Melon Production Using Four Hydroponic Systems

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Abstract

Melon plants (*Cucumis melo* L.) were grown using four hydroponic systems of which three used the closed circulating nutrient solution system by deep-flow technique (DFT) but with different designs of growth containers namely, the triangular, double-U and U-shaped PVC containers. The fourth used an open fertigation system with plants grown in polybags containing coconut fiber (coco peat) as the growth medium. Comparisons were made among the systems in terms of nutrient solution electrical conductivity (EC), growth, yield, fruit total soluble solids (TSS) and leaf nutrient composition. Irrigation was applied based on crop transpiration (ET). Electrical conductivity of nutrient solution in triangular containers tended to be higher than the other systems especially during reproductive growth. The EC of nutrients in the solution was lowest with the double-U shaped among the different types of containers. Melon fruit fresh weight was highest with the double-U shaped containers compared to the other systems. However, no significant difference of fresh fruit weight was observed between polybags and triangular containers On the other hand, fruit quality as measured by the TSS (Brix 16) was highest in the U-shaped system compared to the other systems. The N, P, K, Ca and Mg content of leaf tissue of plants in the U-shaped container was also the highest compared to the other systems. During vegetative growth, Leaf Area Index of plants grown in polybags was significantly higher than in the other systems. In conclusion, there is evidence that the superior performance of U and Double-U shaped system was due to better aeration and temperature control.

INTRODUCTION

Soilless cultivation of melons (*Cucumis melo* 'Premai') has been developed in Malaysia because of the market demand for better fruit quality and also quantity. Soilless culture requires frequent irrigation and high fertilization rates and, when used with free drainage (open system) can result in possible contamination of ground and surface water sources. The problem of water and nutrient loss has been dramatically limited through the development of closed growing systems (Siddiqi et al., 1998; Van Os, 1999; Avidan, 2000).

Increase in root mass in the NFT trough creates anaerobic condition, subsequently causing root death (Cooper, 1979). Redesign of NFT single Gully to W shaped can provide enough water availability and oxygen for each part of split root system in W shaped (Cooper, 1976). However, there is a lack of information about how the melon plant responds to split root system using DFT. The objective of this work was to compare four soilless culture systems for growing melon in Malaysian climate condition.

MATERIALS AND METHODS

This experiment was conducted in a polyethylene 500 m^2 greenhouse situated at the Batu Arang farm of Taman Perindustrian Green World Genetics Sdn, K.L. Malaysia. Melon Seeds of 'GWG1' hybrid were germinated in vermiculite on 13 March 2011. At the two true-leaf stage (10 days after seedling) melon plants were transplanted into four systems of planting which were the treatments in this experiment:

1. Fertigation system: polybags (Ø 17 cm, h 19 cm) containing 3.4 L of a cocopeat.

2. U-shaped troughs: one whole PVC tube (200 mm) was cut into the two U-shaped troughs (6 m long, 0.20 m wide)
3. Double U-shaped troughs: two pieces of U-shaped PVC was attached to form a double U- shaped trough.
4. Triangular containers: one sheet of polyethylene was folded to form a triangular trough.

For treatments number 2, 3 and 4, the troughs were placed 40 cm above the ground with a slope of 1.5% and oriented N-S. The seedlings were placed in polybags and all troughs with plant density of 2.1 plants/m^2. These planting systems were replicated three times in a randomized complete block design.

Plants were fertilized with the following complete nutrient solution: 944 mg $Ca(NO_3)_2 \cdot 4H_2O$, 114 mg $NH_4H_2PO_4$, 492 mg $MgSO_4 \cdot 7H_2O$, 32.5 mg EDTA-Fe, 2.86 mg H_3BO_3, 2.13 mg $MnSO_4 \cdot 4H_2O$, 0.22 mg $ZnSO_4 \cdot 7H_2O$, 0.08 mg $CuSO_4 \cdot 5H_2O$, and 0.02 mg $(NH_4)6Mo_7O_{24} \cdot 4H_2O$. The target pH and EC were adjusted to 5.5 and 2.5 mS/cm, respectively. In all tanks, in order to prevent undesirable changes of the ion concentration, the solutions were adjusted for mineral concentration weekly and completely renewed every 2 or 3 weeks.

Irrigation was based on solar radiation and was performed whenever cumulative solar radiation outside the greenhouse RGo reached 3350 and 1600 kJ m^{-2}. The amount of water applied E (Fig. 2) in kg m^{-2} was calculated using the relation below:

$$E= \frac{T}{(1-D)} \qquad (1)$$

where: D is the drainage rate and T is the crop transpiration in kg m^{-2} estimated (Fig. 1) using the relation below:

$$T = \beta RGo \qquad (2)$$

where the coefficient β is given by

$$\beta = k_c \, \delta \, \alpha/\lambda \qquad (3)$$

where: k_c is the crop coefficient; δ is the greenhouse cover transmission to solar radiation, α is the evaporation coefficient and represents the energy of solar radiation that is converted to heat through transpiration and λ is the latent heat of vaporisation of water in kJ kg^{-1}.

The drainage rate D was maintained near 60%, in order to maintain optimal conditions of water supply to the plants. The greenhouse cover transmission to solar radiation δ was calculated as the mean ratio of inside to outside solar radiation equaled with 0.31. The maximum and minimum *kc* values of melon crops was measured 1.1 and 0.4, respectively (Caudal et al., 1985), while the evaporation coefficient α was taken equal to 0.6, as is usually considered for greenhouse crops (Baille, 1999).

Whenever the values of solar radiation outside the greenhouse *RGo* reached 3350 and 1600 kJ m^{-2} the amount of water was measured based on data given above for the values k_c (of 0.4), δ (of 0.31) and α (of 0.6), equaled to 0.5 and 0.2, respectively.

Measurement

Greenhouse air temperature in °C, incoming and outside solar radiation in W m^{-2} were recorded by means of a weather station (WatchDog, Model 2700), located in the middle of the greenhouse. Nutrient solution temperature in °C and EC in mS/cm, were measured with a multiple sensor (Hanna Instruments, Model HI-98311). Plant measurements were conducted two times at 25 and 85 days after sowing (DAS) during the experiments from 19 July until 30 October 2011. Three plants per treatment were removed at the two growth stages and their leaf area index (LAI-2000 Plant Canopy

Analyzer from LI-COR) and leaf nutrient composition (N, P, K, Ca and Mg) were recorded following the technique described by Novosamsky et al. (1983). A complete block design was used to compare four hydroponic systems. The SAS software was used for the statistical analysis of the data, and results were analysed by ANOVA at the level of statistical significance of $P<0.05$.

RESULTS AND DISCUSSION

Leaf Area Index (LAI)

Figure 3 shows the total LAI of melon plants grown in polybags, U, double U and triangular shaped containers during the measurement. The values of LAI observed in the plants grown in polybag containers were significantly higher than those observed in plants grown with triangular containers. However, at 85 DAS there was no significant difference between polybag, U and double U shaped containers possibly due to a shoot pruning for all plants.

Well-developed leaf area accompanied with good irrigation condition would increase transpiration rate and consequently it causes to convert part of solar energy into the latent heat. In the greenhouse a high value of LAI enhances the canopy and stomatal conductance (Katsoulas et al., 2002) and it consequently affects air temperature and vapor pressure deficit especially in the hot weather conditions.

Electrical Conductivity (EC) of Nutrient Solution

Figure 4 shows the EC of nutrient solution measured during the study. The mean values of EC of solution extracted from polybags and triangular containers were higher than those observed for the EC with U and double U shaped containers. However, there was no significant difference between the EC values of nutrient solution in both U and double U shaped containers. The mean value of EC observed in polybags and triangular containers were 0.8 and 1 mS/cm, respectively.

Solution Temperature

The temperature of solution circulating in triangular containers was higher than the other containers. This could be attributed to the fact that the materials used for triangular (polyethylene), U and double U shaped (PVC) are different. There was no significant difference between the temperature of solution in polybags, U and double U shaped containers. In general, root zone temperatures above 28°C may seriously impair uptake and root growth so temperatures outside this range should be avoided (Bar-Yosef, 2008). In the hot weather condition, temperature of solution increases due to solar radiation and aerial temperature. Root zone temperatures are highly influenced by daily variations in soilless systems rather than soil systems (Kafkafi, 2001) but possibilities for accurate control of root temperature are more easily carried out in soilless cultures than in soils systems (Olympios, 1999), through cooling or heating systems.

Leaf Nutrient Content

Figure 6 shows the leaf nutrient content of melon crops measured at 25 DAS was affected by the four different containers. The results revealed that N, P and K mean values of leaf tissue of melon grown in polybags, U and double U shaped containers were higher than those reported in melon plants grown in triangular containers. However, there was no significant difference between N and P value of polybags, U and Double U containers. De Pinheiro Henriques and Marcelis (2000) found a strong decrease in dry matter production of lettuce (*Lactuca sativa* L.) with decreasing rate of N supply, which was accompanied by an important decline in LAI. In agreement with our results, we observed a reduction in LAI values of melon grown in triangular containers due to decreasing N uptake by the leaves.

Ca, K and Mg contents of melon leaf observed in U shaped containers were higher than the other containers. However, there was no significant difference between the Mg content of melon leaf grown in polybags, double U and triangular containers.

Fruit Fresh Weight

As shown in Figure 7, the fruit fresh weight of melon grown in double U was the highest with 2.48 kg/plant, but there was no significant difference between the fruit yield of melon grown in U and double U containers. The superiority of U and double U shaped containers over the other two may have been attributed to the greater space for plant root growth which could increase N uptake surface for melon crops. On the other hand, high amount of N application can stimulate the vegetative growth at the expense of fruit yield (Mills and Jones, 1979; Hartz and Hochmuth, 1996).

Fruit Total Soluble Solids (Brix)

Figure 8 shows that the Brix mean values of melon fruit grown in U shaped container was higher than those observed in polybags and triangular containers. However, there was no significant difference between the Brix values of melon fruit grown in polybags and triangular containers. The Brix value of fruit in U and double U containers were 16 and 14%, respectively. High proportion of K in the nutrient solution (14.2 vs. 3.4 meq L^{-1}) increased fruit dry matter, total soluble solids content and lycopene concentration of tomato (Fanasca et al., 2006) and also from our results it appears that the higher Brix observed in U shaped containers was due to higher K uptake by melon plants (Fig. 6).

CONCLUSIONS

Significant reduction of LAI that contribute to lower fruit fresh weight occurred in triangular containers. Melon grown in U and double U containers had higher LAI and consequently showed higher fruit fresh weight and quality. The EC of solution in triangular and polybags containers was higher than the EC in U and double U-shaped containers, indicating that plants in the former were not able absorb enough nutrients in those containers probably due to higher solution temperature compared to U and double U containers. The superior performance of U and Double-U shaped system was due to better aeration and temperature control.

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Figures

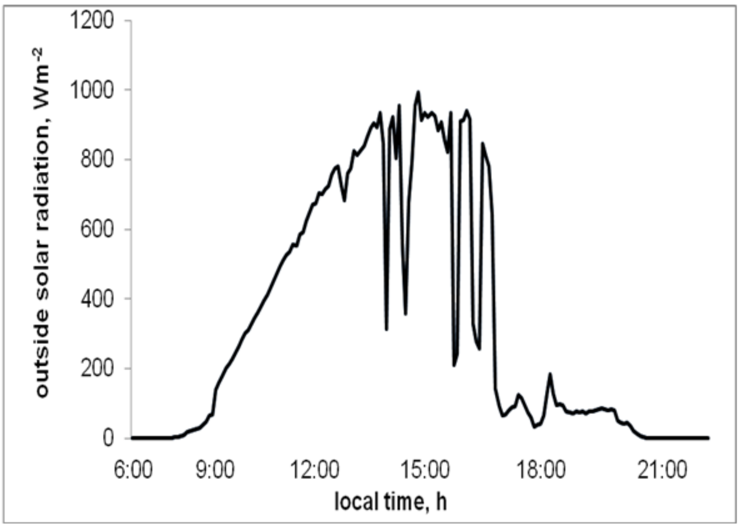

Fig. 1. Outside solar radiation in, W m^{-2} and time of day during versus time of day during 19 July 2011.

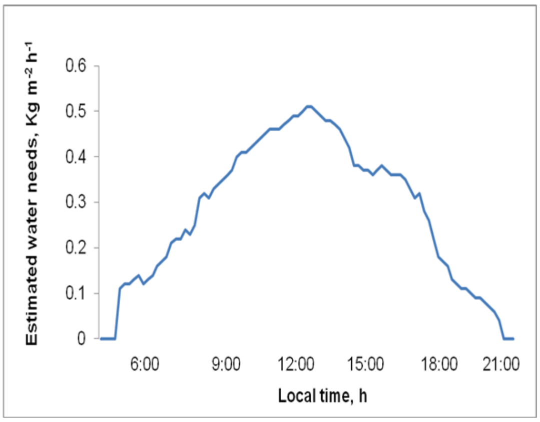

Fig. 2. Water needs E in kg m^{-2} h^{-1} of a melon crop, calculated using estimations of transpiration rate.

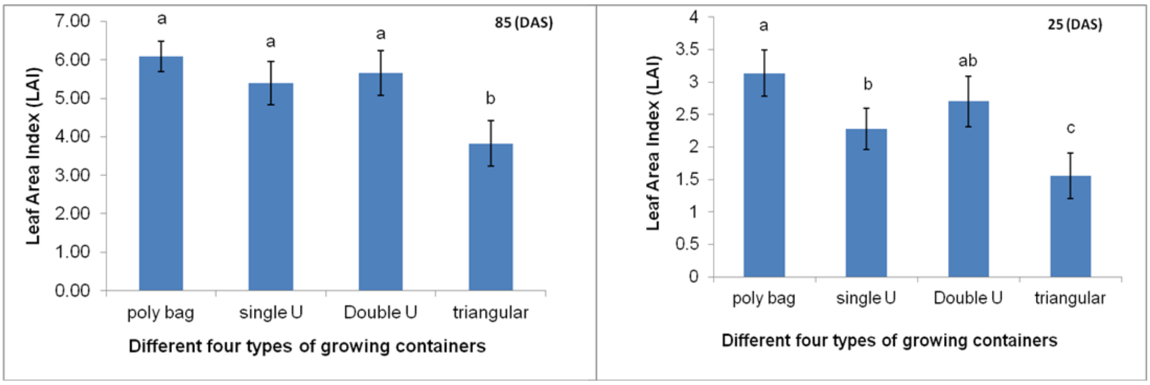

Fig. 3. LAI of melon plants grown in four hydroponic systems at 25 and 85 days after sowing. Error bars represent standard deviation of values and bars with the same letter are not significantly different (LSD 0.05).

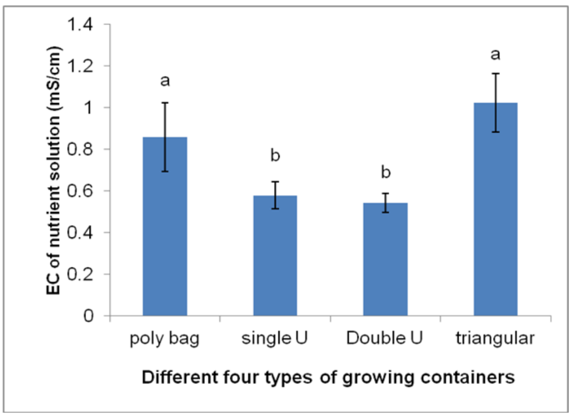

Fig. 4. Electrical conductivity (EC) of nutrient solution compared in four hydroponic systems. Error bars represent standard deviation of values and bars with the same letter are not significantly different (LSD 0.05).

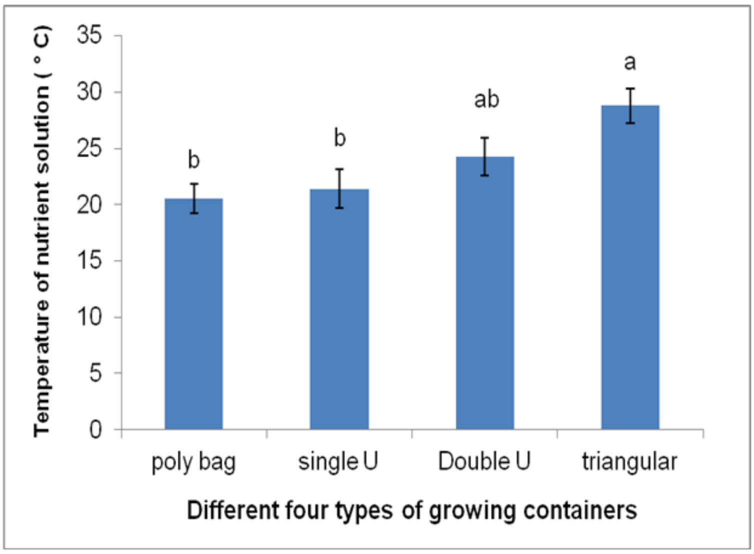

Fig. 5. Temperature of nutrient solution compared in four hydroponic systems. Error bars represent standard deviation of values and bars with the same letter are not significantly different (LSD 0.05).

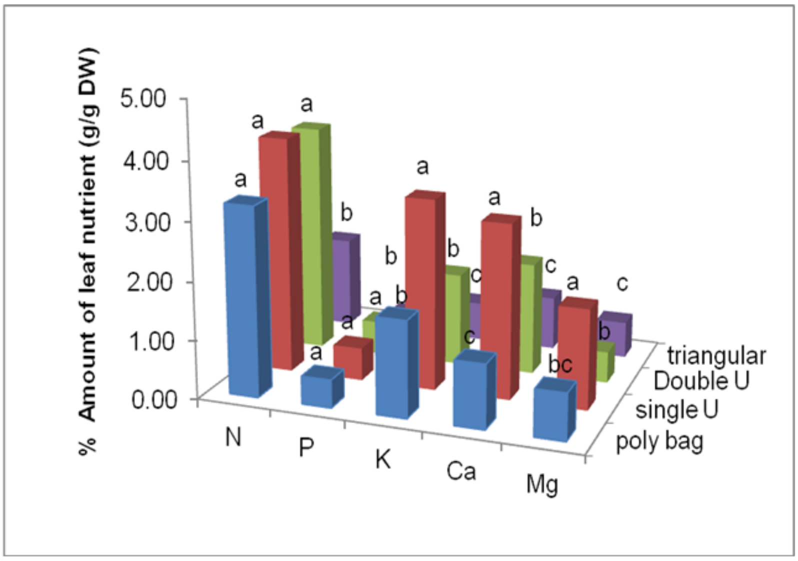

Fig. 6. Leaf nutrient content in, g/g dry weight of melon leaf tissues grown in different hydroponic systems. Bars with the same letter are not significantly different (LSD 0.05).

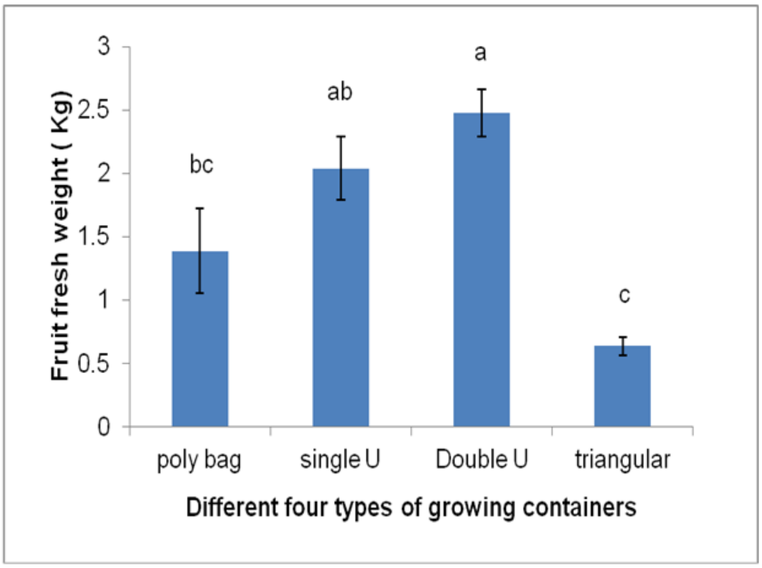

Fig. 7. Fruit fresh weight of melon crop responded to four types of growing containers. Error bars represent standard deviation of values and bars with the same letter are not significantly different (LSD 0.05).

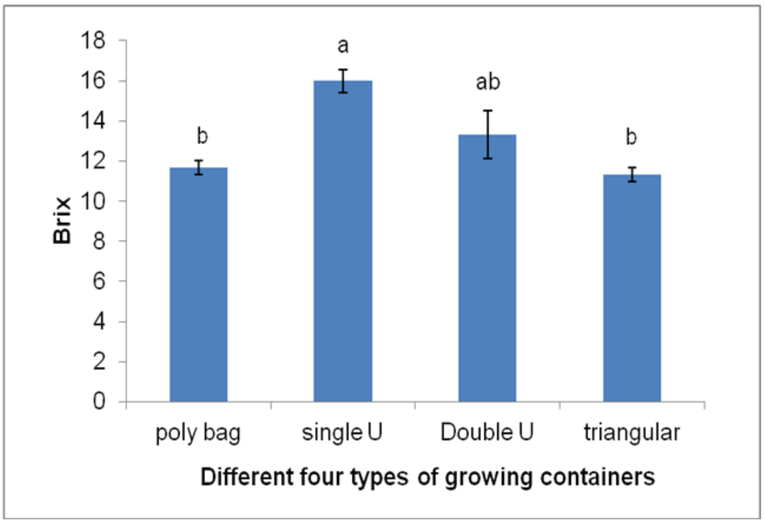

Fig. 8. Total soluble solids (Brix) of melon crop responded to four types of growing containers. Error bars represent standard deviation of values and bars with the same letter are not significantly different (LSD 0.05).