WATER USE AND CROP COEFFICIENT OF SUBSURFACE DRIP-IRRIGATED HEAD LETTUCE IN CENTRAL ARIZONA

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1. INTRODUCTION

Lettuce is one of the leading fresh market vegetable in planted area, production, and value in USA, ranking only behind potato in each of these categories. This crop is comercially grown in over 20 states being California, Arizona, and Florida in this order, the main producing states (Swaider et al., 1992. Furrow and subsurface drip irrigation are the main irrigation systems used with that crop. Results on lettuce water use obtained in the 60's in furrow-irigated fields are still the main source of data in Arizona (Erie et al., 1965). On the other hand, the use of subsurface-drip irrigation systems to grow lettuce and other row crops are increasing fast since this method is seen to last longer and to save more water. The purpose of this work was to determine the seasonal water use by subsurface-drip irrigated head lettuce under arid conditions and to derive basal crop coefficients to be used in irrigation scheduling and water management programs.

2. MATERIAL AND METHODS

This research was carried out at the Maricopa Agricultural Center (33°04'07" N, 111°57'18" W) of the University of Arizona in the Fall-Winter period of 1996/97 and 1997/98. The soil in the area is a deep, well-drained and slowly permeable soil formed in old alluvium, classified as Casa Grande sandy loam. Average temperature range: -2°C to 17°C (winter) and 25°C to 42°C (summer). Average annual rainfall: 185 mm. Weather data during the seasons were taken from the nearest AZMET (AriZona METeorological network) weather station.

The experimental area consisted of three plots with four beds each, 15 cm high, 100 cm width, and 18.6 m long. Three small weighable lysimeters (Martin et al.; 2001) were installed in each plot at midway of one of the center beds. A lysimeter comprised an outer rectangular retaining shell and an inner tank, with an internal area of 0.929 m^2 A suction system was used to collect the drainage water from the bottom of the inner tank. The lysimeter weighing equipment was made of a four-wheel Spirit sprayer chassis, a digital weighmeter, a load cell, and hook-ended chains to lift the lysimeters up (Folta, 1996). The beds were subsurface-drip irrigated with turbulent flow twin-wall drip irrigation tapes, with outlets at 23 cm spacing. The tapes were buried at about 15 cm depth at the center of each bed. Planting dates were on 24 Oct. 1996 and on 23 Oct. 1997. Nitrogen fertilization was made with UAN-32 liquid fertilizer injected directly into the system by a differential pressure type injector.

Soil water content in the crop root zone was monitored with a TDR device which was calibrated against the gravimetric method. In 1997, soil moisture status was also monitor with digital tensiometers. The amount of water applied in each irrigation to avoid plant stress and to promote potential ET conditions inside and outside the lysimeters was based on a MAD = 35%. TDR readings were taken inside and outside the lysimeters before every irrigation. All attempts were made to avoid irrigating for a MAD > 35%, in which case deviation from potential conditions could have occurred. Soil total available water was 0.130 $cm^3\ cm^{-3}$. The lysimeters were always weighed before an irrigation but not always right after it. For those days when the lysimeters were not weighed after irrigation, the irrigation depth was estimated based on the lysimeter weight variation on the days when they were weighed after irrigation. The lettuce ET was obtained by solving the water balance in the lysimeters.

Basal crop coefficient over a given time interval Δt was calculated by dividing the crop ET (ETc) by the average reference ET (ETo) over Δt. Cumulative growing degree-days from plant emergence (CGDD) was used as normalizing factor to draw the crop coefficient curve. A multiple linear regression with up to six coefficients (equation 1) was performed to fit the data (Fox et al., 1992; Slack et al., 1996).

$$K_c = \sum_{i=1}^{6} C_i \sin[iY(t)] \qquad (1)$$

where C_i = regression coefficient. The regression analysis was performed with the constant value set to zero. The variable Y is obtained through equation 2.

$$Y(t) = \pi \frac{\sum_{i=1}^{t} (GDD)_i}{C_o} \qquad (1)$$

where C_0 determines the value of CGDD where the Kc returns to zero or some minimum value. In this work, C_0 = 1450°C-d (Slack et al., 1996). Once the C_i values were determined, Kc could be obtained for any time in the season (equation 1). GDD were calculated using the sine curve method. Following recommendations by Slack et al. (1996), the minimum threshold temperature (T_h) was set to 3.33°C and the upper limiting temperature (T_u) was set to 21.1°C. The value of CGDD used to make a given pair (CGDD, Kc) corresponded to the average value during Δt.

Lettuce crop coefficients were calculated based on three different ET_0 methods, i.e., the Hargreaves equation, the FAO 24 Penman equation, and the FAO Penman-Monteith equation with a hypothetical reference crop.

3. RESULTS AND DISCUSSION

The average soil water depletion at both 30 and 45 cm depths in the lysimeters was lower than the maximum allowed of 35% (Table 1).

In general, the soil water depletion outside the lysimeters were higher than inside. The depletion was also higher at 30 cm depth compared to the 45 cm depth in both inside and outside the lysimeters.

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Table 1 – Average and maximum soil water depletion inside and outside the lysimeters during the growing seasons

Relative position	1996 depletion (%)		1997 depletion (%)	
	0-30 cm	0-45 cm	0-30 cm	0-45 cm
Inside	29.5 (43.1)[a]	16.7 (31.5)	28.6 (35.4)	16.5 (23.1)
Outside	45.6 (60.0)	44.2 (56.2)	50.5 (62.3)	42.6 (52.3)

[a] number in parenthesis indicates the maximum observed soil water depletion (%)

Table 2 shows the average lettuce ET and other components of the water balance in the lysimeters. The differences in the drainage depth between the seasons were probably due to failure of the drainage systems in suctioning water, some ceramic cylinders had to be isolated due to vacuum leaking, and due to the rain depth, which was much higher in 1997 (121 mm) compared to 1996 (16 mm).

Table 2 – Average values of some of the components of the water balance in the lysimeters

Season	Lysimeter weighing period (°C-d)	I (mm)	Rain (mm)	D (mm)	ETc (mm)
1996	480 – 1100 (48– 23 DAE)	94	14	19	100
1997	439 – 1098 (46–133 DAE)	114	91	86	134

The numbers in Table 2 do not tell much in terms of seasonal water use (planting to harvest) because they correspond approximately to the second half of the crop cycle. They mainly show the water use in the most sensitive period of the crop, i.e., the head development and maturity. The lettuce plant makes approximately 70% of its total growth in the 3 weeks preceding maturity (Swiader et al., 1992). Therefore, the bulk of the water use by the crop should occur during that short period.

Data on Kc from both 1996 and 1997 were combined (N=27) giving the regression coefficients below. The coefficients used in the AZSCHED (AriZona irrigation SCHEDuling model) (Fox et al., 1992) to estimate lettuce K_c are also shown for comparison purposes. These coefficients were taken from Slack et al. (1996) who developed them from the lettuce consumptive use data as reported by Erie et al. (1965). AZSCHED used a Penman type equation to estimate ET_o.

The regression coefficients C_1, C_2, C_3, C_4, C_5, and C_6 found were:

Hargreaves: 0.616954, -0.368184, 0.008742, -0.063537, -0.069951, r^2 = 0.73

FAO Penman: 0.698154, -0.147565, 0.226208, 0.086888, 0.067600, 0.041552, r^2 = 0.65

FAO Penman-Monteith: 0.653031, -0.263022, 0.059591, -0.018222, -0.023868, r^2 = 0.60

AZSCHED: 0.677148, -0.368022, 0.202237, -0.118670, 0.030264.

4. CONCLUSIONS

a. The average lettuce water use was 117 mm, over the measurement period;

b. The highest predicted Kc peaked 0.88 with Hargreaves method, at 1050°C-d;

5. REFERENCES

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