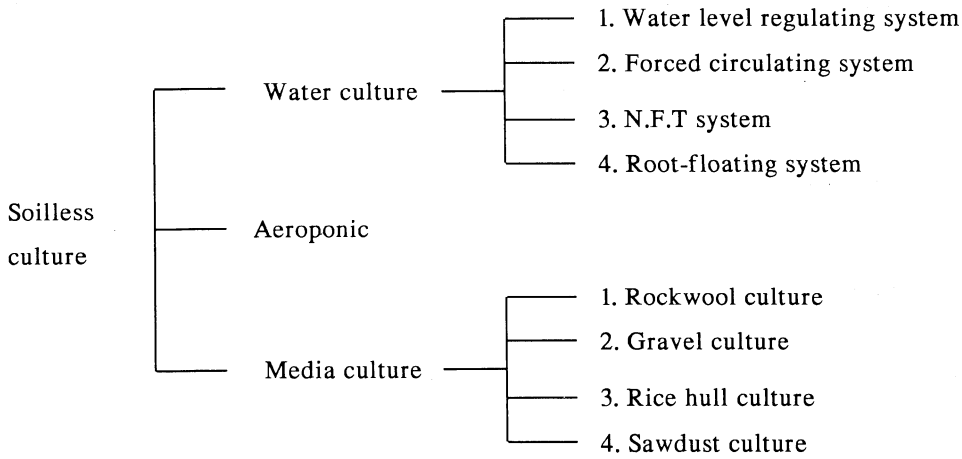


Fig. 2. Soilless culture systems in Taiwan

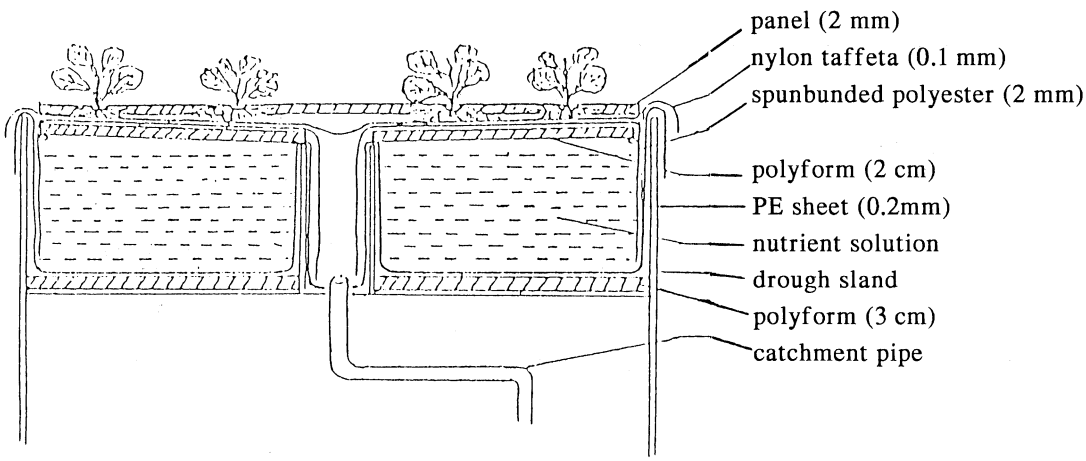


Fig. 3a. Diagram of capillary-circulating hydroponic system

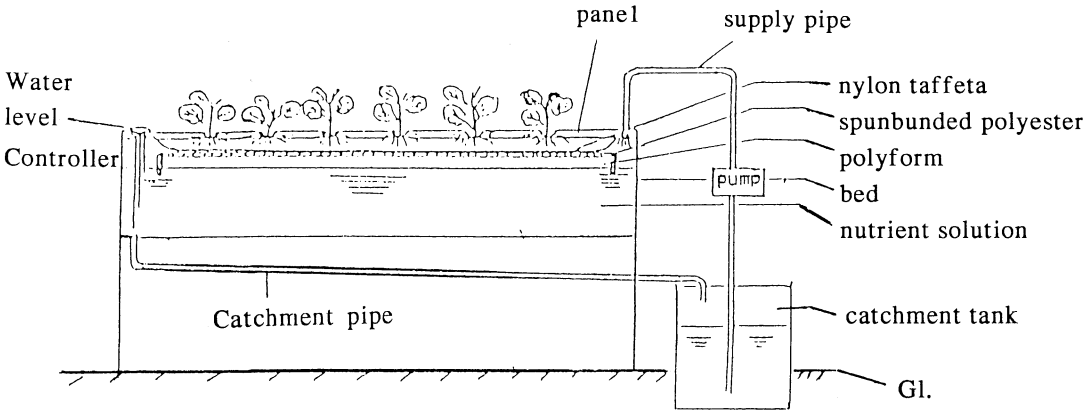


Fig. 3b. Diagram of capillary-circulating hydroponic system

COMMERCIAL-SCALE WATER CULTURED CROPS

Up to the present, more than 95% of the crops grown by water culture systems are vegetables (Table 1). Leaf vegetables, such as pea sprout, water convolvulus, leaf lettuce, pei-tsai, kale, amaranthus and spinach, comprises 90% of the water cultured vegetable. The trend is different from that of the temperate zone where fruit vegetables, e. g. tomato and cucumber, are prevailing. As leaf vegetables are short-termed crops, plants are harvested every 20 to 30 days, about 15 to 20 times a year. Water convolvulus, a perennial crop, can be harvested every 10 to 20 days and more than 24 times a year. This is a system that is close to plant factory (Table 2).

Table. 1. Cultivated crops in hydroponics

Leaf vegetables : amaranthus, chinese kale, leaf lettuce, pea sprout, pei-tsai, spinach, water convolvulus.
Fruit vegetables : cucumber, melon, tomato.
Flowers : carnation.

Table. 2. Harvesting times of water convolvulus grown by root-floating water culture system

Area	Growing period	Growing days	Harvesting times	Yield kg/m^2	Annual yield kg/m^2/year
Kaohsiung	Apr.-Oct.	10-13	17	1.8	43.2
	Nov.-Mar.	18-20	7		
Taichung	Apr.-Oct.	10-14	16	1.54	35.4
	Nov.-Mar.	20	7		
Taipei	Apr.-Oct.	13-15	12	1.65	29.7
	Nov.-Mar.	24-25	6		

COMPOSITION OF NUTRIENT SOLUTION AND ITS MANAGEMENT

The management of nutrient solution follows (or slightly modified) the formula developed by Yamasaki et. al., (1976). The apparent absorption concentration and composition of nutrient solution for some vegetables are listed in Table 3.

The n/w method for calculating solution composition and concentration is also being studied on some tropical vegetables. The following formulas describe the calculation (Fig. 4):

At the beginning a certain amount of nutrient (m) is dissolved in water (a), so that the concentration of the solution is:

$$y=m/a$$

After a period of time, some water (w) and nutrient (n) is lost in the system. The new solution concentration is now:

$$y_1=(m-n)/(a-w)$$

The concentration of water removed can be calculated from the above two equations:

$$n/w=a/w(y-y_1)+y_1 \quad (\text{if } y>y_1)$$

$$\text{or } n/w=y_1-a/w(y_1-y) \quad (\text{if } y_1>y)$$

Due to evaporation the n/w value does not show exactly the water amount absorbed by plant roots, the ratio, however, is valuable in the management of solution concentration. An example is the NO_3-N concentrations and water amount in a leaf lettuce growing solution were 7.5 me/l (y, initial concentration), 600 1 (a, initial water amount) and 7.7 me/l (y_1, final concentration), 124 1 (w, water removed). The n/w value of NO_3-N in water at the end can be calculated as:

$$n/w=7.7-600/124(7.7-7.5)=6.73(me/l)$$

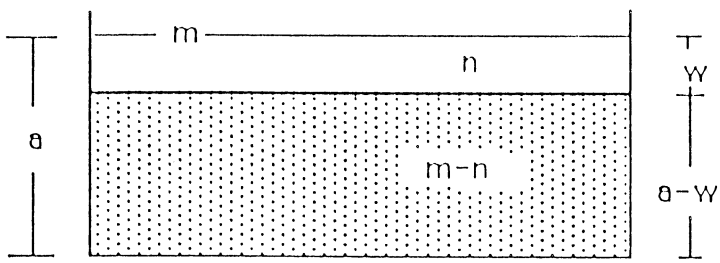
By using this method water convolvulus, leaf lettuce, pei-tsai and melon were studied (Table 4). The formula has also been put into commercial-scaled culture with the results of water convolvulus, leaf lettuce, pei-tsai shown in Fig 5, 6 , 7. The management of culture solution can become easier when EC and pH is kept stable. Optimum n/w value in the culture solution is essential for plants to get balanced growth. From the results achieved so far, it is proved that the concentration and composition obtained from n/w can be used practically.

Table. 3. Optimum n/w of some vegetable crops (Yamasaki. etc. 1976)

Crops(cultivar)	me/l				
	NO_3-N	P	K	Ca	Mg
Melon(Pearl)	13	4	6	7	3
Cucumber(Suyo)	13	3	6	7	4
Tomato(FTUR-3)	7	2	4	3	2
Sweet pepper(Shimofusa)	9	2.5	6	3	1.5
Lettuce(Great lake 366)	6	1.5	4	2	1
Eggplant (F_1 Nagaoka-2)	10	3	7	3	2
Turnip(Kana machi)	14	2	10	4	2

Table. 4. Optimum n/w of some tropical vegetables

Crops(cultivar)	(n/w) me/l				
	NO_3-N	P	K	Ca	Mg
Leaf lettuce(Ta-Chiou)	7	1.5	4.5	2.5	1
Water convolvulus(Chu-yue)	10	4	7	3	2
Earl's melon(spring)	13	4	5.5	7.5	4
Earl's melon(summer)	14	4	7	7	4



Beginning solution concentration $y=m/a$

End solution concentration $y_1=(m-n)/(a-w)$

Concentration of water removed $n/w=a/w(y-y_1)+y_1$

or $n/w=y_1-a/w(y_1-y)$

where m, n are nutrient; a, w are water amount.

Fig. 4. n/w method for calculating solution composition and concentration.

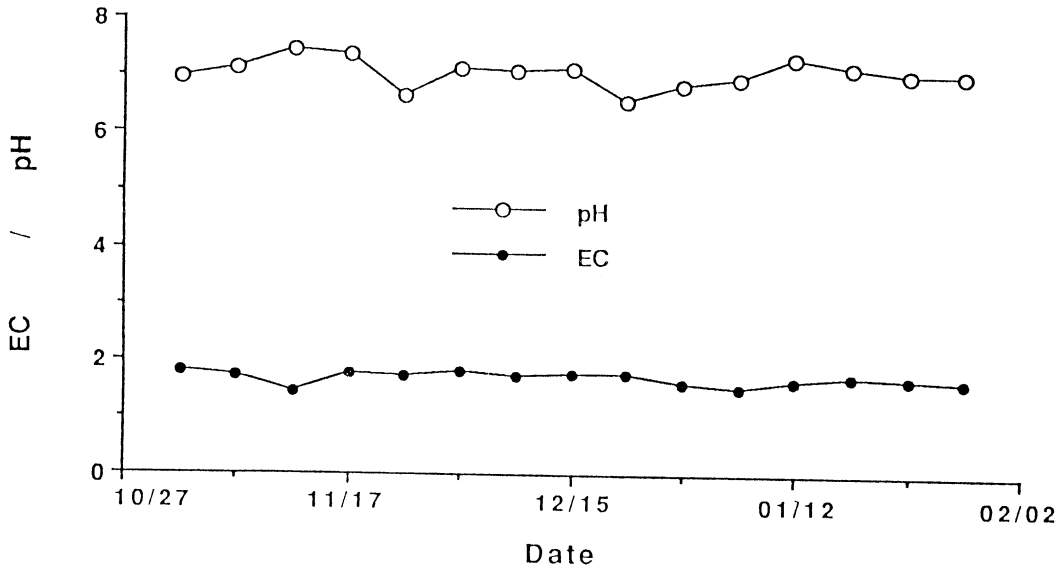


Fig. 5. Variations of pH and EC of water convolvulus grown in winter.

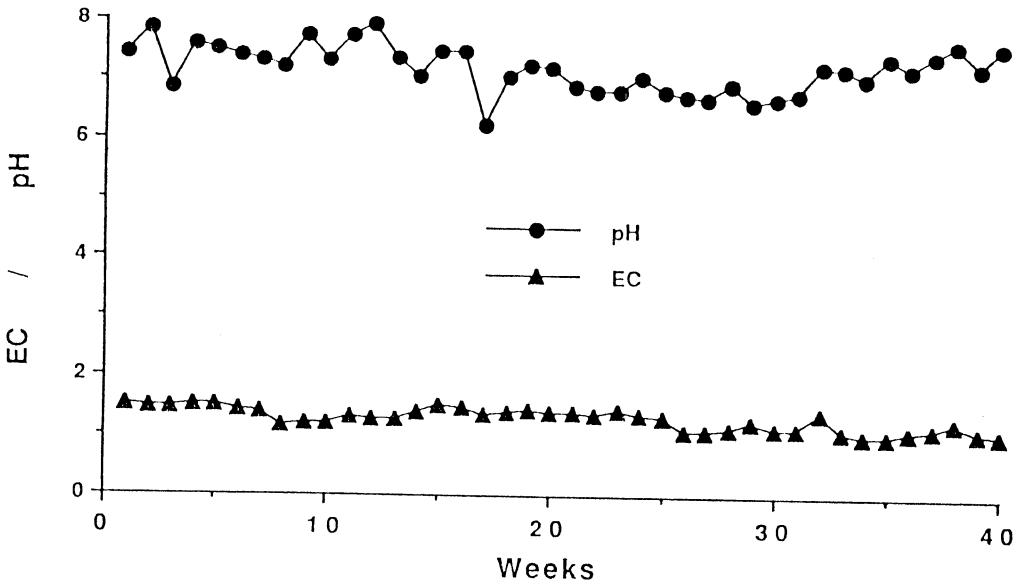


Fig. 6. Variations of pH and EC of leaf lettuce grown in root-floating water culture system

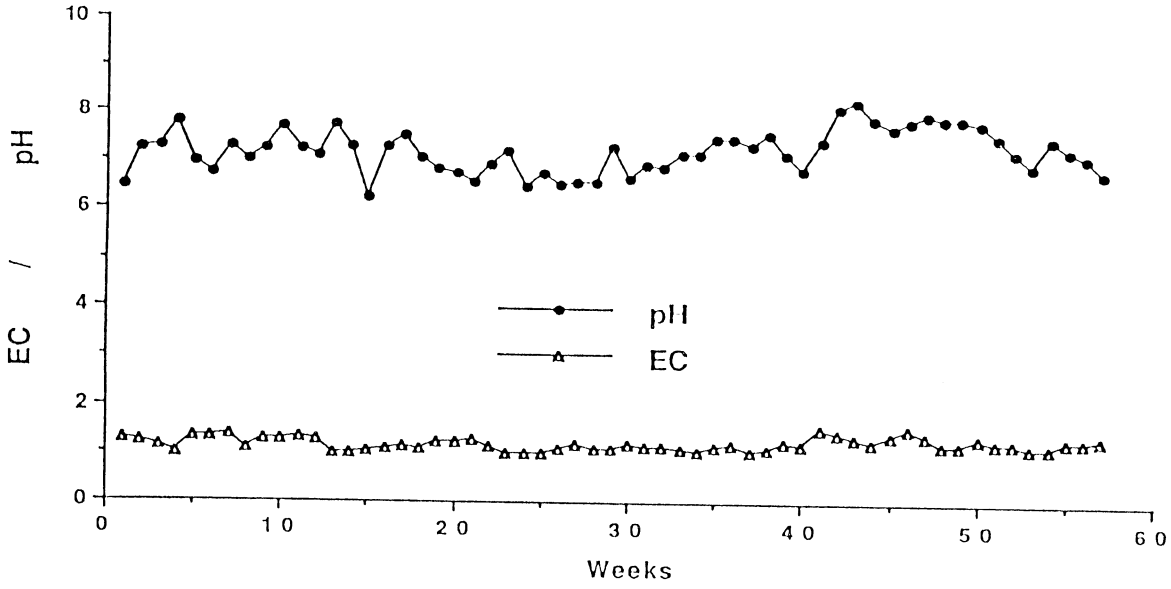


Fig. 7. Variations of pH and EC in the cultural solution of pei-tsai grown by root-floating culture system.

Based on the daily consumption, the two curves of water removal by muskmelon grown in diffrernent seasons are shown in Figure 8 and 9. According to the water removal data, the development of muskmelon can be divided into 4 stages, namely, the vegetative stage, the pollinated stage, the fruit development stage and the fruit mature stage. The quantity of water removed in the growing seasons was recorded the highest in the fruit development stage. The pollinated stage, the fruit mature stage and the vegetative growth stage were the second, third and last, respectively, with regard to water removal. A day/night water removal study by muskmelon plants showed that there was not much difference during the night, while quite different in the day. The amount of water removed per plant in the summer is much higher than in the spring (Fig. 10 and 11).

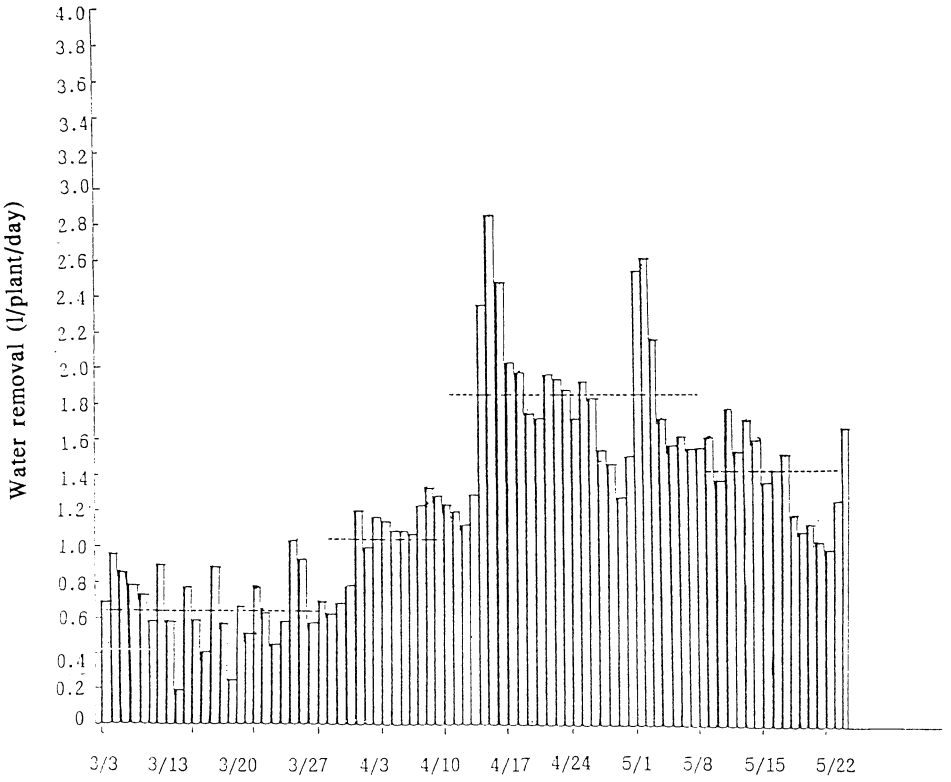


Fig. 8. Water removal by muskmelon grown in spring(1987)

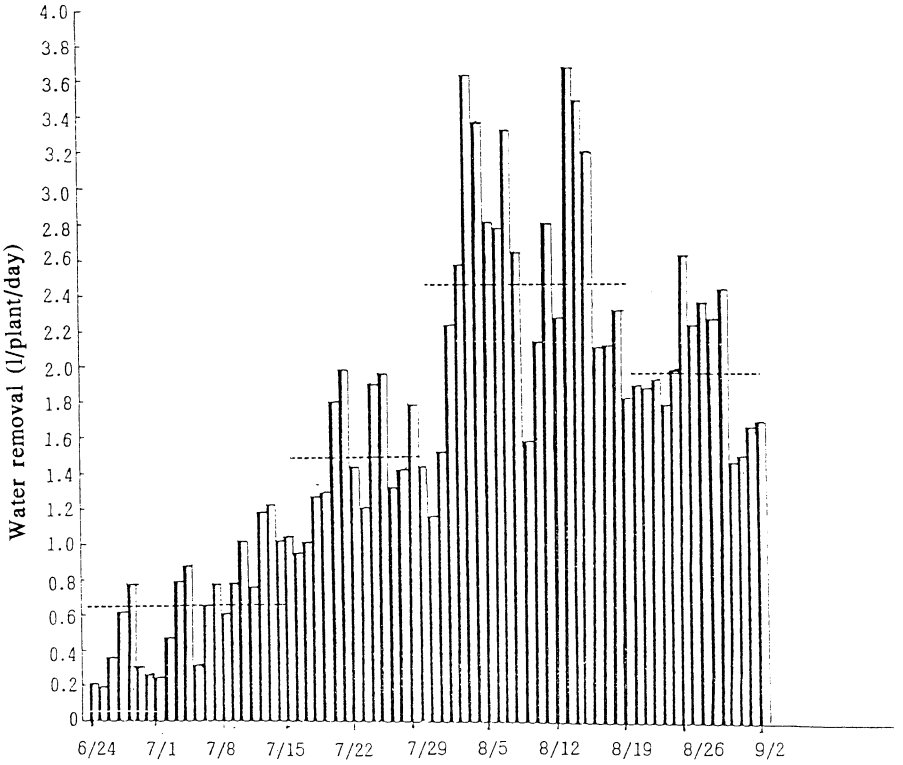


Fig. 9. Water removal by muskmelon grown in summer (1987)

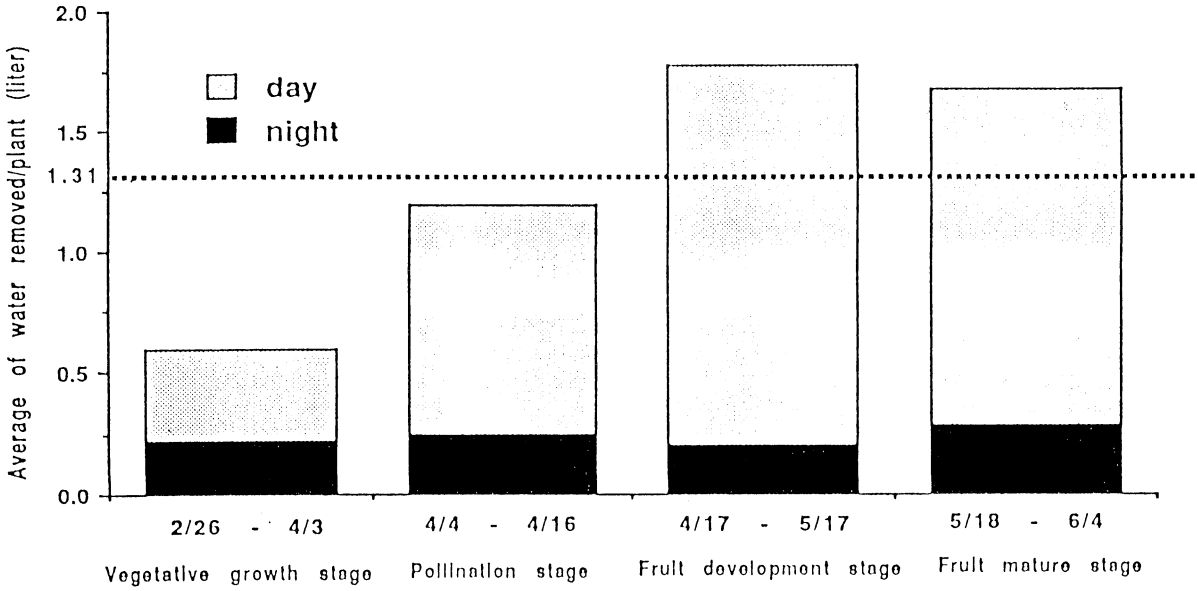


Fig. 10. Water removed by muskmelon grown in the spring of 1989.

PEA SPROUT PRODUCTION

Milled rice hull or sawdust as culture medium, or hydroponics in form of mist-spray are the two soilless culture systems used in pea sprout production in Taiwan. The seeds are first kept at 20-24℃ in the dark for germination and then transferred to 60% shading to commence green color formation. Usually 1.4-1.5 kg pea sprouts can be produced from 1 kg seeds.

Process of pea production

1. Seed selection

Dun pea seed selected by sieve #14

2. Germination

1)Seed soaked in running water for 6-8 hrs.

2)Seedling tray (60 × 30 × 3 cm) filled with rice hull or sawdust as growing medium.

3).Sowing 300-400 g seeds in each seedling tray.

4).Spray with water and keep up high humidity.

5).Keep the trays with seeds at 20-24℃ in darkness for 4 days.

3. Sunshine

1).Seedlings are transferred to greenhouse with 40% light for 4-6 days to develop chlorophyll

and expand the young leaves.

2).Keep spray with water

4.Harvesting

Pea sprouts are harvested at 10-12 cm height about 8-12 days after sawing by machine.

5.Package and storage

Packed in plastic bags and stored at 5℃.

FUTURE NEEDS

1.To develop suitable soilless culture systems for fruit vegetables.

Although there are advantages for growing leaf vegetables, e.g. short growing and cash return cycles, the high labor cost, i.e. more than 60% of the running cost goes to labor for seeding, planting, harvesting and packaging make the industry uncompetitive. It is thus desirable to develop cultural systems for fruit vegetables, such as tomato, cucumber, muskmelon, luffa or bitter gourd, that have long growing season and do not need constant renewal planting and harvesting like the leaf vegetables do in future.

2.To establish nutrient compositions and concentrations for the tropical areas

Despite the well establishment of a variety of nutrient formulas for many crops in the temperate zone, it is still necessary to develop new or modified formulas from those developed ones for tropical areas due to the fact that the crop species, weather condition, i.e., temperature, day length and light intensity, and culture systems in the tropics are different from that of temperate areas. Through the basic studies, the establishment of the nutrient management systems will be able to prevent the drastic changes of the concentration and pH in the solution which is very harmful to the plants and diminish the need of constant solution renewal.

3.To develop adequate techniques for controlling root diseases, e. g., *phytophthora, pythium* and *fusarium,* etc., in the circulated water culture systems.

4.To create low cost equipments and installations.

Although there are many advantages for water culture, the cost for the external structures and internal facilities, such as instruments for automation and others, is still relatively high. To create low cost equipments and facilities is a must for further development of soilless culture.

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台灣蔬菜之無土栽培

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關鍵字：養液栽培、蔬菜、台灣

摘　要

台灣之無土栽培始於1969年。礫耕、水耕於1984年，岩綿耕於1988年開始有經濟生產。目前栽培面積估計約有35公頃。其中水耕約20公頃，以蘿菜、葉萵苣、白菜、芥藍、茼蒿、莧菜等爲主，岩綿耕1.2公頃以番茄爲主，礫耕0.5公頃以金針菜爲主。另有13公頃的木屑或稻殼耕，以生產豌豆苗爲主。

栽培方式可分爲水位調節法、强制循環法、養液薄膜法、浮根法和岩綿法。

養液之組成與濃度，大部分依據或修正山崎等所發表之n/w處方。另下列數種熱帶性蔬菜之配方，經試驗後，訂定如下：

	NO3-N	P	K	Ca	Mg(me/l)
葉萵苣	7	1.5	4.5	2.5	1
蘿　菜	10	4	7	3	2
溫室洋香瓜(春作)	13	4	5.5	7.5	4
(夏作)	14	4	7	7	4

今後尚待加强研究事項：

1.發展適當之果菜類栽培。

2.建立適合熱帶地區養液組成濃度。

3.加强循環式的根部病害防治技術，如*Phytopthora*、*Pythium*、*Fusarium*等。

4.發展較爲低廉的裝置和設備。

討　論

余增廷問：

溫室水耕栽培洋香瓜一株可結四十個果實、番茄一株可結一萬多個果實，請評估一下其經濟效益？

沈再發答：

日本於世界博覽會所展示一株番茄從種植後可連續收獲12,000～15,000個果實。此爲意指作物有此潛力，只要技術上突破。因爲在一個較大的空間，於很長的時間，在環境與養液之控制下，可達到此目的。但此並非爲目前的經濟栽培方式，所以其經濟效益不能估算。相反的以正常之栽培方式，如番茄每十公畝地以水耕或岩綿耕種植約2,500株，每年一作或二作，其產量可達25～30公噸，洋香瓜每十公畝種約2,000株，每株只留一果，每年可3～4作，其果實品質一致，才是正常可行經濟的評估。

賴森雄問：

1.台灣發展水耕之前途如何？
2.利用水耕栽培果菜類蔬菜之前途如何？

沈再發答：

1.水耕爲養液栽培或無土栽培的一種，在此應指養液栽培。台灣之養液栽培僅有5～6年的歷史，由於時間短，技術上仍尚未完全確立。並且因台灣位亞熱帶地區，環境條件與作物種類不儘與溫帶地區相似，有待克服的問題很多，諸如栽培方式，養液之組成濃度……等，仍有待時間考驗與各方面的配合努力。目前爲止約有20公頃之養液栽培面積，另有約近10公頃的豆苗生產。由於可避免連作障害，經營上之設施化使勞力的減輕，並可增加收量提高品質，在土壤栽培不適的地區也可生產。雖然其投資大，養液之緩衝力較小，而仍有病蟲害侵害的危險。但是技術之突破的話，仍有前途的。也許高價的花卉或組織培養種苗生產的結合，種苗工廠的生產方式都是有潛力的。
2.目前台灣仍以短期的葉菜類爲主，葉類除小部份的番茄第一、二位農家之洋香瓜外，尚沒有其他菜葉類。由於菜葉類生產期短，其播種，定植，收穫，包裝等仍需費大量工，所以期待有較長期的果葉類發展。葉菜類只有營養生長時期，期間短較易栽培，果菜類除營養生長外，尚有生殖生長，還有果實的品質問題，所以技術要高，本省有需要發展適合熱帶地區的果菜種類，但並非2～3年的短時間就可一蹴而成，尚有待大家的努力。







Fig. 11. Gravel culture used for day-lily porduction.

Fig. 12. Root-floating system used for water convolvulus production.

Fig. 13. Root-floating system used for muskmelon production.





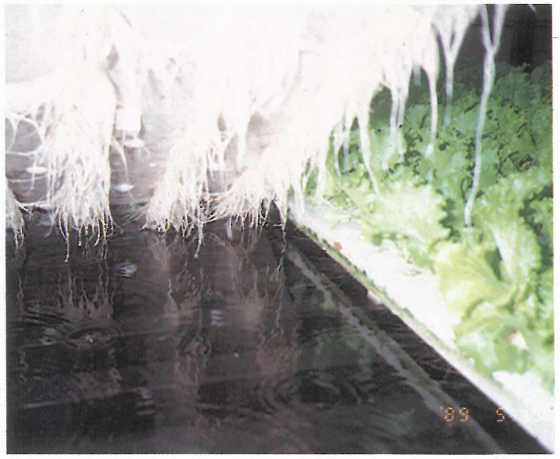


Fig. 14. Rockwool used for tomato production.

Fig. 15. Pea sprout production.

Fig. 16. N. F. T. improved system used for vegetables production.

14

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