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EVAPOTRANSPIRATION IN A SUNFLOWER (Helianthus annuus L.) CROP IN A SEMIARID ZONE

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In the last few years the sunflower crop has been making a spectacular increase in Spain, specially in the southern part of the country. In the 1971 season, 291 000 Has. were harvested while 10 years ago this crop was almost unknown like oil seed crop.

Most of the sunflowers are grown under dry farming conditions. If we have a look at the climatic characteristics of Southern Spain during the sunflower growing season, we can observe a rainy and warm spring and a hot and dry summer. In these conditions the crop can only succeed in deep soil of high water retention, since the sunflower has a long root system which can explore areas in the soil not reached by other crops.

Some growers wanted to start sunflower cultivation by irrigation, but they did not know the plant's water requirement.

This study was done to find out the evapotranspiration (ET) in a sunflower crop, which the starting point for establishing the irrigation calendar and the sunflowers' water requirements.

The study was carried out in "Alameda del Obispo" farm, in the Guadalquivir Valley, near Cordoba (37° 51' latitude North). On the same farm exists a weather station from which the climatic parameters were taken.

In table 1 are given the average monthly mean temperature (10 years) and of rainfall (40 years). The yearly rainfall average is 687,5 mm and the monthly distribution percentage is indicate.

The ET was measured directly in a Thornthwaite evapotranspirometer. The tank had a surface of 4 square meters and a depth of 1 m. It was filled with sandy loam soil from the nearby plot. The tank and surrounding area were planted with sunflower cv. Peredovik with a density of 75 000 plants/Ha (30 plants inside the tank). In this way the "oasis effect" was avoided. The seed was sown on April 22, and the crop was harvested in early September. During the growing season the water table remained constant at 0.9 meters from the surface and the ET in the tank was recorded every day.

The evaporation from a free water surface (E_o) was calculated from the known Penman formula :

$$E_o = \frac{\Delta R_n/C + \gamma E_a}{\Delta + \gamma} \qquad (1)$$

where C is the heat of vaporization, γ is a psychrometric constant = 0.485 mmHg/°C, Δ is the slope (rate) in the relationship function between temperature and vapour pressure at the air temperature, R_n is the net radiation, and E_a was defined by Rijtema as the following function :

$$E_a = 0.182\ u\ (e_a - e_d)$$

where u is the wind velocity in m/sec., e_a is the saturation vapour pressure of the air at 2m. level, e_d is vapour pressure of the air at 2 m. level, and $(e_a - e_d)$ is, then, the vapour pressure deficit.

Table 1 - Mean temperature and rainfall

Month	Mean temperature	Rainfall	
		mm.	%
January	8.9	83.7	12.17
February	10.6	75.5	10.98
March	12.8	94.3	13.72
April	15.4	66.6	9.69
May	19.0	52.3	7.61
June	24.3	18.9	2.75
July	27.7	3.5	0.51
August	27.7	3.6	0.52
September	24.1	27.3	3.97
October	18.5	81.4	11.84
November	13.1	91.1	13.25
December	9.5	89.3	12.99

In this study neither the intensity of the light nor the quantity of water are limiting factors, therefore the factor considered by Rijtema, dependent on the number and openness of stomates, was not considered. Then, the following equation which directly gives the ET of the crop, was established :

$$ET = \frac{\Delta\ R_n/C + \gamma\ E'_a}{\Delta + \gamma} \qquad (2)$$

where E'_a is dependent on a "F" factor and on the saturation deficit. Thereafter :

$$E'_a = F\ u\ (e_a - e_d)$$

The net radiation (R_n) is given by the equation :

$$R_n = R_i\ (1 - r) - R_o$$

where R_i is the short-wave radiation income on a horizontal surface, R_o is the net back radiation (from surface to sky) and r is the reflection coefficient of the surface.

R_i was recorded by a Robitzch radiometer. We considered a reflection coefficients of 0.05 for the water and 0.23 for crop. R_o, which is dependent on the air temperature, atmospheric water vapour and cloudiness, was calculated from the Brunt formula :

$$R_o = \sigma\ T_a^4\ (0.56 - 0.092\ e_d)\ (0.10 + 0.90\ n/N)$$

where σ is the Stefan-Boltzman constant, T_a is the mean air absolute temperature, n is the number of hours with sunshine, and N the maximum number of hours with sunshine without cloudiness.

Combining (1) and (2) :

$$E_0 - ET = - 0.18 \frac{\Delta}{\Delta + \gamma} \frac{R_i}{C} + \frac{\gamma}{\Delta + \gamma} (F - 0.182)\, u\, (e_a - e_d)$$

With this formula it is possible to get the factor "F" values, since all the other factors in the equation are known. These are the real F values.

To obtain factor F by a simpler method have been recorded wind velocity (u), crop height (h) and the real F values every day from June 1st to July 10. Figure 1 gives the plant growth ; on June 1st the plants are 20 cm. high and by July 10 have reached their maximum height, and growth upward is finished ; this happens when the plants are flowering. Figure 2 shows the evolution through the time of the three factors, F, u and h. Taking factor F as a function of the wind velocity and of crop height, a multiple linear correlation was studied. The results of this correlation and the analysis of variance for the regression are expressed in Table 2.

Table 2 - Multiple linear correlation results and analysis of variance for the regression

Variable	Mean	Standard deviation	Correlation x vs y	Regress. coeffic.	Std. error of reg. coef.	Computed T values
h	1. 14212	0.63943	0.80949	0.83086	0.12400	6.70029
u	1.40399	0.63046	- 0.69673	- 0.53156	0.12576	- 4.22655
Dependent : F	0.91394	0.86456				

Intercept 0.71131
Multiple correlation 0.87608
Standard error of estimate 0.42798

Analysis of variance for the regression :

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value
Attributable to regression	2	22.37435	11.18717	61.07615
Deviation from regression	37	6.77720	0.18316	
Total	39	29.15155		

The multiple linear correlation among the variables was significant at the 1% level. Then, the factor F can be expressed by the formula :

$$F = 0.83\, h - 0.53\, u + 0.71 \qquad (3)$$

Below 45 cm height (h) the daily F values are negatives. This formula is good until the point at which the plant stops growing (1st. period). From this moment on the correlation between F and u is bad (correlation coefficient = 0.20074).

For the second period (flowering to ripeness) F was correlated with p, percentage of days to ripeness in the flowering-ripeness period (correlation coefficient = 0.73445). The new F value for the second period is given by the formula :

$$F = 1.65\, p + 0.07 \qquad (4)$$

In the second period, the factor F is more influenced by physiological factors than by climatic factors. When the cycle is finishing the plant needs less water, independent of the available energy for evaporation.

Fig. 3 shows the theoretical F values obtained from formula (3) in the first period and formula (4) in the second period.

Table 3 gives the ET values obtained by 3 methods employing the average values of every 10 days from June 1st to August 31. The three methods for ET are :

1 - Penman's formula (1) with 0.8 like correction coefficient.

2 - ET measured in the evapotranspirometer.

3 - ET calculated from formula (2) with F values given by the (3) and (4) equations.

Table 3 - Evapotranspiration values by 3 different methods.

Period	Days		Penman	Evapotrans-pirometer	Proposed model
1 st. :	June	1-10	38.7	22.7	20.6
	"	11-20	45.9	67.9	56.0
	"	21-30	52.0	95.5	82.3
	July	1-10	55.0	96.7	102.6
2 nd	July	11-20	49.6	56.6	86.9
	"	21-31	55.6	74.4	85.7
	August	1-10	46.1	69.0	65.5
	"	11-20	47.1	59.2	51.3
	"	21-31	42.6	40.5	37.4

These values are represented in Fig. 4. The inflexions in Fig. 2 and Fig. 3, in the middle and late July, are consecuences of a heavy hail-storm which took place on July 14 th and many leaves of the sunflower plants were damaged. For this reason to calculate F in (4) the figures were taken from July 27 and were afterwards extrapolated to the earlier period in which the storm occurred.

In conclusion Fig. 4 shows that the Penman formula is not good enough to determine ET in a sunflower crop in Southern Spain, since it gives values which are too low. The model proposed in this work gives ET values closer to the real values measured in the evapotranspirometer. The maximum consumption of water recorded was 1.5 liters per plant and day. This maximum coincided with the flowering period. It has been established that the ET is more influenced by the crop height (h) than by wind velocity (u), this can be due to the values being so low for u recorded in summer in this area.

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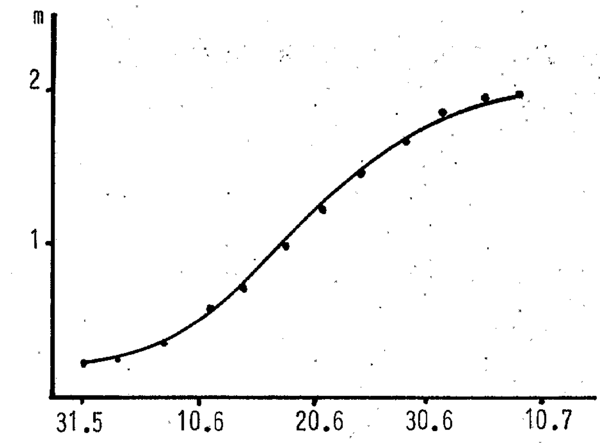

Fig. 1 - Sunflower growing curve

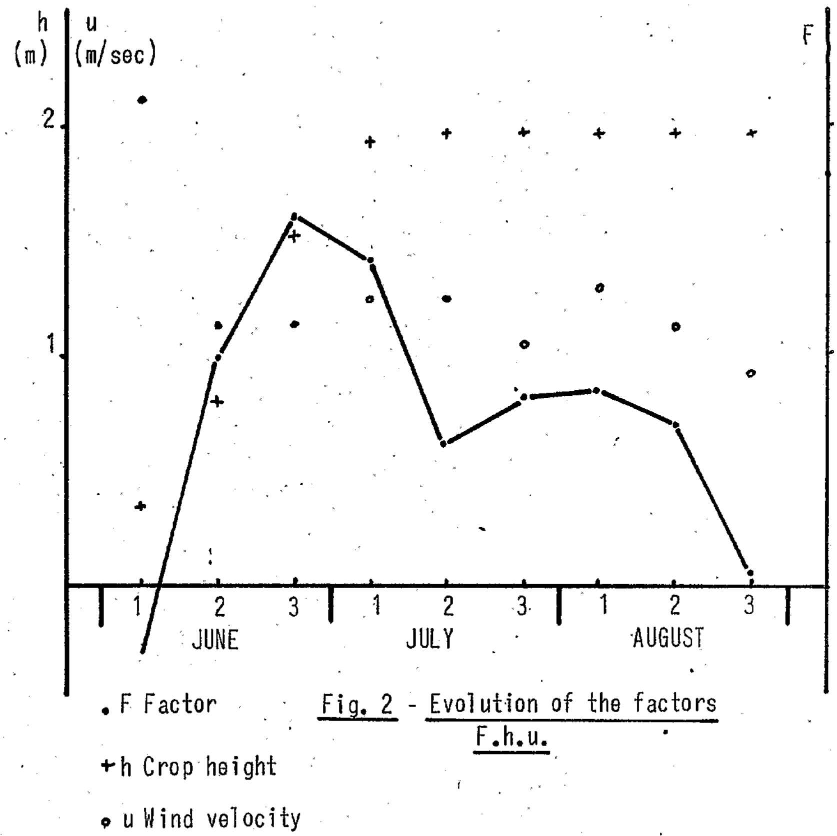

Fig. 2 - Evolution of the factors F.h.u.

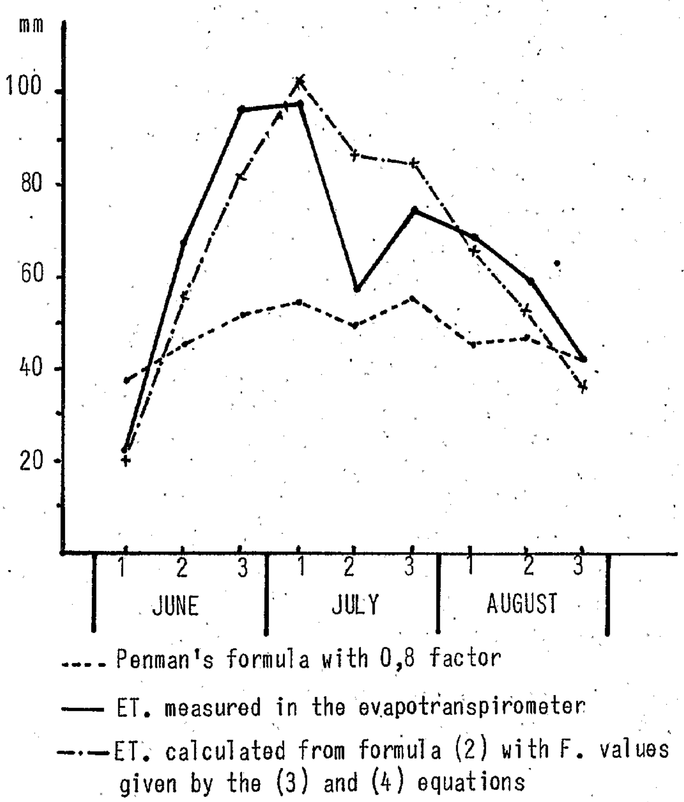

Fig. 4 - ET. calculated by 3 methods

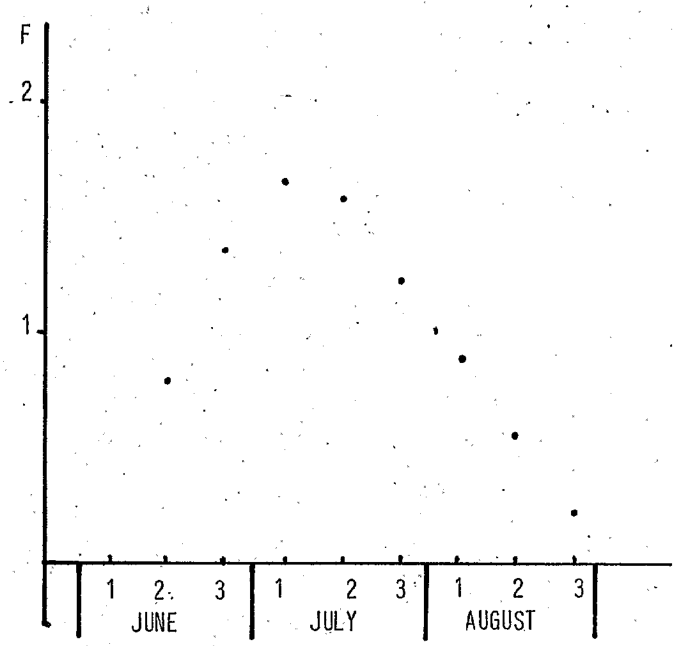

Fig. 3 - Evolution through time theoretical F values