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CROP MODELLING AND WATER USE EFFICIENCY OF PROTECTED CUCUMBER

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Abstract

Crop modelling is considered an essential tool of planning. The automation of irrigation scheduling using crop models would contribute to an optimisation of water and fertiliser use of protected crops. To achieve this purpose, two experiments were carried. The first one aimed at determining water requirements and irrigation scheduling using climatic data. The second experiment was to establish the influence of irrigation interval and fertigation regime on water use efficiency. The results gave a simple model for the determination of the water requirements of protected cucumber by the use of climatic data: **ETc = K* Ep.** K and Ep are calculated using climatic data outside the greenhouse. As for water use efficiency, the second experiment highlighted the fact that a high frequency and continuous feeding are highly recommended for maximising yield.

1. INTRODUCTION

Crop growth and production are the results of complex processes relating plants to their physical environment in the soil-plant-atmosphere continuum.

Classical agronomic approaches of crop responses to water were largely based on empirical experiments whereby yield is related to water (or water and other related inputs) applied as an independent variable [1]. When the total quantity per season is considered, typical "macro" production functions are generated [2]. When optimal timing and depth of irrigation is considered, "micro" water production functions are obtained. As such, response patterns are identified, simplicity is maintained, but explanation for such a response may remain unclear [1].

In general terms, a "crop response function", or preferably an "engineering production function" [3], is wanted to proceed towards the solution of the optimisation study. Consequently, crop modelling is considered as an essential tool of planning, management, and environmental impact assessment, scaling up and down between the farm (irrigation scheduling, productivity and economic evaluation) and the region (policy decision making, resource management).

Production in greenhouses has a higher efficiency of water use that might be improved further by a greater possibility of environmental, cultural practices and management.

Transpiration of greenhouse crops is one of the processes one would really like to control. This is due to two quite different and sometimes contradictory considerations. One is that crop production is related to water consumption [4]. The other has more to do with the saving of energy [5] . In fact, the application of energy saving devices (as double cover, thermal screens or reduced air exchanges), results in a lower rate of vapour removal, and a higher ambient humidity. Consequently, whatever the rationale for either increasing or reducing the transpiration rate of a crop by means of manipulating the greenhouse climate or the management of water and nutrients requirements of the crop, the relationship between these factors should be accurately known.

Previous studies in Lebanon determined the water and nutrient requirements of protected cucumber [6,7,8,9]. In addition, a simple method was established on a large scale for irrigation scheduling for different protected crops based on climatic data outside the greenhouse [10]. The study was completed by the determination of the actual evapotranspiration of cucumber (ETc) through a coefficient (K) and the evaporation from the small pan (Ep) [8]. The coefficient (K) was calculated as a function of days after sowing (DAS).

$$\mathbf{ETc = K^{*}\ Ep}$$

By changing the season, the plant growth varies according to the climate and consequently K will change. Therefore, it will be interesting to determine K as a function of plant growth (leaf area index "LAI" or plant height).

For a further saving in water use of protected cucumber, two experiments were carried out: the first one aiming to determine water requirements and irrigation scheduling using climatic data; the second experiment was to establish the influence of irrigation interval and the fertigation regime on the water use efficiency.

2. MATERIALS AND METHODS

The first experiment was run to determine, using air temperature outside greenhouses, plant growth of protected cucumber in terms of plant height and leaf area index. The leaf area index (LAI) as well as plant height were measured every 3 days. LAI was determined using a non-destructive method described by Parceveaux and Massin 1970. These measurements will serve to the determination of "K" factor relating the evaporation of small blue pans to the actual evapotranspiration of the crop. The work was executed starting from October 1997 till May 1998 (2 different periods of plantation, cycle I and cycle II).

Based on 250 mm of water requirements for cucumber, another experiment was done to highlight the influence of irrigation interval (2 vs. 3 days) and of fertigation regime (continuous vs. discontinuous feeding) on water use efficiency of protected cucumber. The experiment lasted from April to July 1998.

For this purpose, 4 treatments: T_2C, T_2D, T_3C & T_3D with 5 replicates were distributed in a block randomised system. Irrigation was scheduled according to the evaporation of a small blue pan (Ep) and a coefficient K depending on days after sowing (DAS).

A neutron probe determined the water consumption of the plants. Plant water status was characterised by the measurement of predawn leaf water potential using a pressure chamber [11]. Water potential in the soil was followed by tensiometers installed at 25 and 50 cm.

3. RESULTS AND DISCUSSION

3.1. Modelling of cucumber growth

Drawing the values of plant height (H) and LAI measured at two periods (Fig. 1), we can conclude that the plant rate of growth varied according to the season. Consequently, for the same day after sowing (DAS), cucumber plants had shown different values of H and LAI according to the season.

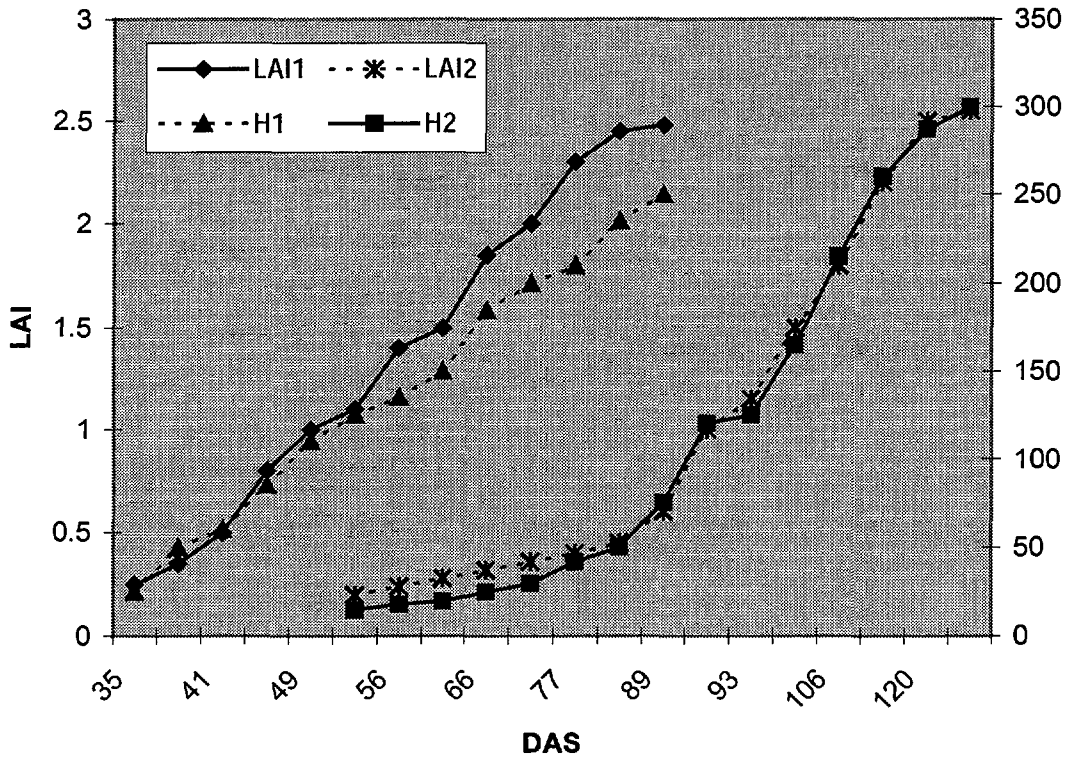

Figure 1. Influence of the season on the growth of protected cucumber.

While modelling H and LAI as a function of DAS, different equations were obtained:

$H_1 = 4*DAS - 93$ $\quad$ $LAI_1 = 0,04*DAS - 1,14$

$H_2 = 4,8*DAS - 303$ $\quad$ $LAI_2 = 0,04*DAS - 2,86$

However, LAI was related to H independently of the season:

$LAI_1 = 0,0093*H$ $\quad$ $LAI_2 = 0,0086*H$

This result is in harmony with Yang et al. (1990) who found the following equation:

$LAI = 0,0089*H - 0,0965$

According to several authors, for the same level of water and nutrients in the soil, plant growth is a function of the cumulative value of temperature. Therefore, we determined LAI and H as a function of $\Sigma(T)$ for the respective period.

The correlation showed similar equations regardless of the season:

$H_1 = 0,21*\Sigma(T) - 139$ $\quad$ $LAI_1 = 0,0023*\Sigma(T) - 1,6938$

$H_2 = 0,24*\Sigma(T) - 216$ $\quad$ $LAI_2 = 0,0022*\Sigma(T) - 1,93$

Combining the values of H and LAI of the 2 seasons, we obtain:

$LAI = 0,002*\Sigma(T) - 1,56$ $\quad$ $H = 0,21*\Sigma(T) - 159$

In a previous study (Metri, 1997)[8], K was determined as a function of H:

$$\mathbf{K = 0,3153*Log\ (H) - 0,3851}$$

Replacing K with its value in the previous equation:

$$\mathbf{K = 0,3153*Log\ (0,21*\Sigma(T) - 159) - 0,3851}$$

So K will be determined by the cumulative value of temperature of the growing period. This model is supposed to be valid for all growing seasons.

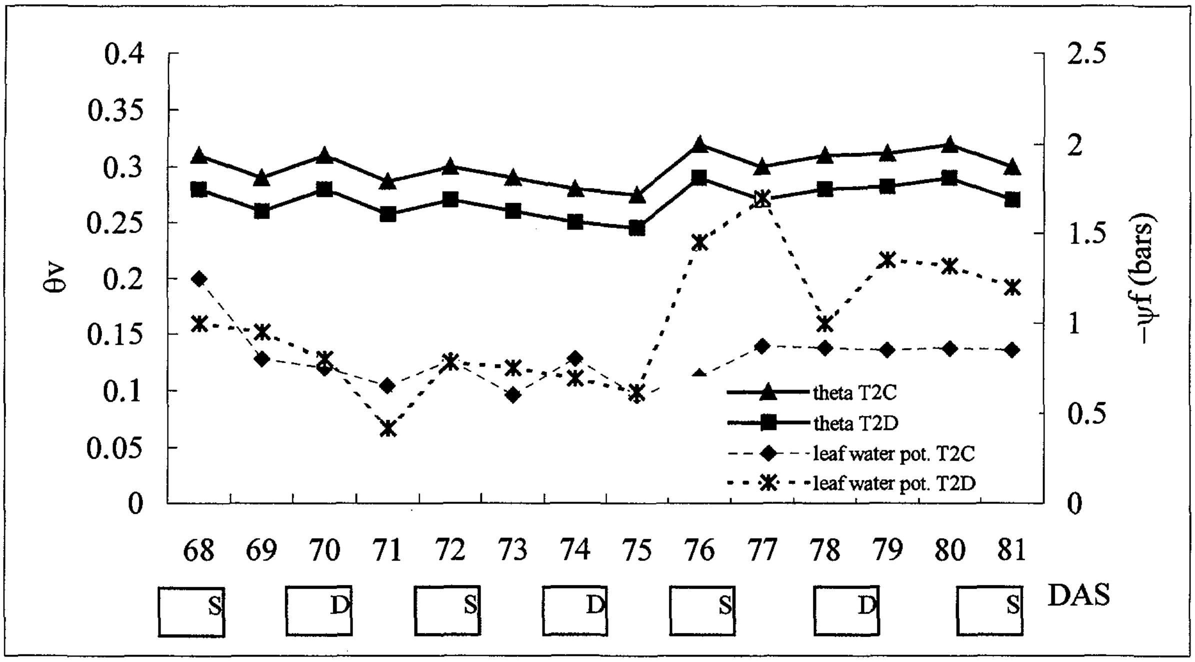

Figure 2. Evolution of predawn leaf water potential and water content for the treatments T2C and T2D.

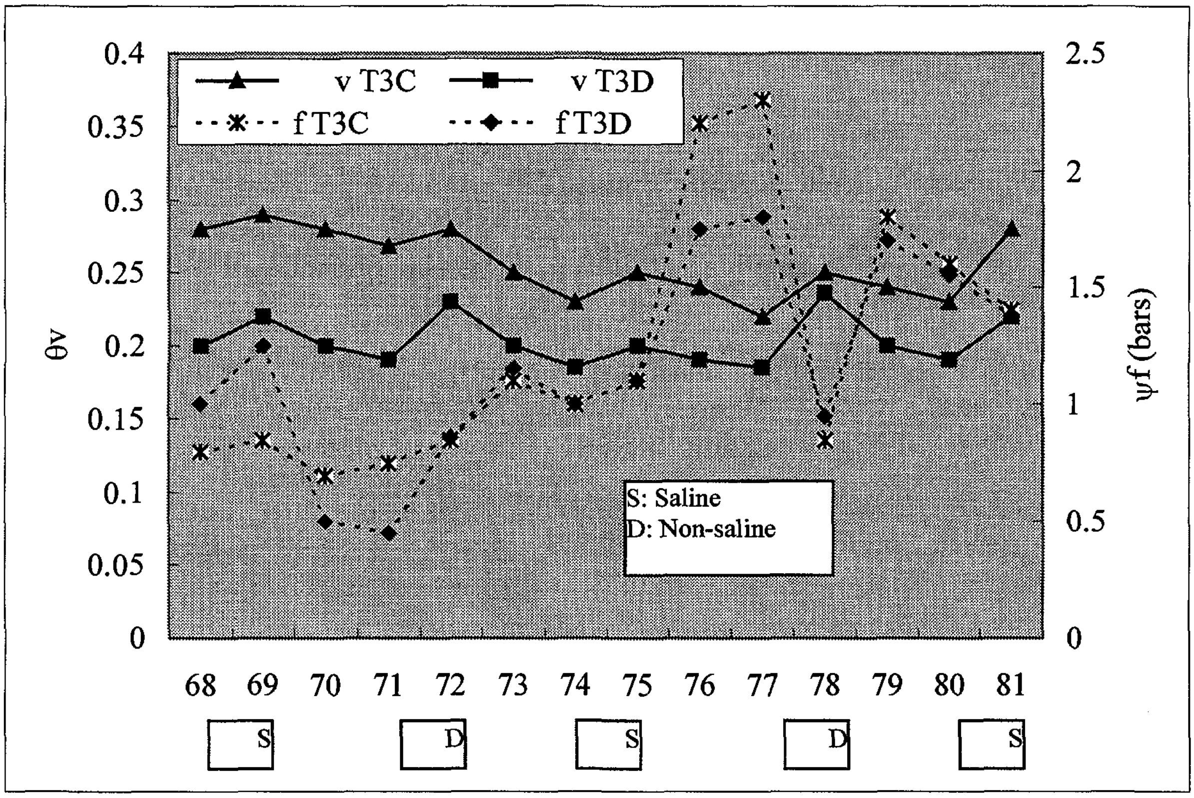

Figure 3. Evolution of predawn leaf water potential and water content for the treatments T3C and T3D.

3.2. Water use efficiency of protected cucumber

3.2.1. Leaf water potential

The predawn leaf water potential of the 4 treatments was measured during 14 days (68 till 81 DAS). The values obtained are drawn with the variation of water content in the soil for T2C and T2D (Fig. 2) as well as for T3C and T3D (Fig. 3).

3.2.1.1. Effect of fertigation regime:

The effect of fertigation regime was translated in a fluctuation of predawn leaf water potential (ψ_f) of the discontinuous treatments between an irrigation with fertilisers (S) and irrigation with water (D). The difference was reduced mainly during the period "68–73 DAS" which was characterised by a low climatic demand. In the following period, "74–81 DAS", the climatic demand increased and the difference was accentuated. (ψ_f) was relatively lower in the treatments with continuous feeding than in the treatments of the discontinuous regime due to higher fluctuation of salinity in the soil.

3.2.1.2. Effect of irrigation frequency

As for the fertigation regime, the predawn leaf water potential (ψ_f) was affected. Treatments with a high frequency of irrigation (T2) maintained a lower (ψ_f) with respect to treatments with low irrigation frequency (T3). This shows the effect of irrigation frequency on the plant water status with the variation of water content in the soil.

3.2.2. Leaf Area Index (LAI)

The leaf area index (LAI) was measured 4 times for all treatments: on the 53, 77, 97, 118 DAS. According to the values obtained (Table I), the irrigation frequency and fertigation regime nfluenced the leaf growth. LAI of treatments with high frequency of irrigation was positively affected as well as treatments with continuous feeding. This result sounds in harmony with the trend of leaf water potential discussed in the previous paragraph.

3.2.3. – Water consumption

Water consumption measured by a neutron probe showed significant differences among treatments (Table II).

As a consequent of leaf water potential and LAI, water consumption varied accordingly with a maximum value for T_2C and low values for T_3C and T_3D.

3.2.4. Yield

Yield in terms of fresh fruits was largely affected by the irrigation frequency and fertigation regime (Table III). The treatments T2 showed a higher yield than the treatments T3 due to lower stress. Discontinuous feeding affects negatively the yield even within treatments with a high irrigation frequency (T2D).

3.2.5. Water use efficiency (WUE)

Water use efficiency is the ratio between yield and water consumption during the growing period. Treatments with low irrigation frequency showed higher WUE (TABLE IV). Although, the difference between treatments was non-significant.

TABLE I. LEAF AREA INDEX (LAI) OF DIFFERENT TREATMENTS

DAS	***T2C***	***T2D***	***T3C***	***T3D***
53	2.3	2.14	2.27	2.09
77	3.49	3.19	3.42	2.9
97	4.09	3.65	3.76	3.3
118	4.46	4.19	4.22	3.86

TABLE II. WATER CONSUMPTION OF THE DIFFERENT TREATMENTS

Treatment	T2C	T2D	T3C	T3D
Quantity (mm)	223.08a	178.56ab	131.33b	130.65b

Threshold of significance of 5%.

TABLE III. RELATIVE YIELD OF THE DIFFERENT TREATMENTS

Treatment	T2C	T2D	T3C	T3C
Yield (kg)	492.52 a	396.71 ab	390.13 b	348.15 b

Threshold of significance of 5%.

TABLE IV. WATER USE EFFICIENCY OF THE DIFFERENT TREATMENTS

Treatment	T2C	T2D	T3C	T3D
Efficiency (kg/l)	0.08a	0.08a	0.12a	0.11a

Threshold of significance of 5%.

3.2.6. Relationship between water consumption and yield

To establish this relationship, the following equation was used:

$$\left(1-\frac{Ya}{Ym}\right)=Ky\left(1-\frac{ETa}{ETm}\right)$$

With

Ya	actual harvested yield	Ym	maximal harvested yield
Ky	yield response factor	ETa	actual evapotranspiration.
ETm	maximum evapotranspiration.		

The result of the combination of the different values of water consumption and yield gave the following equation:

$$\left(1-\frac{Ya}{Ym}\right)=0.9155*\left(1-\frac{ETa}{ETm}\right)$$

4. CONCLUSION AND PERSPECTIVE

These experiments were a continuation of previous studies in order to improve water use in agriculture in general and to protect crops in particular.

The first experiment allowed the establishment of the factor K as a function of climatic data. The automation of irrigation is therefore possible by the connection with a weather station.

The second one highlighted the effect of irrigation frequency and fertigation regime on the yield and WUE of protected cucumber. A high frequency and continuous feeding are highly recommended for maximising yield. Low frequency and discontinuous feeding increase the WUE but not significantly.

REFERENCES

[1] STEDUTO, P. Modelling for crop response to water: physiological aspects. Options Méditerranéenes, Sér. A/nr 31 (1997) 289–312.

[2] YARON, D., BRESLER, E. Economic analysis of on-farm irrigation using response functions of crops. In: Advances in Irrigation, Vol. 2, Hillel, D. (ed). Academic Press, New York, (1983) 223–255.

[3] DEYBE, D., FLICHMAN, G. A regional agricultural model using a plant growth simulation program as activities generator. An application to a region in Argentina. Agricultural Systems, 37 (1991) 219–227.

[4] VAN KEULEN, H., VAN LAAR, H.H. The relation between water use and crop production. In: Van Keulen, H. and Wolf, J. eds., Modelling of Agricultural Production: weather, soils and crops. Pudoc, Wageningen (1986) 117–129.

[5] STANGHELLINI, C. Transpiration of greenhouse crops, an aid to climate management. Ph.D. dissertation, Agric. Univ., Wageningen, The Netherlands (1987).

[6] AKL, G. Détermination des besoins en eau du concombre de serre sous différents régimes d'irrigation fertilisante. Mémoire de fin d'études, Université Libanaise, Faculté d'Agronomie. (1996) 60 p.

[7] ABOU-JAOUDE, R. Fertigation du concombre printanier sous serre: besoins en azote. Mémoire de fin d'études, Univ. Libanaise, Faculté d'Agronomie. (1996) 53 p.

[8] METRI, P. Pilotage de l'irrigation du concombre sous serre à partir d'un bac évaporant. Mémoire de fin d'études, Université Libanaise, Faculté d'Agronomie. (1997) 70p.

[9] CHELALA, C. Interaction entre l'azote et le Potassium dans la culture du concombre printanier sous serre. Mémoire de fin d'études, Université Libanaise, Faculté d'Agronomie (1997).

[10] ABI ZEID, R. Pilotage de l'irrigation sous serre. DEA Agriculture Durable. AUPELF – UREF (1997) 41 p.

[11] SCHOLANDER, P.F., HAMMEL, L.H., BRADSTEET, E.D., HEMMINGSEN, E.A. Sap pressure in vascular plants. Science 148 (1965) 339–346.