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Development of an NFT System of Soilless Culture for the Tropics

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ABSTRAK

Penciptaan satu sistem pengeluaran tanaman tanpa tanah yang berdasarkan Teknik Nutrient Film (NFT) telah dikaji. Jenis longkang politin yang digunakan untuk NFT di rantau-rantau iklim sederhana didapati tidak sesuai untuk iklim tropika panas. Satu rekaan palung tohor yang menggunakan penebat haba didapati berkesan untuk mengawal peningkatan haba dalam zon akar. Tanaman-tanaman muskmelon, sayur-sayuran dan pokok-pokok hiasan telah ditanam dengan berjayanya dengan sistem palung NFT yang diciptakan ini. Sistem ini adalah murah, berekonomi, menjimatkan tenaga buruh dan berkegunaan serbaguna.

ABSTRACT

The development of a soilless crop culture system based upon the Nutrient Film Technique (NFT) was studied. The conventional polythene gullies used for the NFT in temperate regions were found not suitable for the hot tropical climate. An insulated NFT shallow trough design was effective in controlling heat build up in the root zone. Muskmelon, vegetables and ornamental plants were successfully grown with the NFT trough system designed. This system is cheap, economical, labour saving and versatile.

INTRODUCTION

In the soilless production of crops, various systems have been developed. These range from the fairly simple sand culture systems to the elaborate and expensive large-scale commercial systems (Gericke, 1940; Harris, 1970; Sholto Douglas, 1976; Lim, 1982). The large-scale systems have mainly been developed overseas for use within glasshouses in cool temperate climatic zones.

Universiti Pertanian Malaysia (UPM) has successfully set up a large-scale system for the production of various fruit and leaf vegetables (Lim and Wan, 1984). This system, the H-system, involves the use of a large volume of nutrient solution circulated in troughs containing the plants. The adaptation from the cooler temperate environment to the hot local condition was provided by the large volume of nutrient solution circulated and the use of cooling equipment. In Europe and other temperate regions, a system that has found wide application employs the nutrient film technique (NFT) which supplies the nutrient solution to the plant roots in a low volume (Cooper, 1982). This system, besides using less nutrient solution, is also simple to build and relatively inexpensive. In this study, the principle of the NFT was applied to the designing of a soilless cultivation system for use under local conditions. The new system that was designed was also evaluated for use in the production of various crops.

MATERIALS AND METHODS

A study was initially set up to determine the effect of various system designs on the root zone temperature. Following this, the cultivation of various crops was carried out. In one study, the production of muskmelon *(Cucumis melo* L.*)* was compared between the newly designed NFT trough system and the H-system. In another study the production of lettuce was compared between two versions of the NFT trough design and normal cultivation using soil. The cultivation of various vegetables and ornamental plants was also studied using the NFT troughs.

In the study of root zone temperature, several designs of the growing units were compared. These units consisted of the conventional polythene gullies and specially designed, shallow insulated NFT troughs. The polythene gullies were made of 0.125 mm thick black polythene sheets folded into a triangular tent, 25 cm wide at the base, 30 cm high at the apex, 100 cm long and closed at the solution inlet end. Polythene gullies with external surfaces of black or white were compared. The NFT trough were constructed from 2.5 cm thick polystyrene boards and were 25 cm wide by 100 cm long. Polystyrene trough covers with a reflective white polystyrene surface were provided. An internal air space of 2.5 cm height was provided between the cover and the bottom of the trough. Each of these growing units received a continuous film of water flowing from one end down to the other throughout the period of measurement. The maximum and minimum daily temperatures were recorded for a period of 10 days.

In the second study the production of muskmelon was compared between the non-reflective insulated NFT troughs described above and the H-system. A replica of the H-system was constructed and consisted of a deep trough in which nutrient solution up to a depth of 6.5 cm was circulated. In the NFT troughs, seeds were planted in 5 cm rockwool cubes while in the H-system they were shown directly on to 2 cm gravel chips contained in small lattice baskets suspended in the nutrient solution. Plants were spaced 50 cm apart in both systems. Holes of 5 cm square were made in the polystyrene covers to insert the rockwool cubes or to suspend the lattice baskets.

In another study the production of lettuce *(Lactuca satiua* L.*)* using 2 types of NFT trough designs were compared to that grown on a soil mixture made up of 3 parts loam and 1 part sand. The NFT troughs compared consisted of the earlier designed trough with an air-space of 2.5 cm between the cover and the bottom and a redesigned trough in which the cover was placed flush the bottom of the trough over the film of nutrient solution (no air-space). The lettuce plants were spaced in a triangular arrangement 20 cm apart. The lettuce grown in the soil mixture was watered at least twice daily with the same nutrient solution used for the NFT troughs. The plants were harvested 40 days after sowing.

Using the non-reflective NFT troughs, various other vegetables and an ornamental were grown experimentally. These included fruit vegetables such as long beans *(Vigna sesquipedalis* L.*)*, Chinese kale *(Brassica alboglabra* L.*)* mustard greens (*B. chinensis* L., *B. rapa* L., *B. juncea* L.), lowland cabbage (*B. oleracea var. capitata* L.), cucumber (*Cucumis sativus* L.), hot pepper *(Capsicum frutescens* L.*)*, and marigold *(Tagetes species)*.

RESULTS

Root Zone Temperature

The polythene gullies were found to absorb a large amount of heat particularly when they were exposed directly to the sun. During the day the temperature within the polythene gullies rose up to a recorded maximum of 54°C. The temperature within the polythene gullies was influenced by the colour of the external surface. The black polythene gully was significantly hotter inside than the white surface polythene gully (Table 1). The polystyrene NFT troughs were significantly cooler than the two types of polythene gullies. The NFT trough with a reflective top was also significantly warmer than the trough with the non-reflective white top. No difference was found in the temperature within the NFT trough with the non-reflective white top and the outside maximum air temperature.

The minimum night temperatures of all polythene gullies and the polystyrene NFT troughs were significantly lower than the minimum air temperature. The coolest growing unit was that of the NFT trough with the non-reflective white top.

Muskmelon Experiment

The muskmelon plants grown in the polystyrene NFT troughs grew normally and bore fruits *(Plate 1)*. The growth rate of the plants as indicated by the number of opened leaves after 6 weeks were no different from that grown in the H-systems. The development rate of the fruits was also similar (Table 2). The mean fruit weights were 1.20 kg for the NFT trough and 1.07 kg for the H-system. However, the difference was not significant. The brix measurements for the fruits were similar for both the systems and averaged about 13 percent. Although no difference was evident in the productive capacities of the NFT trough system and the H-system, it was observed that the stems of the muskmelon grown in the H-system became brown and dry from the collar upwards toward

TABLE 1
Maximum and minimum temperature within various NFT growing units

Type of NFT growing units	Temperature (deg. C)	
	Maximum	Minimum
Black polythene gully	49.5	24.0
White polythene gully	40.4	23.2
Reflective polystyrene trough	37.9	24.5
Non-reflective polystrene trough	35.6	23.1
External shade air temperature	35.9	25.8
L.S.D. (P = 0.05)	1.71	0.92

TABLE 2
Comparison between muskmelon grown in the H-system and the NFT trough system

Character measured	H system	NFT trough	t statistic
Leaf number	26.2	27.3	0.740 ns
Fruit circumference (cm)			
Week 2	20.7	24.0	0.959 ns
Week 3	30.7	32.8	1.121 ns
Week 4	36.1	37.0	0.533 ns
Week 5	38.8	39.4	0.300 ns
Week 6 (harvest)	41.3	42.4	0.598 ns
Fruit flesh thickness (cm)	3.35	3.33	0.078 ns
Fruit weight (kg)	1.07	1.20	1.016 ns
Brix (%)	13.1	13.2	0.128 ns

ns = not significantly different at P = 0.05.

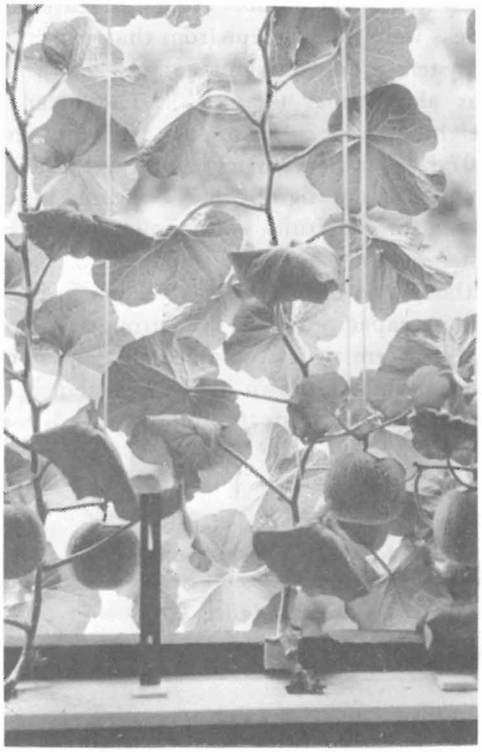

Plate 1

fruit maturation *(Plate 2)*. The stems of the muskmelon plants grown in the NFT troughs remained a healthy green.

Lettuce Experiment

The lettuce crop was harvested 42 days after sowing. The NFT troughs produced superior yields compared to those grown on soil (Table 3). The soil grown lettuce were very slow in their growth right from the seedling stage and were still relatively small compared to the lettuce plants grown in the NFT troughs at harvest *(Plate 3)*. There was no difference found between the two types of NFT troughs. The presence or absence of an air-space above the root mat did not significantly influence the yield.

Vegetable Production

The vegetables grown using the insulated NFT troughs are given in Table 4. In all cases the growth of the vegetables was very rapid after the initial seedling stage. All these vegetables were

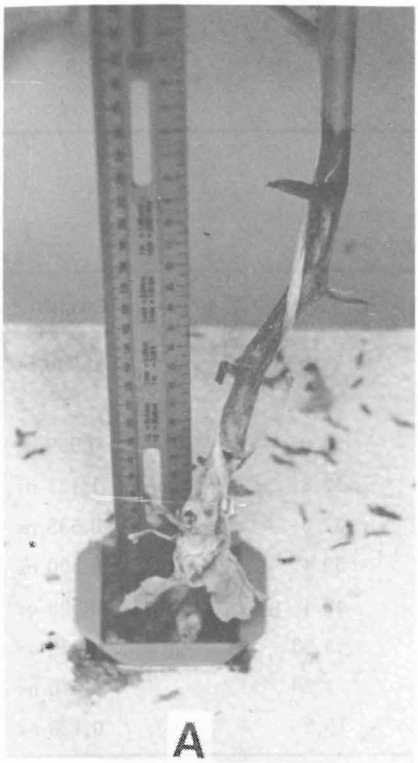

Plate 2A

Plate 2B

TABLE 3
Mean plant weight of lettuce produced from NFT troughs and soil

Cultivation method	Fresh weight (g)	S.E.
NFT trough, raised cover	264.8	45.32
NFT trough, flush cover	294.4	42.90
Soil mixture	12.92	3.12

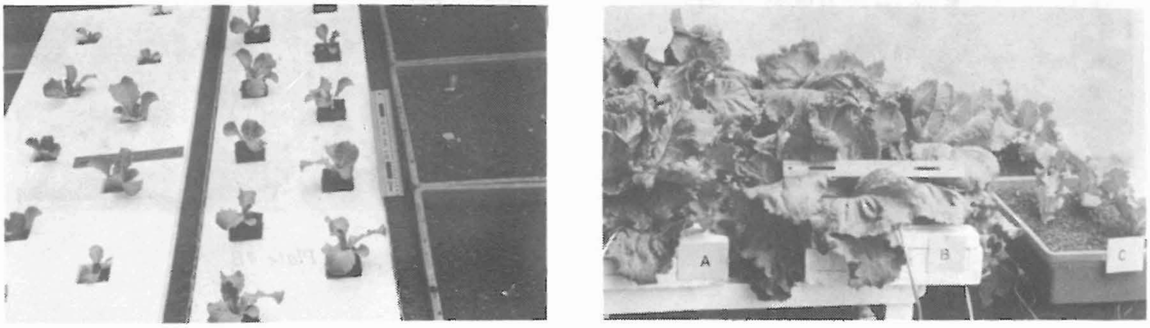

Plate 3

TABLE 4
Production of vegetables using the NFT trough system

Vegetable	Trough area (sq. m.)	Days from sowing	Yield (kg)
Chinese kale	0.5	40	3.81
Mustard greens:			
B. chinensis	0.5	40	2.90
B. juncea	0.5	45	6.14
B. rapa	0.5	25	1.97
Lettuce	1.0	45	10.11
Cabbage (head)	0.5 (10 plants)	40	6.42
Cucumber	0.5 (6 plants)	40 – 55	3.72
Long bean	0.5 (10 plants)	45 – 70	2.55
Hot pepper	0.5 (6 plants)	60 – 90	2.50

to 45 days after sowing. The mustard green, *B. rapa* was earliest. It began flowering 25 days successfully grown to maturity using the NFT trough system *(Plates 4* and *5)*. Many of the leafy vegetables were ready for harvesting between 40 after sowing and had to be harvested. Among the leafy vegetables grown, the high yielders were the mustard, *B. juncea* and lettuce. The cabbage grew vigorously producing compact heads up to 1.15 kg after 40 days. The fruit vegetables also grew rapidly.

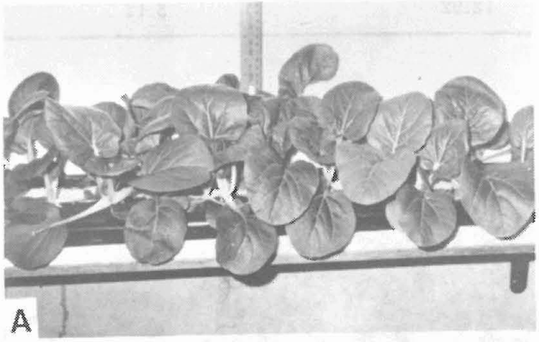

Plate 4A

Plate 4B

Plate 4C

Plate 4D

Plate 4E

Plate 4F

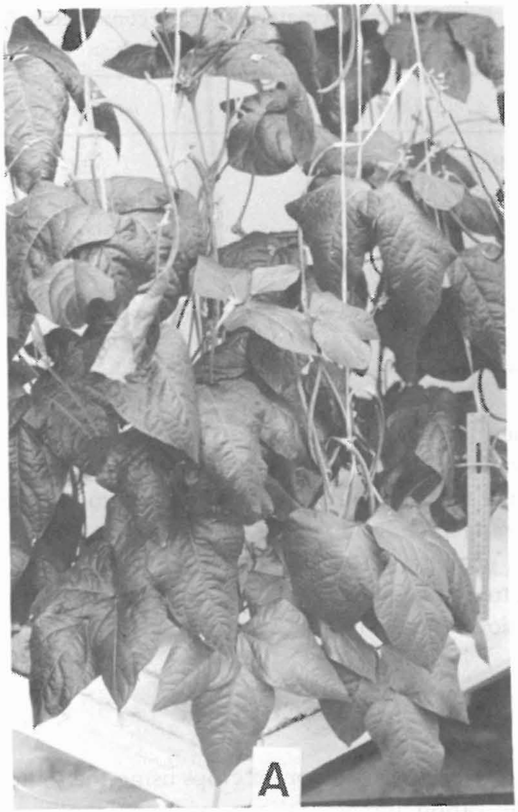

Plate 5A

Plate 5B

Plate 5C

Ornamental

The NFT trough was also suitable for growing ornamental plants. Marigold plants took 45 days from seeding to the first bloom. The flowering period was extended and continued over one month *(Plate 6)*. Due to the size of the plants some plant support was necessary.

Labour Requirements

In the cultivation of the various crops, the NFT troughs were found to be easy to use and required very little labour to plant, maintain and clean for reuse. Seeding was very rapid as the seeds were sown directly on to the rockwool with the help of a pair of forceps. Depending upon the crop, sowing a trough of one meter long only required less than 5 minutes. Maintenance consisted of nutrient replenishment and

Plate 6

pH control of the nutrient solution and the normal activities such as the provision of plant supports, pruning or pollination as required by the particular crop. After harvesting, the cleaning up of the NFT troughs was very rapidly carried out. It was only necessary to remove the polystyrene covers and roll up the root mat for disposal. The troughs remained clean and could be used for planting another crop immediately *(Plate 7)*. Reseeding of a new crop merely consisted of replacing the polystyrene cover, inserting fresh rockwool cubes and planting the seed. In the studies, no sterilization of the system was carried out and the various crops grown did not suffer any adverse effect.

Construction Costs

The cost of constructing the NFT trough system is low when compared to the various commercial systems available locally and abroad. All the materials used for construction were readily available locally. The actual cost would depend on the design and layout of the system. For an arrangement given in *Fig. 1* the cost for the basic set up for an area of 100 square meters is estimated to be about $950 ringgit excluding installation expenses (Table 5).

Plate 7

TABLE 5

Estimated cost of materials for the construction of an NFT trough system for 100 sq. m area

Material	Amount ($)
Polystyrene NFT troughs	450
Piping, tubing, etc.	150
Pump and electrical parts	200
Nutrient solution tank	150
Total	950

DISCUSSION

In the production of crops using the soilless cultivation method, the provision of optimum conditions to the root system of the plants is very important. As most soilless production units are located above the ground, they are directly exposed to solar radiation particularly when the plants are still small. This can lead to the rapid increase of temperature within the growing units. For most crops the optimum root zone temperature is between 25 to 30°C (Cooper, 1982). Therefore, the maintenance of the root zone temperature as close as possible to the optimum is necessary.

The study has shown that the polythene NFT gullies that are being widely used in temperate soilless crop production system are not suitable for use in the tropics. The high daytime temperatures within them are well beyond the optimum root zone temperature for crop production. Although the white coloured polythene gully is cooler than the black polythene gully by about 10°C, the average maximum temperature of 40°C is still too high for seedling establishment and good plant growth. Under local conditions where a high intensity of solar radiation is experienced, the simple polythene gully would not be suitable. The use of polystyrene boards in the construction of NFT planting troughs has successfully reduced the heat build up. The plain white polystyrene trough was the most effective in preventing heat build up within the root zone. With this type of growing unit, the root zone temperature was the same as the shade air temperature. No further benefit was derived from having a reflective surface for the polystyrene NFT troughs. In fact, due to the heating up of the reflective layer, the temperature within the trough was slightly elevated above that of the air temperature.

The production of various crops was successfully carried out using the polystyrene NFT troughs. Although the maximum temperature recorded for these troughs was about 35°C before planting, there was no apparent detrimental effect on the seedling establishment as well as later plant growth. This was evident for the yields obtained in the various studies. The continuous flow of the nutrient solution film could have provided some localised cooling effect as the temperature of the nutrient solution in the storage tanks was not more than 30°C during the day. Further reduction in the temperature could have resulted from evaporative cooling around the rockwool cubes and the surface of the solution film. In addition, during the latter stages of crop growth the plants themselves provided ample shade over the NFT troughs. With leafy vegetable, the entire trough was covered by the leaves when the plants grew up.

The production of muskmelon by the H-system at UPM has been very successful (Lim and Wan, 1984). The NFT troughs that were designed were found to produce equally well when compared to the H-system. Although the muskmelon crops were similar with both systems, there was some indication of healthier plants with the NFT trough system. The rotting and drying up of the basal portion of the stems were only found on plants grown in the H-system. It is possible that the deep solution of the H-system may have reduced the oxygen supply to the roots thus affecting the health of the basal portion of the plants. In the NFT troughs the thin film of solution and the air-space provided allowed for maximum gaseous interchange relative to the volume of solution present, thus providing adequate oxygen supply for healthy root and stem development.

The production of vegetables with the NFT troughs is easily carried out. When compared to the conventional growing method using soil, the soilless NFT trough system proved to be superior. Yields of lettuce grown on soil and in the NFT troughs differed greatly even though the soil grown crop was given the same nutrient solution daily. Apparently the soil was unable to provide optimum conditions for the root system and good plant growth. With the NFT troughs there were no restrictions on the development of the plant roots and since the nutrient film was always present, the plants sufferred no moisture or nutrient deficits.

The NFT troughs can be easily modified for the growing of various crops. When changing from one crop to another it is only necessary to modify the location of the planting holes in the cover. In the experiment, multiple-hole covers were used. When planting a particular crop, rockwool cubes were inserted in the holes that aproximate the desired planting distance. The extra holes that were not required were plugged up with a piece of polystyrene. The same troughs could therefore, be used over and over again for many types of crops ranging from muskmelon to leafy vegetables and ornamentals. In contrast, the H-system required different plant containers when changing from crops such as the fruiting vegetables to the leafy vegetables. In addition, the H-system also required gravel of a smaller size for the leafy vegetables. All these modifications were not necessary with the NFT trough system, thus further reducing costs.

The various cropping studies carried out has shown the labour-saving potential of the NFT system. The labour requirement is minimal particularly for seeding and preparation of the troughs for reuse. Labour cost is one of the major expenses in the soilless production of crops (Lim and Wan, 1984). Therefore the rapid cleaning of the system would reduce labour requirements considerably particularly when compared with other soilless systems requiring a solid medium to support the plants. The solid medium inevitably become covered with algae growth and requires laborious cleaning before it can be reused. With the NFT troughs, the covers prevent algae growth within the troughs and the rockwool cubes are discarded after each crop. The convenience and simplicity in the use of the NFT trough are significant advantages especially when large scale application of the soilless culture technique is contemplated.

The potential of the NFT trough design is evident. Its productive capabilities are no less than that of the successful H-system of soilless production used locally. In the studies, the system has shown definite advantages when compared to the H-system. These advantages, besides those already mentioned in respect of labour savings also include the low construction costs and capital outlay. In addition the use of a small volume of nutrient solution can result in considerable savings in the costs of nutrient salts necessary especially when compared to systems using deep solution. The NFT troughs are also suitable for large-scale commercial crop production or for use on a small-scale as a roof-top or balcony garden for the hobbist.

CONCLUSION

The nutrient film technique can be successfully applied to the cultivation of crops in the tropics. However, the conventional polythene gullies used in the temperate countries cannot be used locally because of the high internal temperature resulting from the intense solar radiation. The insulated NFT trough that was designed in this study, effectively controlled the heat build up in the root zone.

The NFT troughs have been found to be versatile and capable of grówning various vegetable and ornamental species successfully. The use of the NFT trough is easy with low labour requirements. Planting and replanting can be rapidly carried out.

The NFT troughs are also easy to construct. The parts necessary for the construction are locally available and the capital outlay for the system is extremely small when compaed to other locally available systems.

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