Development of Energy-Saving Hydroponics Systems without Requiring Electricity

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Abstract

We developed a new hydroponic system that did not require the use of electricity. In this system the irrigation of culture solution was achieved by gravity action, and the supply of nutrients for crops by capillary action. We were able to obtain high yields of tomato, sweet potato, melon and Chinese mustard using this system.

Additional key words : Chinese mustard, melon, sweet potato, tomato

Introduction

Since the area under problem soils such as saline, acid sulphate and sandy soils is continually expanding in the tropics and subtropics, hydroponics may be one of the alternatives for crop production in such regions. However, the usual hydroponic systems so far developed utilized a large quantity of electricity, and their operation was complex, requiring the chemical analysis of nutrients. The development of low-cost and low-input hydroponic systems is, therefore, a challenge to agriculturists[1, 2, 3]. Sakuma and Masaki used porous tips as culture material for hydroponics and succeeded in producing crops easily[4]. We are currently developing and testing hydroponic systems that do not require electricity using porous tips.

Materials and Methods

The new hydroponic system (Fig. 1 and Plate 1) consists of a culture solution tank, a tank for adjusting the liquid level (hereafter referred to as LT) and a culture bed. The position of the culture solution tank is higher than that of LT and the culture bed. Both tanks are connected by a tube. LT is adjacent to the culture bed. This tank is fitted with a floating bulb system (Plate 2) used in toilets to adjust the water level to a fixed position. Bowltap (Toto Co. Ltd., Kitakyushu, Japan) is the name given to this system in Japan. The culture

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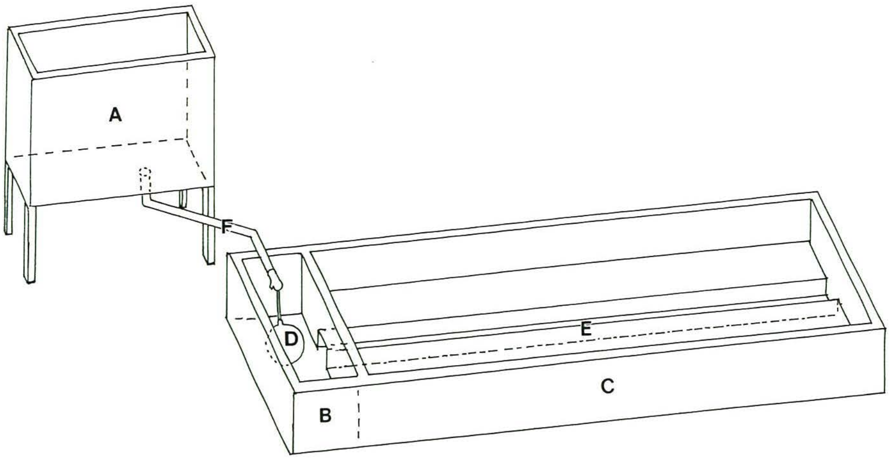

Fig. 1. Illustration of the new hydroponic system
A : culture solution tank, B : tank for adjusting the liquid level, C : culture bed, D : floating bulb system, E : longitudinal canal, F : connecting tube.

Plate 1. New hydroponic system
A : culture solution tank, B : tank for adjusting the liquid level, C : culture bed.

Plate 2. Floating bulb system in the tank for adjusting the liquid level
Arrow : End of canal.

bed has longitudinal canal at the bottom which is connected to LT. We used an expanded polystyrene bed covered with a vinyl sheet as the culture bed. The culture bed consists of a liquid-absorbing sheet, a root barrier sheet and the culture medium. The liquid-absorbing sheet (Toyobo Co. Ltd., Osaka, Japan) is made of polyester fiber that can absorb water well. The root barrier sheet (Toyobo Co. Ltd., Osaka, Japan) is made of polyester, too. This sheet is permeable only to the solution but not to roots, because the sheet fabrics is very dense. The culture medium, which is made of porous polyvinyl alcohol (PVA)

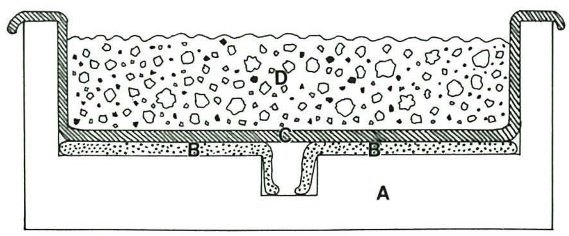

Fig. 2. Illustration of a cross section of the new hydroponic system
A : culture bed, B : liquid-absorbing sheet, C : root barrier sheet, D : culture medium.

material in chip form (Kanebo Co. Ltd., Osaka, Japan), is placed above the sheet.

Tomato (cv. Kyouryoku Beijyu), melon (cv. Earls Seinu) and Chinese mustard plants were cultured using this system in a net house. The average temperature was 22.4°C during the culture period at the JIRCAS Okinawa Subtropical Station on Ishigaki island. Tomato and melon were planted at a distance of 60cm each after raising of seedlings in a pot with PVA material. Chinese mustard seeds were sowed directly on the culture medium (15 cm spacing).

The culture solution was prepared by diluting "Otsuka Ekihi solution" (Otsuka Chemicals Co. Ltd., Osaka, Japan) with water. The basic composition of the culture solution is given in Table 1.

We used this solution mainly, but sometimes we used the original diluted solution when the crop was at young stages of growth.

Results and Discussion

The culture solution is stored in the culture solution tank at first. The culture solution moves continuously and automatically by gravity action from the culture solution tank to LT, because the position of the culture solution tank is higher than that of LT. The level of the culture solution is fixed at a suitable position in LT by using the floating bulb system, and the canal of the culture bed is filled with the culture solution. For raising the level of the culture solution from the canal, it is necessary that the absorbing sheet be sufficiently wet at first. After the absorbing sheet becomes sufficiently wet, the level of the culture solution increases automatically from bottom of the bed through the absorbing sheet, root barrier sheet and culture material by capillary action.

Table 1. Composition of the culture solution (ppm)

Ammonium N	33	CaO	230	Fe	2.7
Nitrate N	233	MgO	60	Cu	0.03
P_2O_5	120	MnO	1.5	Zn	0.09
K_2O	405	B_2O_3	1.5	Mo	0.03

EC 2.6 mS/cm, pH 5.5

Tomato plants grew well in this system (Plate 3) and tomato fruits could be obtained 3 months after the seedling stage. One plant produced 28 fruits (7th influorescence) and the average weight of tomato fruit was 200 g.

Melon grew well (Plate 4), and required 90 days from the seedling stage until harvest. The average yield of melon fruit was 1800g and sugar content was 14.8%. The yield was comparable to that of conventional culture on the ground.

Chinese mustard grew well (Plate 5) and could be harvested one month after the seedling stage. The roots of all the crops formed mats on the root barrier sheet.

Plate 3. Hydroponically grown tomato

Plate 4. Hydroponically grown melon 80 days after seedling stage

Plate 5. Hydroponically grown Chinese mustard 28 days after seedling stage

The amount of the culture solution decreased with the growth of crops. In one day, 25 liter of the solution was used in one bed with 25 melon plants, while 3 liter evaporated from one bed without plants. It appears that the amount of culture solution supplied corresponded to the consumption use of the crop. The amount of solution absorbed in one day depended on the weather conditions, and it increased on fine days compared with cloudy days. For example, a melon plant, 150-cm tall, consumed 1700 ml culture solution per day on fine days, while on cloudy days the amount of culture solution consumed by melon plant was 500 ml. A total of 60 liter of nutrient solution was used for each melon plant.

Using this system, it was also possible to produce tomato plant and sweet potato tubers under field conditions[5, 6]. In other hydroponic systems, tuber enlargement was reduced probably due to the low pressure of compaction. In our system, however, the culture medium (PVA) is assumed to provide enough pressure to achieve tuber enlargement.

No additional equipment was necessary to run this system, except for the renewal of the culture solution when it was depleted in the culture solution tank. Therefore, the operation was very convenient after the system was set up. Although the optimum concentration of the culture solution needs to be determined for each crop, the hydroponic system developed in the present study may be suitable for application to many crops.

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省エネルギー型養液栽培装置に関する試験

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摘　要

養液栽培は土壌から離れた栽培方法であるため，酸性土壌，塩類集積土壌などの不良環境地域においても作物栽培が可能である。今回，我々は多孔体チップを用いた電力を使用しない新しい養液栽培装置を作成した。この養液栽培装置は養液タンク，液量調節タンク，栽培ベッドから構成される。養液タンクの位置を液量調節タンクの位置より高くすることで養液は重力によって自然に供給された。液量調節タンクにボールタップを付けることで液面を一定に調節した。養液調節タンクとベッドの底面の溝とは水平につながっており，栽培ベッドの底面の溝の中の養液量も一定となった。栽培ベッドには底面の溝から養液を吸収されるようにするため吸水マットを敷き，その上に防根シートを被せ，栽培培地として多孔体で親水性のポリビニルアルコールのチップを入れた。一度培地を濡らした後はベット上部の培地まで毛細管現象で養液が供給された。

この装置を用いトマト，サツマイモ，メロン，チンゲンサイを栽培した。作物生育中は，養液タンクの養液が減少し空に近づいた場合に新しい養液を補給した。養液タンク中の養液の減少量は作物の成長とともに増加した。養液の減少量には培地面からの自然蒸発の分を含むが，作物が吸収した養液量がほとんどであるとすると，草丈1.5ｍのメロンでは１日に晴天の日は1700ml，曇天の日には500mlの養液を吸収したことになった。

キーワード：チンゲンサイ，メロン，サツマイモ，トマト

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