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Effects of Low Irradiance on Growth, Water Uptake and Yield of Tomatoes Grown by the Nutrient Film Technique

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ABSTRAK

Kajian terhadap pengaruh radiasi terhadap perkembangan tanaman tomato telah dijalankan menggunakan teknik nutrien cetek. Tanaman didedahkan kepada min radiasi harian 14.7, 8.5, 3.3 dan 0.87 MJ m^{-2} $hari^{-1}$ yang terhasil melalui penggunaan teduhan. Radiasi tinggi (14.7 dan 8.5 MJ m^{-2} $hari^{-1}$) menunjukkan peningkatan luas dan berat kering daun, berat kering batang dan akar. Pokok yang berada di bawah teduhan mempunyai suhu persekitaran 5 °C lebih rendah dari yang berada di bawah cahaya tinggi. Pengambilan air dan kandungan nutrien pada amnya rendah pada pokok yang berada di bawah teduhan. Hasil yang tertinggi diperolehi pada radiasi 14 MJ m^{-1} $hari^{-1}$ Pokok yang berada dibawah paras radiasi kurang dari 8.5MJ m^{-1} $hari^{-1}$ gagal membentuk buah.

ABSTRACT

A study was carried out on the effects of irradiance on growth and development of tomatoes grown using the Nutrient Film Technique(NFT). Plants were exposed to mean daily irradiance levels of 14.7, 8.5, 3.3 and 0.87 MJ $m^{-2}day^{-1}$ achieved by using different levels of shade. High irradiance (14.7 and 8.5 MJ $m^{-2}day^{-1}$) increased leaf area and dry weight, root and stem dry weight compared to the plants grown under lower irradiance. Plants under shade were up to 5 °C cooler than those under high irradiance. Plant water uptake and leaf nutrient concentrations in the leaves were generally lower in shaded plants than those in full sun. The highest fruit production was obtained with an irradiance of 14. 7 MJ m^{-2} day^{-1}. Plants grown under 3.3 and 0.87 MJ m^{-2} day^{-1} failed to fruit.

INTRODUCTION

Horticultural crops in Malaysia are mainly grown in the open. Vegetables grown by this method are vulnerable to changes in weather conditions and can result in crop failure. Soilless culture systems were developed as an alternative to provide some control over the local environment. However, this system requires plants to be grown within some kind of shelter which can protect the plants and the nutrient solution from rain while allowing for maximum light transmission. Plant microclimates are altered by different types of rainshelter(Mohd Razi 1991; Yeoh 1991) and the choice of rainshelter material determines the amount of radiance available. The basic features governing the choice of a rainshelter are: penetration of radiant energy, elimination of condensation, high strength and low costs. The benefits of increasing light intensity for the development of tomato plants during winter months in the temperate region has been reported elsewhere (Boivin *et al.* 1987; MacAvoy and Janes 1989). However, there are reports indicating that plants need an adequate level of shade for optimum growth and yield particularly under conditions of high solar radiation and temperature (Rylski and Spigelman 1986; El-Aidy *et al.* 1990). In general, the light requirements for hydroponic grown plants are not well understood particularly in the tropics. This study was undertaken to determine optimum light level for tomatoes grown in NFT - trough system. The effect of irradiance on microclimate was also studied.

MATERIALS AND METHODS

Four-week old tomato plants (*Lycopersicon esculentum* Mill var Fireglow) were grown in the NFT - trough system (Lim 1985) in a glasshouse with a day temperature of 33 ± 4.5°C decreasing to a minimum night temperature of 23°C. The treatments consisted of irradiance of 14.7 MJ m^{-2} day^{-1} (full sun), 8.5 MJ m^{-2} day^{-1}, 3.3 MJ m^{-2} day^{-1} and 0.87 MJ m^{-2} day^{-1} achieved by using a sunscreen. The total shortwave radiation was determined by using Delta T Device solarimeters attached to microvoltmeters. The plants were supplied with a nutrient solution containing the ion concentrations given by Cooper (1979) with electrial conductivity maintained between 2.4 - 2.6 mmhos. The terminal growth of the plants was restricted to the three above the third fruiting truss. Six plants were grown in each of the NFT-troughs, representing one replicate, with one nutrient solution tank per replicate (Jarret and Charter 1981). The experiment was conducted in a completely randomized design with six replicates.

Plant height and diameter were recorded weekly before the experiment was terminated. At harvest, the leaf area was determined with an automatic leaf area meter, and dry weight of the leaf, stem and root recorded. Fruits were harvested at the orange to red stage; and the number of fruits and the fresh weight were recorded. Fruit diameter of all the fruits harvested was determined using a Vernier caliper. Fruits were also sampled for total soluble solids determined by means of a hand refractometer. Plant water uptake was determined by measuring water loss from the catchment tank of the NFT-trough system. Shoots were analyzed for N,P,K,Ca and Mg using the procedure described by Husni *et al.* (1990).

RESULTS

Vegetative Development

Plant height increased significantly ($P<0.05$) when irradiance was reduced from 14.7 MJ m^{-2} day^{-1} to less than 8.5 MJ m^{-2} day^{-1}. Stem diameter, leaf area and dry weight reduced significantly ($P<0.05$) with diminishing irradiance (*Figs. 1, 2a* and *2b*). The plants grown under the lowest irradiance weighed about 18% less in dry weight than those subject to 14.7 MJ m^{-2} day^{-1} irradiance. Plants grown under the lowest irradiance had thinner leaves than those which had increased irradiance. Similar reductions in the dry weight of stem and roots were observed in plants which had decreasing irradiance (*Fig. 2b*).

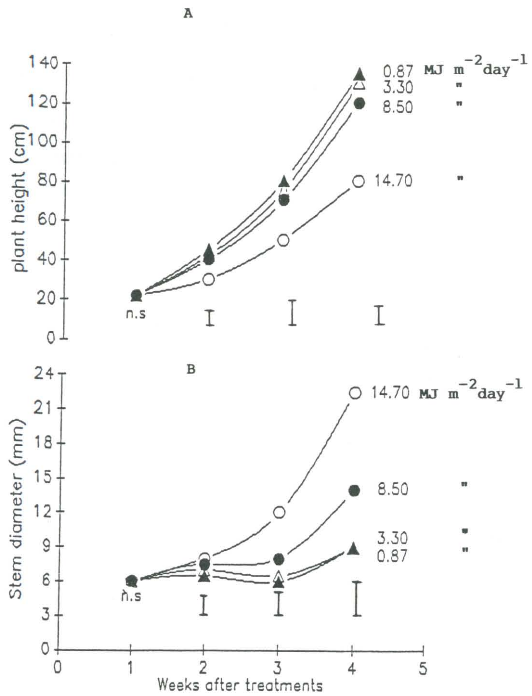

Fig. 1: Plant height (A) and stem diameter (B) as influenced by different irradiance level. (MJ m^{-2} day^{-1}). Bars epresent LSD 5%. Means of 6 plants

Plant Microclimatic Changes

Fig. 3 illustrates the prevailing air temperature within the plant canopy influenced by irradiance levels. Shaded plants were up to 5 °C cooler than those in the full sun. In contrast, there was little effect on the relative humidity which ranged from 82% to 42% RH in the control and between 75% to 43% in plants with the lowest irradiance levels.

Plant Water Uptake

Fig. 4 shows the mean daily plant water uptake and the diurnal changes of plant water uptake recorded after 26 d of plants exposed to the treatments. Plant water uptake was 42%, 68% and 72% greater in the control than it was in plants lower irradiance, of 8.7, 3.3 and 0.87 MJ m^{-2} day^{-1}, respectively. Plant water uptake remained the lowest under irradiance at the 3.3 and 0.87 MJ m^{-2} day^{-1} after 0830 hrs (*Fig. 4a*).

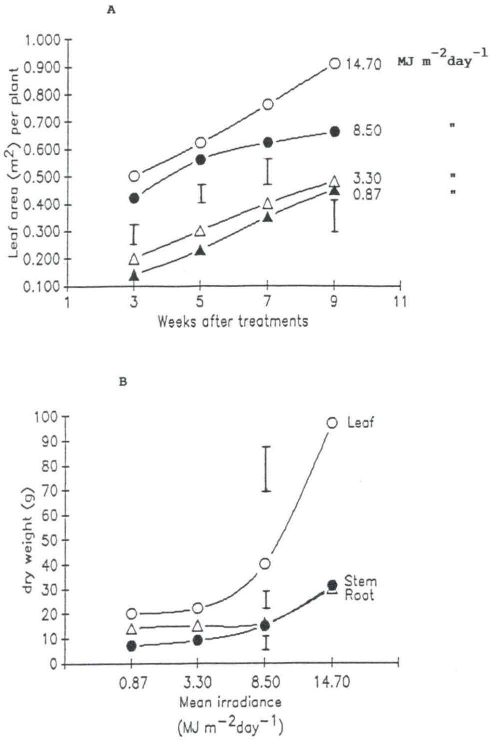

Fig. 2: *Leaf area (A), leaf, stem and root dry weight (B) as influenced by different irradiance levels.*
A: Bars represent LSD 5% at different irradiance levels. (MJ m^{-2} day^{-1})
B: Bars represent LSD 5% for leaf, stem and root at different irradiance levels

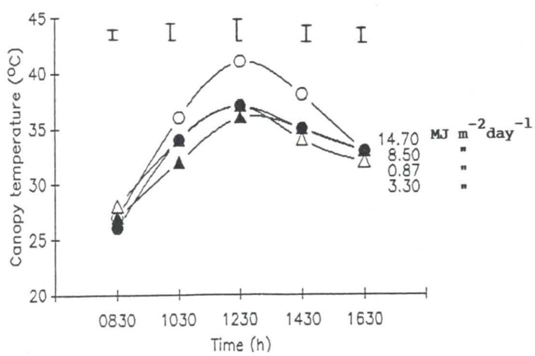

Fig. 3: Changes in canopy temperature as influenced by different irradiance levels (MJ m^{-2} day^{-1}). Bars represent LSD 5%

Leaf Nutrient Concentration

The concentrations of N, P, K, Ca and Mg decreased with diminishing irradiance treatments compared with the controls. Plants with

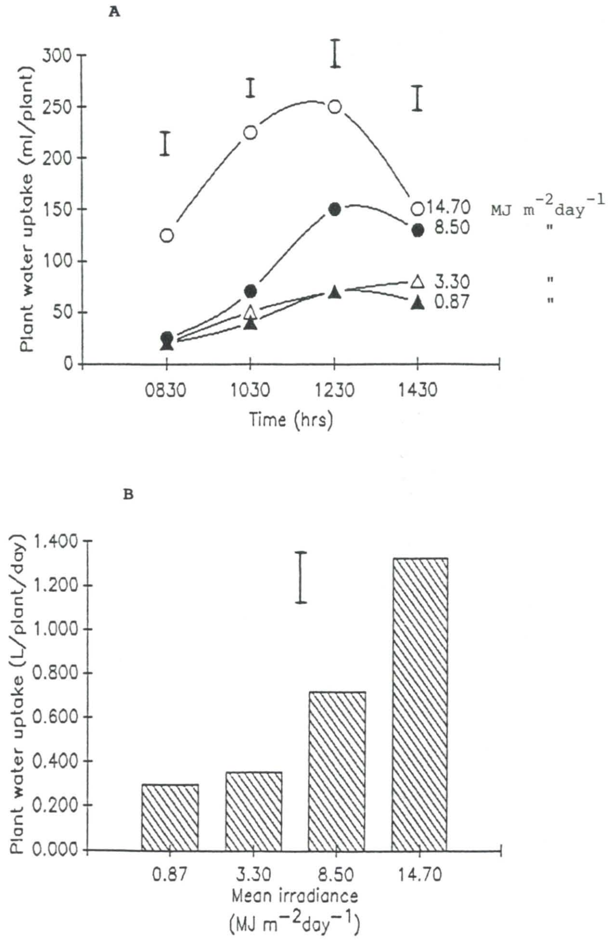

Fig. 4A: Diurnal plant water uptake as influenced by irradiance levels (MJ m^{-2} day^{-1})
B: Mean plant water uptake as influenced by irradiance levels

diminishing irradiance levels had about 15%, 20%, 50% and 10% less concentrations of N,P,Ca and Mg respectively than those in the control (Table 1).

Yield

There was a 38% reduction in yield at 8.5 MJm^{-2} day^{-1} compared to the control while at lower irradiance, no fruit was produced (Table 2). However, at irradiance of 8.5 MJm^{-2} day^{-1}, the incidence of fruit cracks was 20% less than that in the control. The reduced number of fruit cracks, however, may be associated with the smaller size of fruits. Irradiance, nevertheless, did not have an appreciable effect on the number of flowers or total soluble solids (Table 2)

TABLE 1
Effect of irradiance on the concentration of nutrients in the leaves of tomatoes. Data are means of six leaves over a twelve week period

Irradiance ($MJ\ m^{-2}day^{-1}$)	N	P	K	Ca	Mg
14.70	4.30	0.67	5.33	1.21	0.53
8.50	1.66	0.33	2.17	0.84	0.19
3.30	0.85	0.17	0.96	0.92	0.11
0.87	0.65	0.13	0.96	0.80	0.09
LDS (5%)	0.16	0.04	0.28	0.17	0.01

TABLE 2
Tomato fruit growth and yield as affected by irradiance. Plants under lower irradiance treatment failed to produce fruit

Irradiance ($MJ\ m^{-2}day^{-1}$)	14.7	8.5
No. Flower/ Plant	23	21
No. Fruit/ Plant	14.5	11.8*
Fruit diameter (cm)	6.90	5.12*
Fresh weight (g/plant)	1725	1063*
Fruit crack (%)	40	20
Total soluble solids (% Brix)	6.02	5.10

* Indicates treatments significantly different (P=0.05)

DISCUSSION

The decrease in plant dry weight under shade indicates the importance of irradiance in the production of tomatoes under rainshelter cultivation in the tropics. The decrease in dry matter of tomato plants grown under lower irradiance has been reported extensively (Chu and Toop 1975; Gent 1986; Rao and Bhati 1990). Smith *et al.* (1984) reported that the plants grown under shade had smaller roots and had increased resistance to water uptake. Leaves were also thinner and smaller under shade compared to those exposed to the full sun. These factors may have contributed to the reduced overall growth and yield of plants exposed to the lowest irradiance. The decrease in nutrient compositions in plants grown under shade could be due to a reduced root growth and water uptake. Similar results were reported by Kalkafi *et al.* (1984) suggesting that reduction of irradiance to 0.02 kJ m^{-1} day^{-1} resulted in a significant reduction in N and P contents in plants. Similarly, Holder and Cockshull (1988) reported that Ca deficiency symptoms appeared on young expanded leaves of plants grown under low irradiance and high relative humidity. These results, however, contradict those observed by Menzel and Simpson (1988) who reported that shade did not affect nutrient uptake in passion fruit. As shown in *Fig. 2A*, leaf area was reduced in plants under shade; this could probably be the cause for the decrease in yield (Table 2). This study showed that a reduction of light by 20% i.e, an irradiance from 14.7 to 8.5 MJ m^{-2} day^{-1}, was associated with a 38% reduction in yield. Cockshull and Graves (1990) suggested that a 10% yield reduction was associated with a 10% reduction in irradiance. El-Aidy (1985), however, reported that yield of tomatoes was greatest under shade. This discrepancy may have resulted from the influence of other enviromental factors. The greater number of fruit cracks occurring in plants at 14.7 MJ m^{-2} day^{-1} than at 8.5 MJ m^{-2} day^{-1} could be the result of high air temperature and increased water uptake. Furthermore, bigger fruit with higher water content on plants that were grown under 14.7 MJ m^{-2} day^{-1} irradiance may have reduced the elasticity of the fruit skin. Similar effects have been observed by Janse (1990).

CONCLUSION

The study indicates that increased irradiance resulted in a significant increase in growth and yield of plants grown in hydroponic conditions. In the production of tomatoes under rainshelter in the tropics, irradiance must not be lower than 14.7 m^{-2} day^{-1}. Further studies need to be carried out to establish relationships between the energy balance and the growth of plants grown under rainshelter in the tropics.

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