Water use on maize field in Çukurova plain

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1. Introduction

The impact of climate change on crop productivity will be predicted by using SWAP model. Understanding present water use condition is essential to utilize swap model adequately. Maize field was selected to investigate in this study during two growth seasons in 2003 and 2004. The intensive field observation was conducted at maize field near Adana from 14 to 28 August 2003 and from 6 to 16 August 2004. The objectives of our study are as follows,

1) Check the present farm irrigation method and the efficiency

2) Evapotranspiration with the Bowen ratio method as a standard approach for long period is improved by introducing the energy balance flux ratio method.

3) Separation of evapotranspiration into transpiration and soil evaporation with the sap flow measurements. Direct transpiration rate is available for considering crop productivity and stress response analysis.

4) Obtain the crop and miclo-meteorological parameter for SWAP model to predict the future change of the water balance and crop productivity following climate change.

Practical furrow irrigation has been applied every 13-15days. During our observation period, one cycle irrigation period was obtained. Root depth and profile was surveyed for evaluating application efficiency and consumptive use efficiency. Observed results and analysis of water use on maize field were reported for our intensive observation period in August 2003 and temporal data are also reported for August 2004 in this manuscript

2. Field observation
2.1 Site in 2003

The observation was conducted at commercial field (Sorakuri, ÖZEKİCİ farm), located 40km south from Adana and 100 km from the Mediterranean Sea. The size of the field size was about 10 ha and surrounded by another huge maize fields. Ground water table near this field was about 1.0m and soil was clay loam soil.

Maize (*Pioneer G-98*) were grown on furrows and distances between plants are about 20cm. The furrow has 40 cm width and the distance between two furrows was 70-75cm. Crop heights were 3-3.5m. The sowing date was 19 June 2003 and harvest date was 8 November 2003. Irrigated water was applied by furrow surface irrigation on 10 and 23 August. During observation period, no rain was accounted.

2.2 Site in 2004

The observation was conducted at the research field for agricultural structures and irrigation department of Cukurova university in Adana. The soil of this site is classified as clay Mutlu soil series. Maize was grown almost same condition as we saw in 2003. Crop heights were changed from 1.6m to 2.7m within 12days. Irrigated water was applied by furrow surface irrigation on 11 and 12 August for 102mm.

2.3 Measurements
1) Transpiration

As an application for the estimation of transpiration in field conditions, the hourly variations of transpiration was estimated satisfactorily by using both methods at the same time without using predetermined calibration coefficient for the heat pulse method. (Takeuchi et al.1995) In this study, the heat pulse method and the stem balance method was applied on same stems.

Six sample plants (1.9-2.2cm in diameter, 309-347cm height) for monitoring sap flow were selected form 100 plants with measuring the diameter of each stem. Heat pulse probes were inserted at No.3 nods (23-31cm height) while the stem heat balance gauges were installed at No.4 nods (37-44cm height) for 2003 observation.

2) Evaporation

The microlysimeter technique allowed researchers make gravimetric measurements of daily

evaporation under a crop canopy without drastically modifying the field and soil environment. Three microlysimeters, 0.2m long and 0.105m in diameter were installed midway between the rows, 2 rows apart from the sap flow measuring plot.

3) Evapotranspiration

Evapotranspiration was measured by Bowen ratio method and the energy balance flux ratio method (the EBFR method). In the EBFR method, the latent heat flux (evapotranspiration rate; F kg s^{-1}m^{-2}) is calculated by complementing the flux ratio equation (1) and energy balance equation (2).

$$LF=LH_s(\rho_{w1}/\rho_1-\rho_{w2}/\rho_2)/C_p(T_{d1}-T_{d2}) \qquad (1)$$

where L(J/kg) is the latent heat of vaporization, H_s(W/m^2) the sensible heat flux measured by the eddy correlation method, ρ(kg/m^3) the dry air density, ρ_w(kg/m^3) the water vapor density, C_p(JK^{-1}kg^{-1}) the specific heat for constant pressure and ρ_w/ρ the mixing ratio and T_{d1} and T_{d2} temperatures at two heights z_1 and z_2, respectively.

$$LF=p \cdot Rn-q \cdot G-H \qquad (2)$$

where Rn (W/m^2) is net radiation, G(W/m^2) the soil heat flux, and p, q are coefficients related to in-balance in energy balance equation.

The sonic anemometer was applied to measure the sensible heat flux and its sampling time was 10Hz, and the averaging time was 30 minutes. The dry and wet bulb temperature was measured at three heights, 3.375m(z_1), 3.7m, and 4.14m(z_2).

4) Additional measurements

Soil moisture was measured by ADR soil moisture sensor and SENTEK soil profile sensor. Root profile was surveyed and determined by root analyzer.

3. Results

3.1 Observations 2003

An example of obtained data is shown in Fig.1. It was clear sky day on 16 August, air temperature on the canopy showed constant value from 11:00 to 17:00. In the afternoon, prevailing wind blew from the south seacoast constantly.

Sap flow rate measured by the stem heat balance method were shown higher than 100g h^{-1} at mid-noon, so combined approach with the heat pulse and the heat balance methods was applied to compute accurate sap flow rate. Daily sap flow rate was 741, 679, 784, 903, 770, 919g d^{-1} among 6 plants, while average value was 800g d^{-1}. These values are

corresponding to 85 to 115% of average value.

In Fig.2, sap flow rate on cloudy day (26 August) is shown. On this day, daily sap flow rate was 661, 631, 752, 969, 673, 849 g d^{-1} among 6 plants, while average value was 755 g d^{-1}. These values are corresponding to 83 to 128% of average value. On cloudy day, sap flow rate was fluctuated among plants clearly. Transpiration rate was computed by normalizing the sap flow data on a population basis, 5.33 and 5.04 mm d^{-1} for 16 and 26 August respectively.

Soil evaporation rate was reduced from 1.3 to 1.0 mm d^{-1} during first 3 days after irrigation, and then indicated 0.9 to 1.0 mm d^{-1} constantly. The ratio between transpiration and evaporation was changed from 16.6% to 23%.

In Fig.3, evapotranspiration rate (ET) estimated by Bowen ratio method and EBFR method was compared with transpiration rate for two days as examples. In EBFR method, the flux is calculated in case that wind direction is agreed with allowable measuring direction for sonic anemometer in this system. On 19 August, similar curves were obtained between the Bowen ratio method and the EBFR method. On the contrary, the Bowen ratio method indicated greater that the EBFR method on 25 August. In this day, the sensible heat was estimated negative value in Bowen ratio method, while EBFR method with eddy correlation showed positive value. This discrepancy may come from the small difference between two wet and dry bulb temperature sensors. So, water use on maize field was analyzed below with transpiration by sap flow measurement and soil water evaporation by miclolysimeter in this study. In Fig.3, transpiration rate (sap flow:T) was also compared with EBFR method. Evaporation (E) was not considered in these figures, so E+T is greater than ET. This subject was investigated in 2004 whether vertical one dimension measurement is enough to capture all ET components.

The time lags between ET and T were also found on several days as shown in Fig.3. In fig.4, the verification experiments for this time lag were conducted in August 2004. An enclosure with black screen (1.1×1.55×2.0m) was applied to make shadow effect for potted maize plants. This is the consideration of inside of maize canopy. Sap flow was measured with the stem heat balance method and transpiration was measured by mass loss method. A significant time lag between two curves was not obtained. So it is concluded that the time lag shown in Fig.3 was not related to water flow inside of plants as we saw on tree species. This will be come from

complicated structure with tall maize canopies.

54 % of plant root was concentrated from 10 to 20 cm from soil surface within 40cm furrow. Between furrow, root was not find significantly. The changes of soil moisture content near plant stem indicated significant stepped reduction in daytime within 20 cm soil layers from surface. It is also clarified that irrigated water penetrated immediately with passing cracks formed before irrigations.

3.2 Water use on maize field

The relationship between transpiration and reference evapotranpiration (ET_0) is indicated in Fig.5. Moderate water stress was shown within six days after the previous irrigation. After the irrigation on 23 August, transpiration was recovered and indicated liner relationship between T and ET_0. Before and after irrigation, the value of T/ET_0 was 0.906 and 0.978, respectively. The Kcb_{mid} for sweet corn is 1.10 and for field corn is 1.15. Our value was smaller than kcb_{mid} although our plants were larger than normal plants.

Total water use amount between irrigation intervals was estimated 13.6 liter/plant, which is corresponded with 91mm/irrigation. On the contrary, irrigation water was applied with the depth of 100-200mm by soil sampling data. This is possible to conclude that maize were not suffered water stress condition and water saving will be achieved on farm basis and irrigation system bases.

3.3 Temporal results of observation in 2004

Fig.6 indicates the time course of transpiration rate measured by sap flow on maize stem is shown with the net radiation during the observation in 2004. Irrigation was conducted at 11:00 am on 12 August for observed area by furrow irrigation. Transpiration rate was dramatically increasing after irrigation while the change of net radiation was not so high. The growth rate of plants in this period was higher than 10cm and increased after the irrigation significantly. The ET value was also indicated higher value after irrigation. The tendency of ET value during 2004 observation period was also higher than that in 2003. This may come from the structure of maize canopy that can absorb more energy and climatic condition.

4. Conclusions

Field observation was conducted during vigorous growing season. It is difficult to regulate irrigation amount in this irrigation system. Maize was not
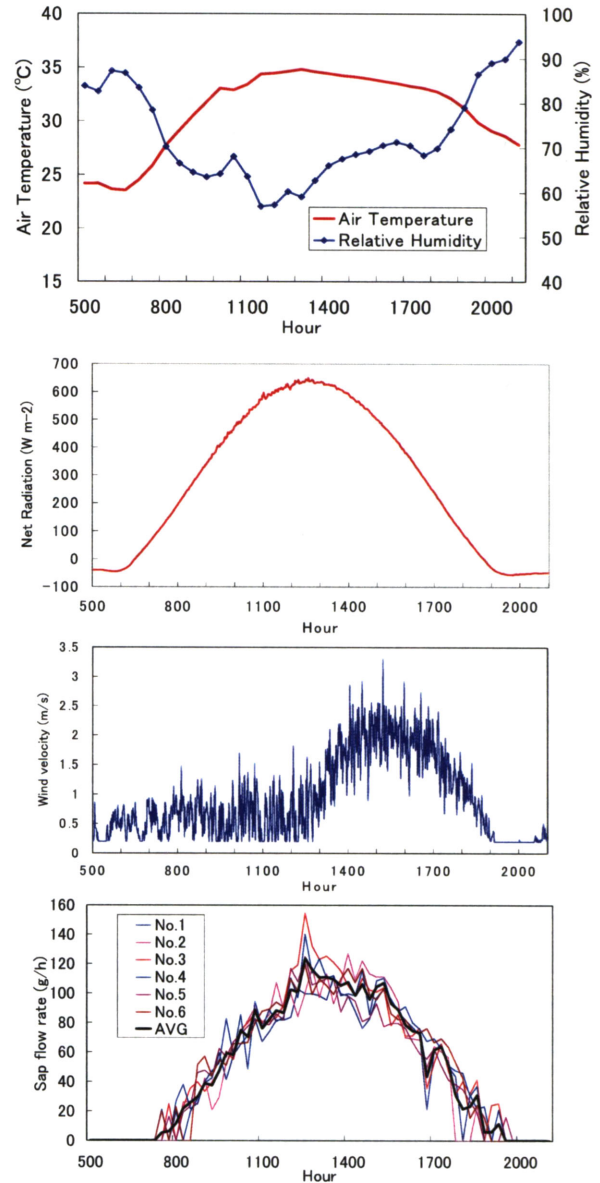

Fig.1 Diurnal course of sap flow rate on 16 August with air temperature, relative humidity, net radiation and wind speed data. (Clear day)
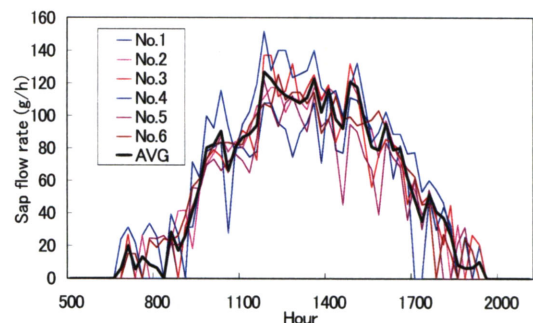

Fig.2 Diurnal course of sap flow rate on 26 August (Cloudy -day)

suffered severe water stress before next irrigations. Roots of maize were concentrated in surface layers

and apparent root water uptake was observed in these layers.

It can be said that water saving is possible on farm bases with considering irrigation system

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Odani, H., T.Yano, and R.Kaneki 2001 : Estimation of the water vapor flux with the energy balance flux ratio method, Trans.JSIDRE No.213 1-10(in Japanese)
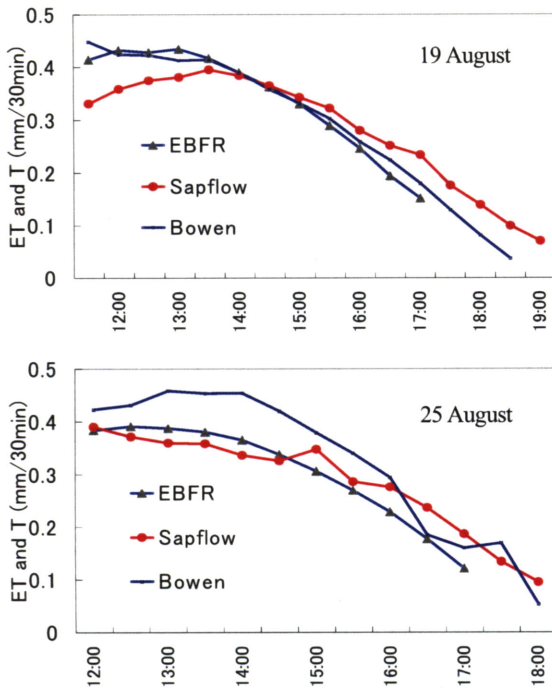
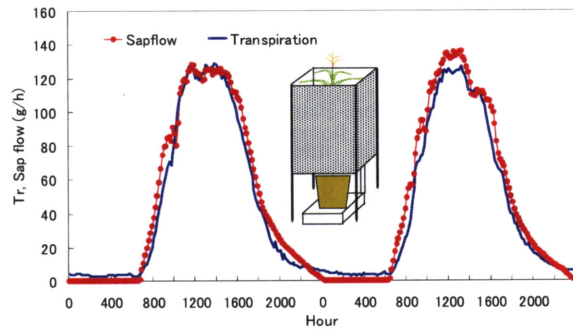**Fig.3** Diurnal course of evapotranspiration :ET and sap flow rate :T on 19 and 25August

Fig.4 Verification experiment for the time lag between transpiration and sap flow with potted maize (Pioneer 31 G-98)
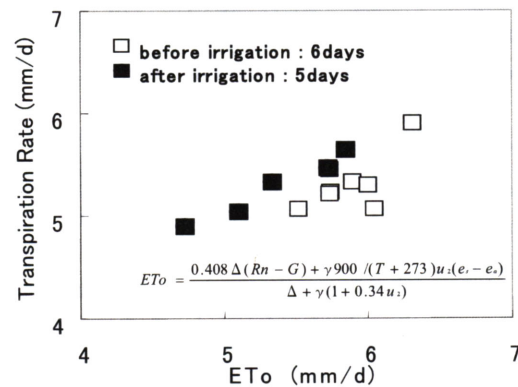

$$ETo = \frac{0.408 \Delta (Rn - G) + \gamma 900 /(T + 273) u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

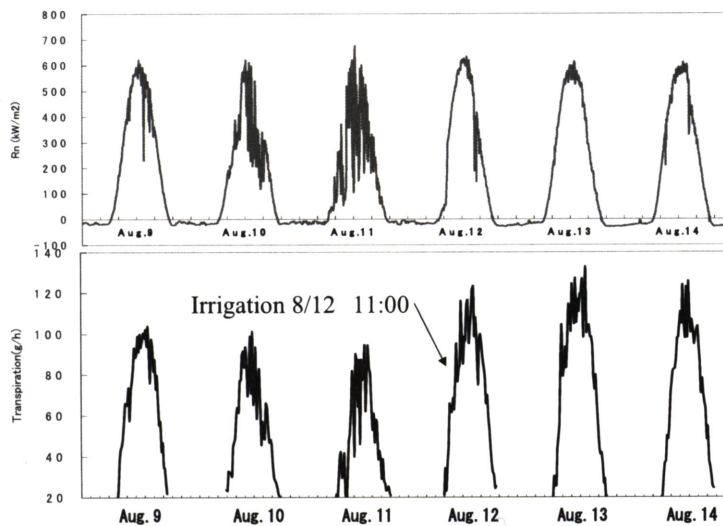**Fig.5** Relationship between T and ETo

Fig.6 Time course of transpiration rate before and after irrigation with net radiation in August 2004.