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IRRIGATION REQUIREMENTS OF GREENHOUSE VEGETABLES IN CRETE

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Abstract: Studies, over a number of years, were carried out in Crete, Greece to determine the water consumptive uses of drip-irrigated vegetables (tomato, cucumber, eggplant and pepper) grown in unheated greenhouses. The amount of water applied and the irrigation frequency were controlled by tensiometers, so that soil water potential at a depth of 25 cm was maintained at values higher than -20 KPa. Maximum yields for an eight-month growing season (October to May) were obtained with seasonal water application of 260 mm for tomato, 296 for pepper and 325 mm for eggplant. Cucumber was the most water-consuming crop, requiring 290 mm of water application for 3.5 months growing season. The number of fruits per plant was mainly reduced with less water application. The crop maximum evapotranspiration (ETm) in October (at planting) was 0.2 of class A pan evaporation (Epan), located outside the greenhouse. This value remained almost constant until February, since crop growth and production are low due to low temperatures, and then increased gradually up to 1.1xEpan, depending on the crop.

INTRODUCTION

Vegetable crops grown in greenhouses for out of season production are spreading in Greece, like in many areas of the world, since they ensure a relatively higher income to the farmers. On the island of Crete, where climatic conditions are favourable and heating is not usually required, about 46% of the total cultivated area in Greece is found. The main crops are cucumber (45%) and tomato (44%), while far behind are eggplants (5%) and pepper (3.8%). Water scarcity in many of the growing areas in the island, besides the increasing competition for municipal use, makes it necessary to optimise its use by the farmers.

The supply of the required water to the plant is of prime importance for its growth and economic production, especially into greenhouse, where irrigation is the unique source of water for the plant. Drip irrigation, -which ensures efficient water use, improved fertiliser application, salinity control and labour saving-, is mainly used by our farmers but irrigation intervals and water volumes are usually set according to empirical criteria. Although a lot of papers deals with water requirements of greenhouse grown vegetables, the results are not applicable to our region, since they are referred to different climatic conditions (Sonneveld, 1981; Frenz and Lechl, 1981; Catzeflis, 1981), different growing season (Chiaranda and Zebri, 1984, 1986; Hamar and Wannes, 1986) or to heated greenhouses (Eliades, 1988, 1992). The objectives of these studies, carried out over 10 years, were to determine the water requirements of the main vegetable crops (tomato, cucumber, eggplant and pepper), and to relate them with class 'A' pan evaporation and solar radiation.

MATERIALS AND METHODS

The experiments were carried on in unheated greenhouses for two cropping seasons for each crop, at the experimental farm of Subtropical Plants & Olive Tree Institute of Chania, north-west of Crete, (for tomato and cucumber) and at Horticultural Research Station of Ierapetra, south-east of Crete (for eggplant and pepper). The following hybrids, widely used by our farmers, were used: '*Dombito*' for tomato, '*Pepinex*' for cucumber, '*Delica*' for eggplant and '*Sonar*' for pepper. Information on plant population, planting dates and harvesting periods are given in Table1.

Table 1. Information on crop management, grown in unheated greenhouse

Crop	TOMATO	CUCUMBER	EGGPLANT	PEPPER
Hybrid	'Dombito'	'Pepinex'	'Delica'	'Sonar'
plant population	2.0 p/m^2	2.0 p/m^2	1.65 p/m^2	1.65 p/m^2
Transplanting day	Seot., 26	March 10/Aug 26	Oct., 6	Oct., 10
Harvest period				
From	Dec., 12	May 1/Oct, 1	Dec., 18	Dec., 15
To	May, 31	June 30//Nov., 30	May, 31	May, 31

The top 40 cm soil layer of the greenhouse was amended, containing 60-68% sand 16-22% silt and 12-16% clay. Irrigation water was of good quality with electrical conductivity (ECw) of 0.3-0.6 dS.m^{-1}. Cultivation cares (fertilisation, soil fumigation, and pruning, pest and disease control) were exactly the same for all treatments.

Plants were drip irrigated. For tomato and cucumber, the amount of water per irrigation and the frequency of water application were controlled by tensiometers installed at the depth of 15 and 30 cm. Irrigation was started when the soil water potential reached -20 KPa (treatment A), -40 KPa (treatment B) and -70 KPa (treatment C) at the depth of 15 cm, and was stopped when applied water reached at the depth of 30 cm. For eggplant and pepper the amounts of water tested were based on maximum evapotranspiration data obtained by the use of a tensiometer. It was assumed that maximum evapotranspiration (ETm) between two successive irrigations was calculated by the formula ETm = Iw - Dw, where Iw was the amount of irrigation water needed to keep the soil at field capacity (soil water potential higher than -20 KPa); and Dw was the amount of water drained at the soil depth of 45 cm. So, an electro-tensiometer was installed at the depth of 25 cm in order to pilot irrigation. Irrigation was started when soil water potential (SWP) reached at -20 KPa and stopped soon as applied water was reaching at the depth of 25 cm. Drainage at the depth of 45 cm, after a large amount of soil-water content measurements, was considered as negligible. Thus, maximum evapotranspiration was equal with the amount of irrigation water applied to keep SWP higher than -20 KPa, since drainage was zero at the soil depth of 45 cm. Four amounts of water were tested: 100% of ETm (treatment A), 85% of ETm (treatment B), 65% of ETm (treatment C) and 40% of ETm (treatment D). The frequency of irrigation, determined also by electro-tensiometer, was the same for all treatments, but the corresponded water for B, C and D treatments was applied to plants the next day. Irrigation treatments began after plant establishment (fifteen days after transplanting). The experimental layout was complete randomised block design with four or six replications.

Evaporation from a Class A pan evaporimeter and the actual sunshine duration from a Campbel-Stokes sunshine recorder, located outside the greenhouse, 100 m far away, were recorded daily. The potential evapo- transpiration of the crop (ETP) was estimated using the formula:

$$ETP = Rs\grave{e} = C_1 \, Ra \, (a+b \, n/N)$$

where C_1 is the penetration percentage in solar radiation for PE (0.8), Ra is the extra terrestrial radiation in mm, n is the mean actual sunshine duration in hr/day, N is the maximum possible sunshine duration in hr/day and a, b are constants (0.30 and 0.45 respectively).

The mature fruits were harvested once or twice a week, and their number and weight were recorded.

RESULTS AND DISCUSSION

Crop yield response to different amounts of water applied is given in Fig. 1. For tomato, the highest yield (6.3 kg/plant) was achieved with a seasonal water application of 260 mm, while any further increase in water application did not increase yield. With less amount of applied water, fruit yield was reduced significantly, because fruits were smaller (Table 3).

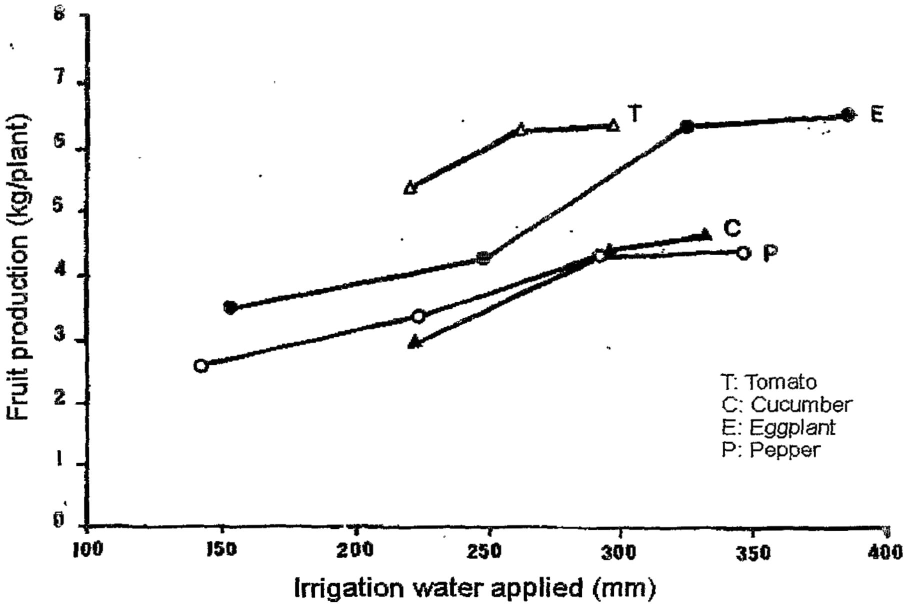

Figure 1. Fruit production per plant in relation to irrigation water applied for the greenhouse crops.

The same pattern was followed by cucumber, although water requirements were much higher than tomato, for a 3.5 months cropping season. The highest yields were obtained with 290 mm of water (Chartzoulakis and Michelakis, 1990), while application of 220 mm reduced yield significantly because of the formation of fewer fruits (Table 2). Eliades (1988) also reported less fruit formation with less water application for the cucumber, cv Maram, grown in a heated greenhouse.

For eggplant the highest yield (6.5 Kg/plant) was obtained with the treatments A and B, corresponding to seasonal water application of 380 and 325 mm respectively. Seasonal water application of 250 and 150 mm reduced the yield significantly in both growing seasons (Chartzoulakis and Drosos, 1995). Although the fruit yield of A and B treatments was almost the same. The water use efficiency for harvested yield (kg of produced fruits per unit of applied water) of treatment B was higher (31.1 instead of 27.2 kg mm^{-1}); such a difference is significant for water sort area such as Crete. Eliades (1992) reported that the eggplant could grow successfully in a heated greenhouse for a 7-month period with as low as 285 mm of water.

For sweet pepper, the highest yield (4.4 Kg/plant) was obtained with 300 mm of water, while less water application reduced the yield significantly.
The effect of irrigation water applied on the number of marketable fruits harvested per plant is shown in Table 2. For cucumber, eggplant and pepper, less water application reduced significantly the number of fruits harvested per plant, while for tomato no reduction was observed.

Table 2: Average number of marketable fruits harvested per plant for the four greenhouse crops as affected by the amount of water applied

Treatment	TOMATO	CUCUMBER	CUCUMBER	PEPPER
A	43.1a	11.5a	27.1a	56.2a
B	42.8a	11.2a	26.3a	55.3a
C	40.8a	8.1b	19.0b	46.1b
D	-	-	16.2b	34.1c

Different letters within column indicate significant differences at $P<0.05$ (Duncan's multiple range test).

Mean fruit weight was reduced significantly with less water application for tomato and pepper, while no significant reduction was observed for cucumber and eggplant (Table 3).

Table 3: Mean fruit weight (g) of the four greenhouse crops as affected by the amount of water applied

Treatment	TOMATO	CUCUMBER	CUCUMBER	PEPPER
A	146a	398a	243a	83a
B	142a	393a	240a	81a
C	127b	385a	228a	65b
D	-	-	231a	61b

Different letters within column indicate significant differences at $P<0.05$ (Duncan's multiple range test).

The water requirements of tomato, eggplant and pepper, when the soil water potential was kept higher than -20 KPa, ranged between 0.5 and 4.5 mm per day (Figure 2). Two periods can be distinguished from Figure 2 for the crop demand for irrigation water; a period characterised with low water requirements (October to February) because rates of plant growth and production are low due to low air temperatures (10 °C) inside the greenhouse. The second period from March to May is characterised by a fast increase of water requirements, due to the increase in the evaporative demand of the atmosphere and the faster rates of plant growth and production achieved under the optimum climatic conditions prevailing at that period. For cucumber, daily water requirements increased from March (at planting) up to June, while at fall cropping season, water requirements reached at a maximum (4.3 mm/day) at September, and then start to decline.

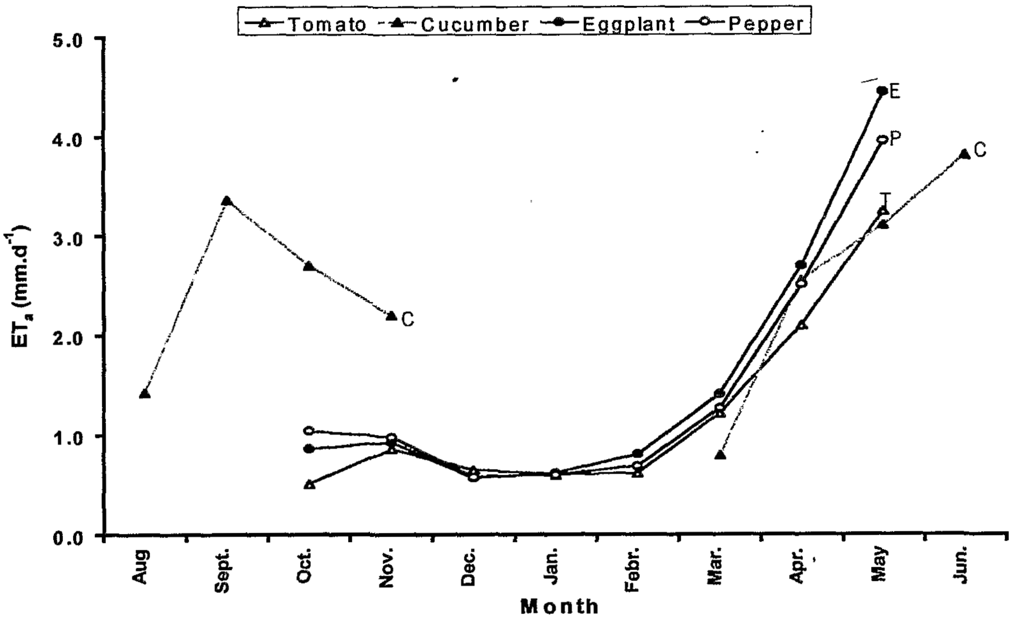

Figure 2. Daily maximum evapotranspiration of the four vegetables crops grown in unheated greenhouse

Although these results are merely indicative, they emphasise that season-al evapotranspiration depends on the length of the cropping season as well as on growing period during the year. More general and useful indications for practical use are drawn from ETm/Epan ratios during the cropping cycle of each species under consideration.

The crop ETm in October for tomatoes was 0.3 of class A pan, located outside the greenhouse, reaching a maximum of 0.45 during November, then declined until February, and then started to increase again (Figure 3). The increase in ETm/Epan noticed at the initial stages of growth of tomato has been also reported by Graaf and Ende (1981). For cucumber the ETm/Epan ratio increased from 0.2 at planting to 1.1 at the end of cropping season in November.

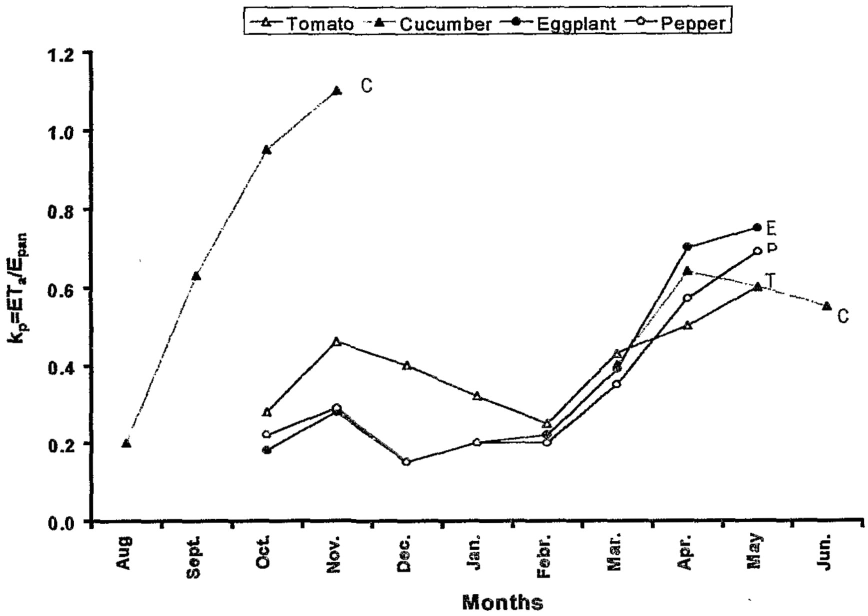

Figure 3. Crop coefficients (kp=ETm/Epan) during the cropping season for the four vegetables grown in unheated greenhouse

For eggplant and pepper the crop ETm in October (at planting) was 0.2 of class "A" pan evaporation (Epan). This value remained constant until February and then increased gradually 0.7 x Epan for pepper and to 0.8 x Epan for eggplant at the end of the experiment, in May (Figure 3). The same course followed the ratio between ETm to potential evaporanspiration rates calculated by radiation method for pepper (Figure 4). Eliades and Orphanos (1986) compared the ratios of ETP, measured with lysimeters, to Epan or to potential evapotranspiration rates calculated by the Blaney-Griddle or Penman formulae, and they found that Epan recorded outside the greenhouse was a reliable measure for tomato evapotranspiration under cover. Since there were no big differences in both ETm and the ETm/Epan ratios between the years and small deviations (15%) in water application from ETm are not expected to affect yield significantly (Figure1), the ETm/Epan or ETm/ETP ratios can be successfully used to estimate the water demand of greenhouse crops.

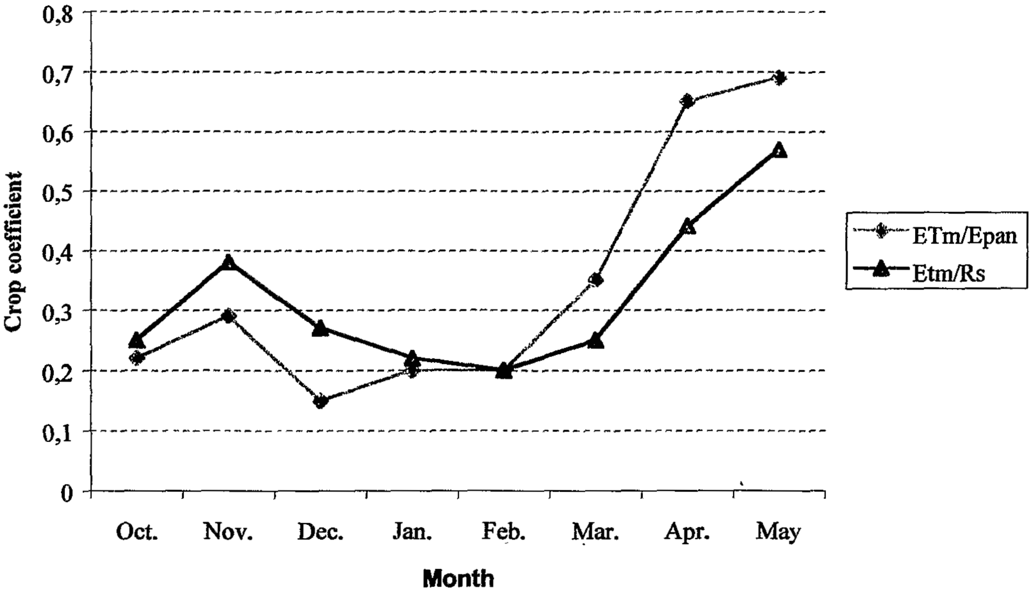

Figure 4. Crop coefficient (Kr=ETm/ETP) for greenhouse grown pepper during cropping season.

CONCLUSIONS

1. Tensiometers can be effectively used for irrigation scheduling in greenhouse crops at farm level, saving at least 100% of the water given empirically to the crops by our farmers.

2. The ETm/Epan or ETm/ETP ratios can be successfully used to estimate the water demand of greenhouse crops, since both Epan and solar radiation are an easy measurement to take outside the greenhouse, and are usually available, since public services are involved in recording them.

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