EFFECT OF CLIMATE CHANGE FOR EVAPOTRANSPIRATION AND CROP GROWTH UNDER THE CUKUROVA CONDITIONS, TURKEY

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1. Introduction

There is a recent consensus among scientists that earth's energy balance will be altered and global temperatures will increase due to greenhouse emissions. It is expected that precipitation will decrease and plant water use will increase due to this change. Naturally, Cukurova Region, which is one of the most important agricultural regions of Turkey will most likely be affected by these changes. Some of the Mediterranean Region's basins such as Seyhan basin which has a semi-arid character may have a arid character in the plain region, and upper basins which currently have sub-humid character could have semi-arid character. This possibility can cause important changes in the soil and water resources management and agricultural production. Soil-water-climate and plant simulation models can estimate the impact of climate changes. One of these simulation models is SWAP model for determining impact of climate changes on agricultural production and yields. The theory of the processes simulated by SWAP 2.0 is extensively described by Van Dam et al. (1997). The transport process at filed scale level and during whole growing season is considered.

Crop growth can be simulated by the code WOFOST 6.0 (Hijmans et al., 1994). The cropping pattern may consist of maximal three crops per agricultural year. The model calculates the radiation energy absorbed by canopy as function of incoming radiation and crop leaf area. If simulation of crop growth is not needed, the user might just prescribe leaf area index, crop height, rooting depth, and root density distribution as a function of development stage (Kroes et al., 1999).

Evapotranspiration covers both transpiration of the plants and evaporation of the soil. Potential and even actual evapotranspiration estimates are possible with the Penman-Monteith equation, through the introduction of canopy and air resistances to water vapor diffusion. This direct, or one-step, approach is increasingly being followed nowadays, especially in research environments. Nevertheless, since accepted canopy and air resistances may not yet be available for many crops, a two-step approach is still recommended under field conditions. The first step is the calculation of the potential evapotranspiration, using the minimum value of the canopy resistance and the actual air resistance. In the second step the actual evapotranspiration is calculated using the root water uptake reduction due to water and/or salinity stress. This two-step approach is adopted in SWAP (Van Dam et al., 1997).

The objective of this study is to determine effect of soil properties, water regime (precipitation and plant water use) and climate parameters on the plant growth and yield with open field experiments that will be carried out in Seyhan Plain in existing and global (or local) conditions and to measure some plant parameters used for SWAP (Soil-Water-Atmosphere-Plant) Model.

2. Materials and Methods

2.1. Research Area

The experiments were conducted in the farm belonged to University of Cukurova Agricultural Structure and Irrigation Department and at a field of 20 ha size in Seyhan Plain placed in South and 30 km far from Adana.

2.2. Plant Variety

In the project, wheat and maize were sown at different time for clarification of the temperature effect on the plant growth and water use. First and second crop maize and wheat which has important planting area in the region were studied. Maize *(Zea Mays L.)* hybrid "Pioneer 31G98" and Adana-99 wheat were used in the project.

2.3. Soil Characteristics of Study Area

The Seyhan Plain experimental field soil chemical and physical properties were reflected in the following Table 1.

Table 1. Chemical and Physical Properties of the Seyhan Plain Experimental Field Soils

Soil Depth, cm	pH	Total salinity, %	CEC meq/100 gr	Exchangeble cation meq/100 gr.			Lime, %	Organic matter	Texture, %		
				Na	K	Ca+Mg			Sand	Loam	Clay
0-10	7.1	0.090	23.9	0.7	1.9	21.3	17.2	1.44	17	49	34
10-27	7.2	0.060	25.5	0.3	1.4	23.8	15.2	0.72	13	45	42
27-49	7.4	0.050	24.1	0.5	0.6	23	23.5	0.58	22	46	32
49-67	7.7	0.057	24.2	0.6	0.3	23.3	27.2	0.46	5	52	43
67-79	7.3	0.054	23.1	1.4	0.3	20.4	28.6	0.33	7	55	38
79-93	7.6	0.058	21.7	1.7	0.3	19.7	30.6	0.13	13	54	33
93-110	8	0.053	18.7	1.9	0.2	16.6	21.3	0.33	22	50	28
110-124	7.8	0.060	23	1.8	0.2	21.0	29.5	0.57	19	51	30
124-140	7.8	0.038	12.3	1.1	0.2	11.1	22.2	0.26	57	18	25

Çukurova University, Agricultural Structures and Irrigation department experimental field soil chemical and physical properties were reflected in the following Table 2.

Table 2. Chemical and Physical Properties of the Irrigation Department Experimental Field Soils

Depth cm	FC g/g	PWP g/g	A_S g/cm^3	P^H	EC_W dS/m	$CaCO_3$ (%)	Specific Weight	Texture
0-30	38.43	24.66	1.34	7.05	0.25	6.63	2.47	C
30-60	38.41	24.46	1.37	7.20	0.18	8.05	2.55	C
60-90	37.31	24.31	1.39	7.05	0.19	8.29	2.60	C
90-120	39.78	25.91	1.36	7.15	0.16	10.66	2.44	C

2.4. Experimental Treatments and Irrigation

Wheat crop experiments were carried out in 2003-2004 and 2004-2005 growing seasons at the experimental field of University of Cukurova, Agricultural Structure and Irrigation Department. The treatments were normal sowing: rainfed (NS-RF) and irrigated (NS-IR) and late sowing: rainfed (LS-RF) and irrigated (LS-IR). Irrigated treatments of wheat were irrigated with drip irrigation system.

Maize crop experiments were carried out in 2003-2004 growing seasons as first and second crops/late sown at a field of 20 ha size in the Seyhan Plain placed in South and 30 km far from Adana and in the year of 2004 growing seasons, maize experiment was carried out as second crop at the experimental field of University of Cukurova, Agricultural Structure and Irrigation Department. Maize experiments were irrigated with furrow irrigation methods.

2.5. Measurement of Actual Evapotranspiration

Actual evapotranspiration of wheat and maize crops were determined using water balance and Bowen Ratio Energy Balance (BREB) Methods given below:

(i) Water Balance Method

$$ET_{WB} = I + P + D \pm R \pm \Delta S \quad (1)$$

ET_{WB}: Actual Evapotranspiration, (mm);
I: Irrigation, (mm);
P: Precipitation, (mm);
D: Drainage, (mm);
R: Runoff, (mm).
ΔS: The Change in Plant Root Zone Water Storage, mm

(ii) Bowen Ratio Energy Balance (BREB) Method

Energy balance equation is given as below.

$$R_n = G + H + L_e \quad (2)$$

R_n: Net Radiation ($W.m^{-2}$)
G: Soil Heat Flux ($W.m^{-2}$)
H: Sensible Heat Flux ($W.m^{-2}$)
L_e: Latent Heat Flux ($W.m^{-2}$)

Also L_e can be written as follows:

$$L_e = \frac{R_n - G}{1 + \beta} \quad (3)$$

Bowen ratio was calculated by (Bowen 1926) using equation as given below:

$$\beta = \gamma \frac{\Delta T}{\Delta e} \quad (4)$$

ΔT: Temparature Differences (^oC)
Δe: Vapor Pressure Differences (kPa)
γ: Psychometry Constant

G, R_n, Δe and ΔT was measured by means of Bowen system and determined crop evapotranspiration of wheat and maize using equation 3.

2.6. Plant Monitoring and Measurements

Leaf Area Index (LAI): Crop samples were taken as four repetitions from one meter length plant row in both treatments. LAI values were calculated from rating of measured leaf area to area taken plant sample.

Biomass: Plant samples designated leaf area index was used due to determine changing of biomass by time in both treatments. Biomass for per unit area was designated from rating of dry weight of plant samples to represented area of samples.

Plant Height: As chance 10 plants were chosen and measured their heights in both treatments.

Harvest Index (HI): Harvest index defined as rate of weight of grain obtained for per unit area to total dry weight as described by Hsiao, (1993).

2.7. Planting and Harvest

Maize was planted in both experiments with row spacing of 70 cm and 15 cm distance on the rows. First crop maize was sowed 06 April 2003 and harvested 10 September 2003. Second crop maize was sowed 19 June 2003 and harvested 08 November 2003 at the Lower Seyhan Plain. Wheat experiment carried out in the year of 2003-2004 at Cukurova University, Agricultural Structure and Irrigation Department was sowed 17 November 2003 and harvested at 01 June 2004 for Rainfed treatment, at 08 June 2004 for Irrigated treatment. The same experimental field was used for second crop maize in 2004. It was sowed at 28 June 2004 and harvested at 25 October 2004. Last experiment was carried out in the year of 2004-2005 for wheat crop. It was sowed as normal sowing (NS) at 17 December 2004, havested at 26 May 2005 for both rainfed and irrigated treatments and late sowing (LS) was sowed at 20 March 2005 for both rainfed and irrigated treatments, harvested at 17 June 2005 for rainfed treatment and 27 June 2005 for irrigated treatment.

3. Results and Discussions

3.1. The Results of Wheat

3.1. 1.Growth Periods

Different growth periods of wheat were observed in the treatments of Agricultural Faculty experimental area. Sowing, different growth periods and harvest dates of wheat are given Table 3. As it seemed in Table 3 irrigation applications caused become different dates of physiological maturity and harvest time between irrigated and non-irrigated treatment of wheat.

Table 3. Growth Periods of Wheat for the Year of 2003-2004

Growth Periods	Rainfed Treatment Date	Irrigated Treatment Date
Sowing	17.11.2003	17.11.2003
Emergency	30.11.2003	30.11.2003
Tillering	27.12.2003	27.12.2003
Erect growth	29.01.2004	29.01.2004
Flowering	09.04.2004	09.04.2004
Physiological Maturity	11.05.2004	17.05.2004
Harvest	01.06.2004	08.06.2004

3.1.2. Plant Height

The changing of wheat height by time is given in Figure 1 for rainfed and irrigated treatment. As seen Figure 1, the plant height of wheat in 2003-2004 growing season was slightly affected by the irrigation at/around flowering stages (DAS 140). Plant heights were reached up to 89.5 cm in rainfed treatment and up to 96 cm in irrigated treatment.

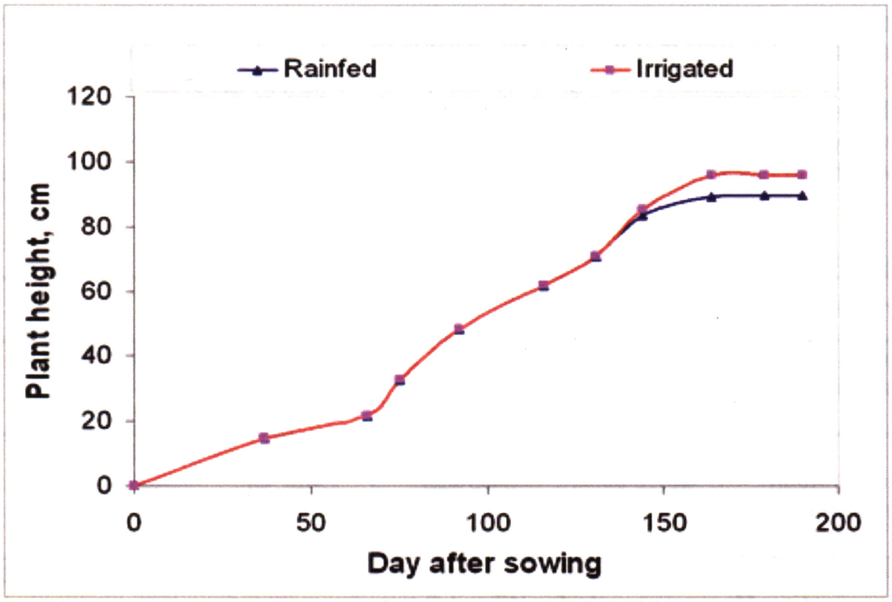

Figure 1. Wheat crop height days after sowing in 2003-2004

Similar results were observed for crop heights in the year of 2004-2005 growing season for different wheat treatments as given in Figure 2.

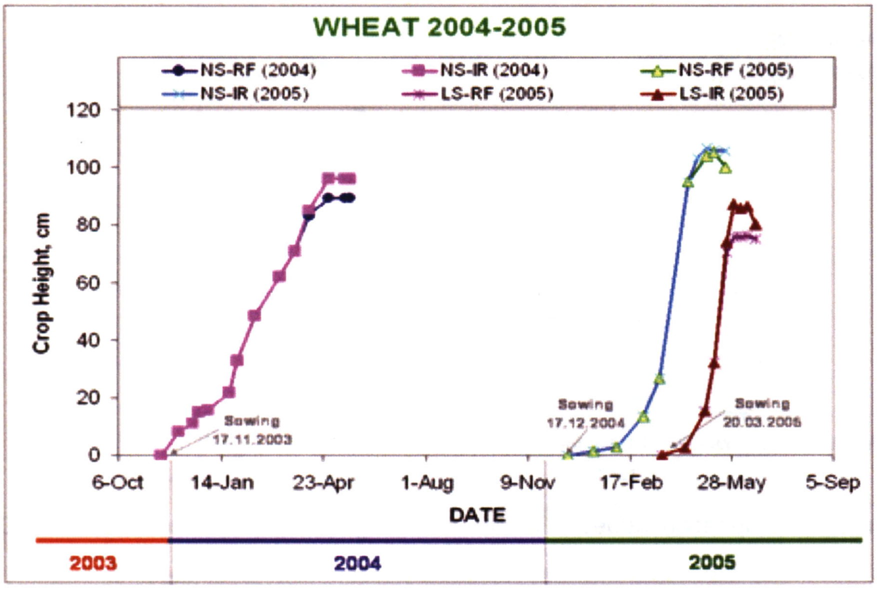

Figure 2. Wheat crop height vs. day after sowing in 2004-2005

3.1.3. Water Use for Wheat Crop

The values of irrigation events, irrigation water amount, rainfall and evapotranspiration are given in Table 4.

Irrigation practices resulted in an increase in the significant water use (Table 4), however, looking at the Table 5 it can be seen that the irrigation applications did not result in better yield. The yield values for irrigated wheat was 5510 kg/ha as compared to 6610 kg/ha in rainfed-irrigated wheat. This might be resulted from the rain distribution in that growing season. The other possible explanation for lower yield in irrigated wheat could be that irrigation might have stimulated the vegetative growth which the higher plant height could be a result of this, and grain production could have pushed back.

Table 4. Wheat Irrigation Events, Iirrigation Water Amount, Rainfall and ET

Years	Irrigation Events	Irrigation Water Amount, mm	Rainfall, mm	ET, mm
2003-2004	2 Germination	43	637	708 (WB-IR)
	5 Irrigation Season	411		494 (WB-RF
		Total **454**		477 (BREB-RF)
2004-2005	3	148 NS	315	554: NS
	2 Germination	63 LS	145	340: LS
	5 Irrigation Season	318 LS		459: LS
		Total 381 LS		

3.1.4. Evapotranspiration Measurements for Wheat Crop

Seasonal evapotranspiration values of irrigated and rainfed wheat treatments calculated by water balance method at the Cukurova Universisty, Agricultural Structures and Irrigation department experimental area in the 2003-2004 growing year are given in Figure 3.

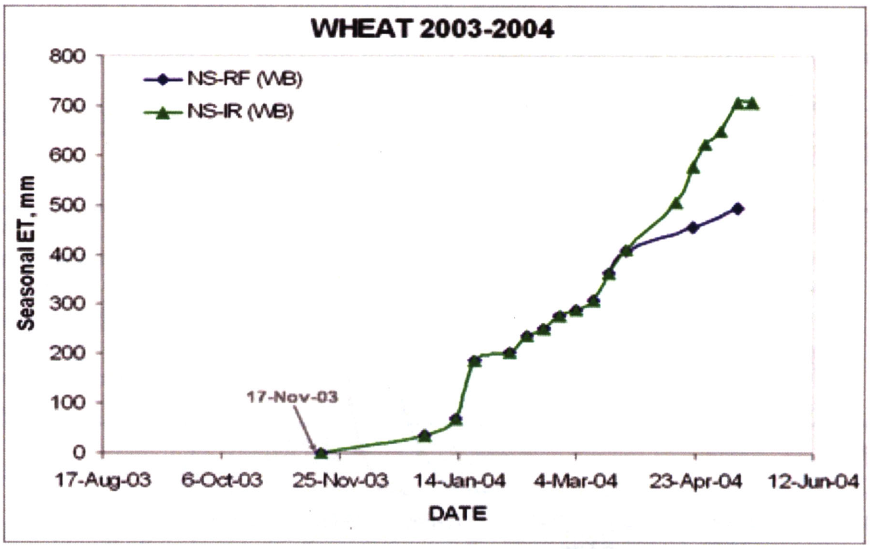

Figure 3. Seasonal evapotranspiration values of wheat according to water balance method in 2003-2004

As seen in Figure 4, seasonal evapotranspiration value of rainfed wheat treatment was measured 477 mm. A strong relationship with a R^2 value of 0.94 was observed when Figure 3 and 4 were combined ($ET_{BREB} = 13.75e^{0.0065ET_{WB}}$ R^2=0.94).

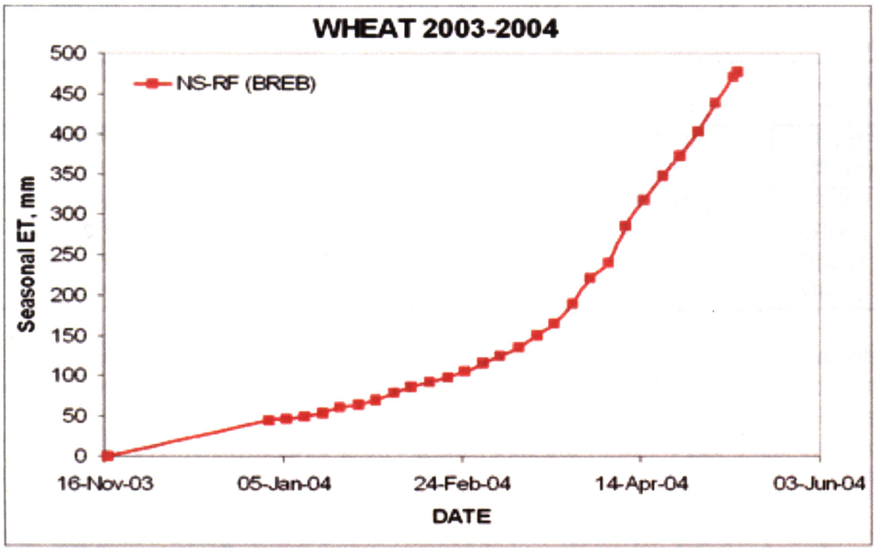

Figure 4. Wheat seasonal evapotranspiration values measured by using BREB Method

3.1.5. Dry matter, Yield, Water Use Efficiencies, Harvest Index for wheat crop

As shown in Figure 5, in the year of 2003-2004 growing season, biomass values of non-irrigated and irrigated treatments of wheat corresponding values were determined as 1779 kg/da and 1645 kg/da, respectively. In the year of 2004-2005 growing season biomass values of different experimental treatments of wheat values are given in Figure 5.

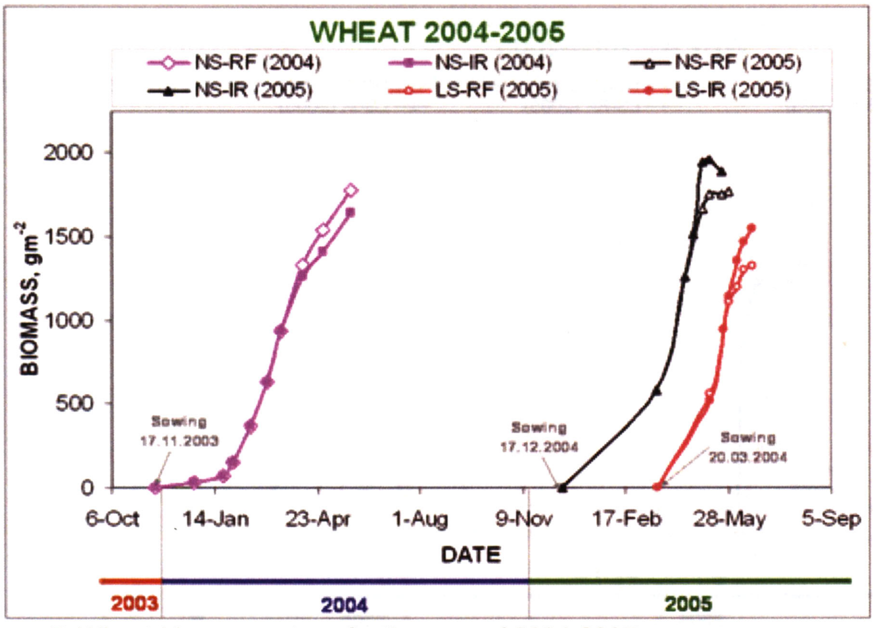

Figure 5. Wheat biomass values for the year of 2004-2005

Biomass water use efficiency WUE_b, wheat yield water use efficiency WUEy, yield, biomass and harvest index values of wheat are given in Table 5.

Table 5.Wheat Biomass Water Use Efficiency, Wheat Yield Water Use Efficiency, Yield, Biomass, Harvest Index

Years	WUE$_b$ kg/ha/m^3	WUE$_y$ kg/ha/m^3	Yield kg/ha	Biomass kg/ha	HI %
2003-2004	3.50-RF 2.69-IR	1.39-RF 0.78-IR	6610-RF 5510-IR	17790-RF 16450-IR	37-RF 33-IR
2004-2005	3.2 NS-RF 3.9 LS-RF 3.2 NS-IR 3.4 LS-IR	1.12 NS-RF 1.09 LS-RF 1.02 LS-IR 1.07 LS-IR	6230 NS-RF 3690 LS-RF 5990 NS-IR 4900 LS- IR	17720 NS-RF 13270 LS-RF 18910 NS-IR 15510 LS- IR	35 NS-RF 28 LS-RF 29 NS-IR 26 LS- IR

It seems that water applications resulted in the reduced water use efficiencies of both yield and biomass. As explained before the irrigation application did not result in the relative yield increase, therefore, the WUEs yielded lower in irrigated wheat.

Similar results for yield were observed in the 2004-05 growing season when NS-RF and NS-IR treatments were compared in Table 5. The biomass yield was higher in the irrigated treatment than that in the rainfed treatment. In the late planting, however, it was clear that irrigation applied treatments yielded in higher yield and biomass. The reduction in WUE in irrigated treatment was not as pronounced as that in the 2003-2004 growing season.

3.1.6. Leaf Area Index for Wheat Crop

Changing of leaf area index by time in wheat is given in Figure 6 for the year of 2003-2004. It was obtained maximum LAI value in wheat after 106 days from sowing and found as 7.82. LAI value was reached zero after 179 and 190 days in rainfed and irrigated treatments, respectively. Changing of leaf area index by time in wheat for both experimental period are given in Figure 6.

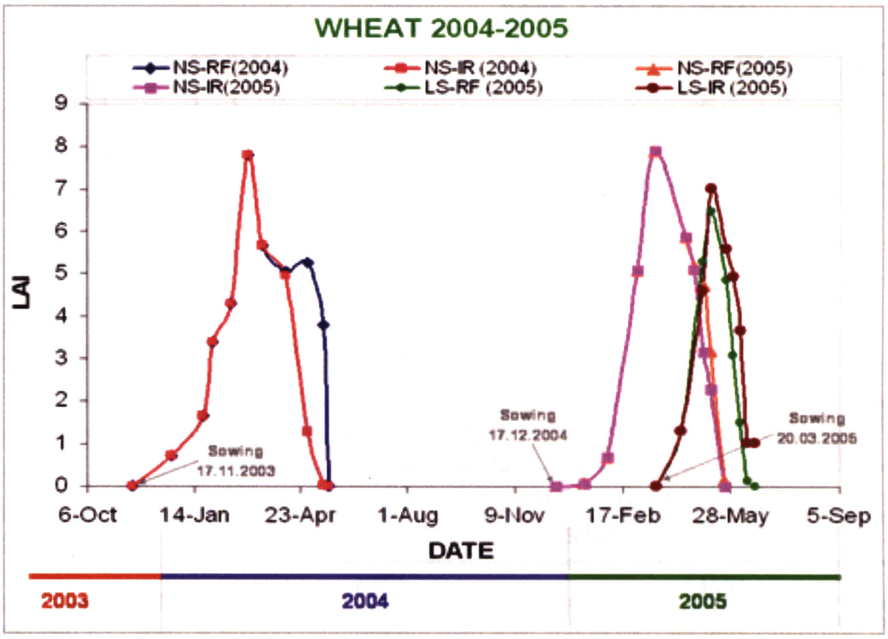

Figure 6. Leaf area index by time in wheat for both experimental period

3.2. The Results of Maize

3.2. 1. Plant height and growing periods

In the maize study similar crop height developments were observed for first crop and second crop corn in 2003 and for second crop corn in 2004 (Figure 7 and 8). As seen in Figures, crop height in 2004 drastically increased from day after planting 20 to silking stage (DAP 55) and pretty much leveled afterwords.

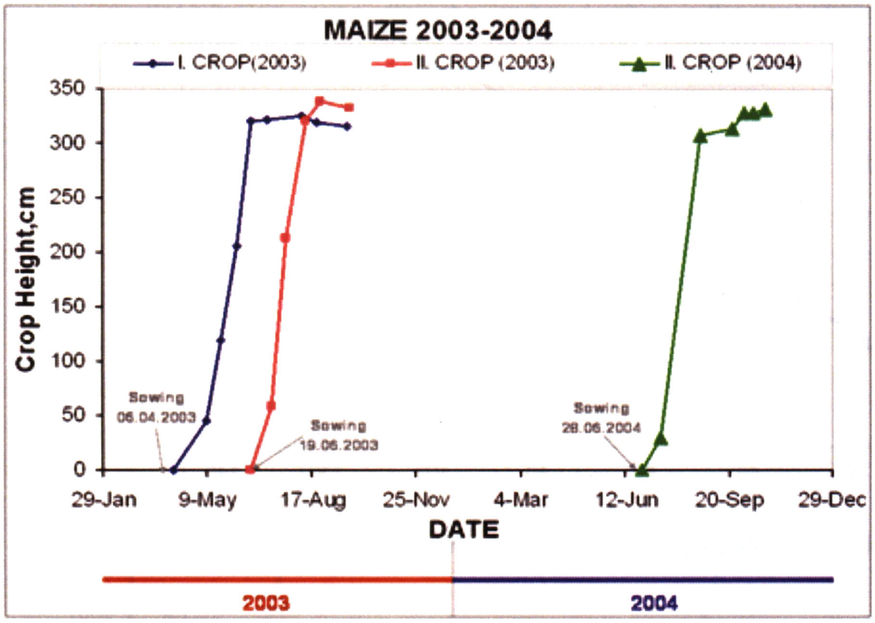

Figure 7. First and second maize height for the year of 2003-2004

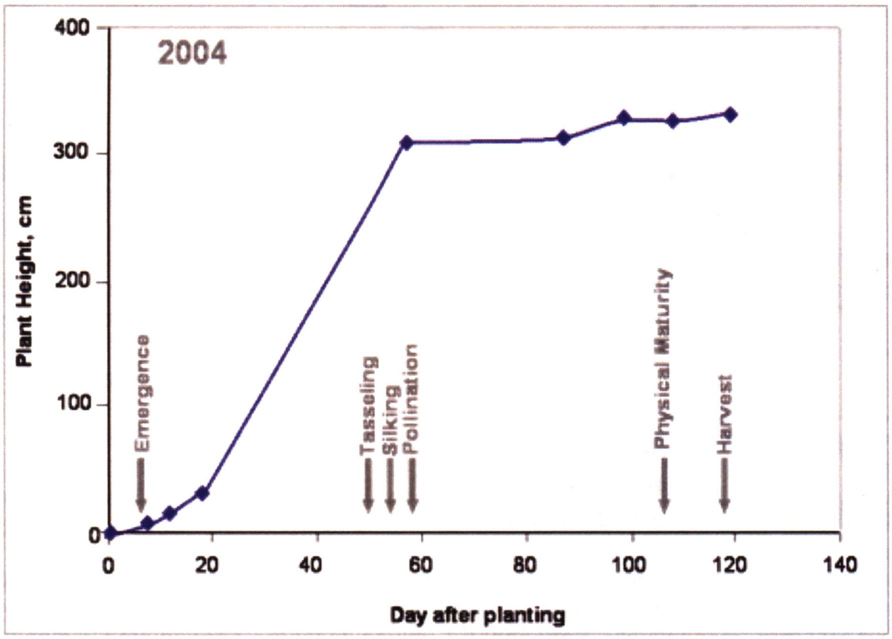

Figure 8. Second crop maize height and growing periods for the year of 2004

3.2.2. Evapotranspiration Measurements for Maize Crop

Seasonal evapotranspiration values of maize measured by using water balance and Bowen ratio energy balance methods in agricultural structures and irrigation department experimental area, are given in Figure 9 and Figure 10, respectively.

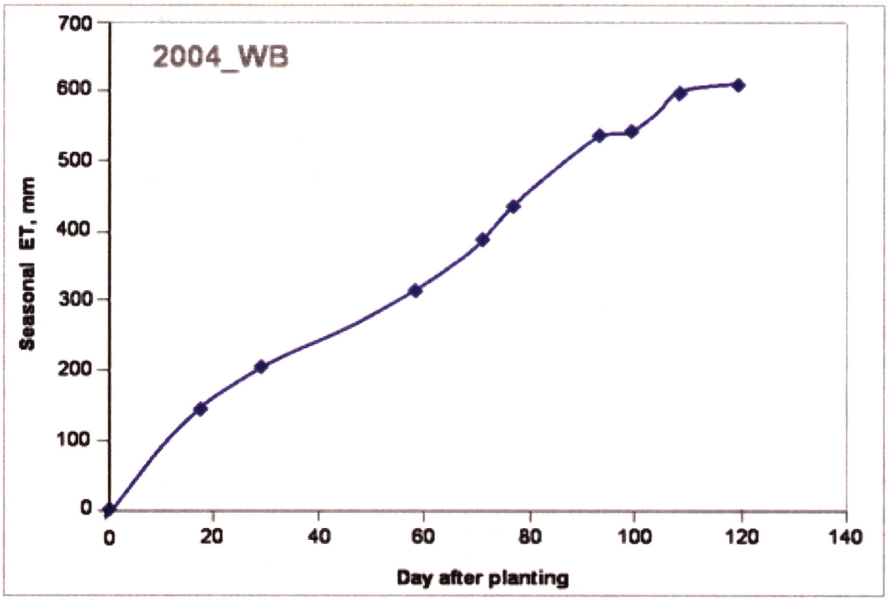

Figure 9. Seasonal ET calculated by water balance method for second crop maize

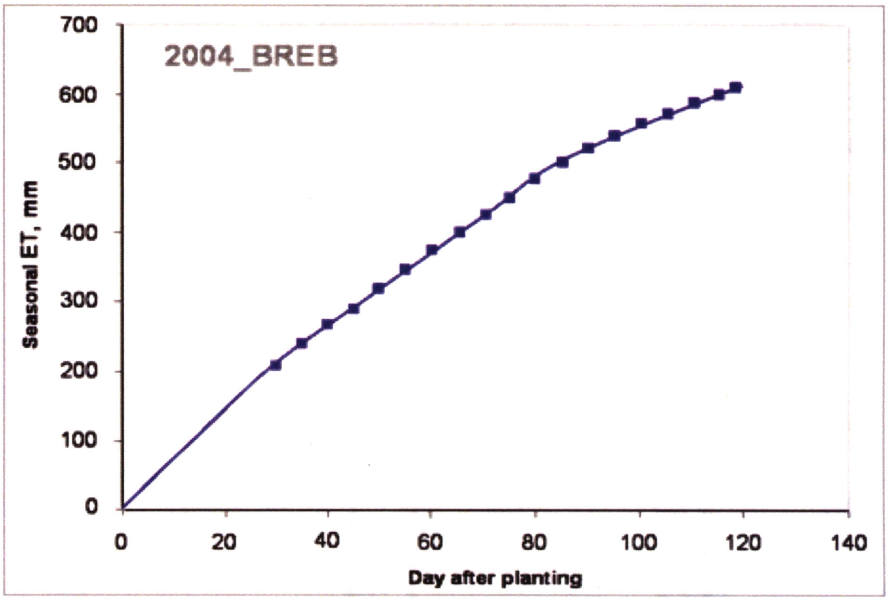

Figure 10. Seasonal ET calculated by BREB method for second crop maize

As seen in Figure 9 and 10, in the year of 2004, seasonal evapotranspiration values of second crop maize calculated by Water Balance and Bowen Ratio Energy Balance methods were measured as 608 and 602 mm, respectively. Seasonal ET values of for the second crop maize from water balance and BREB methods were very closed. This indicates that BREB results could be safely used for evapotranspiration measurement.

3.2.3. Dry matter for maize crop

The soil surface biomass was calculated using dry mass of definite numbers of crops cut from the soil surface. The dry matter values of crop material were determined after 48 hours drying at 70ºC in the oven. According to the Seyhan plain study results, in the first crop maize soil surface biomass production was increased within the expected values in the year of 2003 as given in Figure 11. The biomass values increased slowly at the beginning of the growing period until 47 days later of planting and than faster increasing occurred until 105 days later of planting. The increasing of the biomass continued until the end of the last period of the growing in the year of 2003. In the second crop maize biomass increased rapidly as similar as crop height and leaf area changes. Biomass occurred between the days 21 and 96 and than an important increase could not be seen.

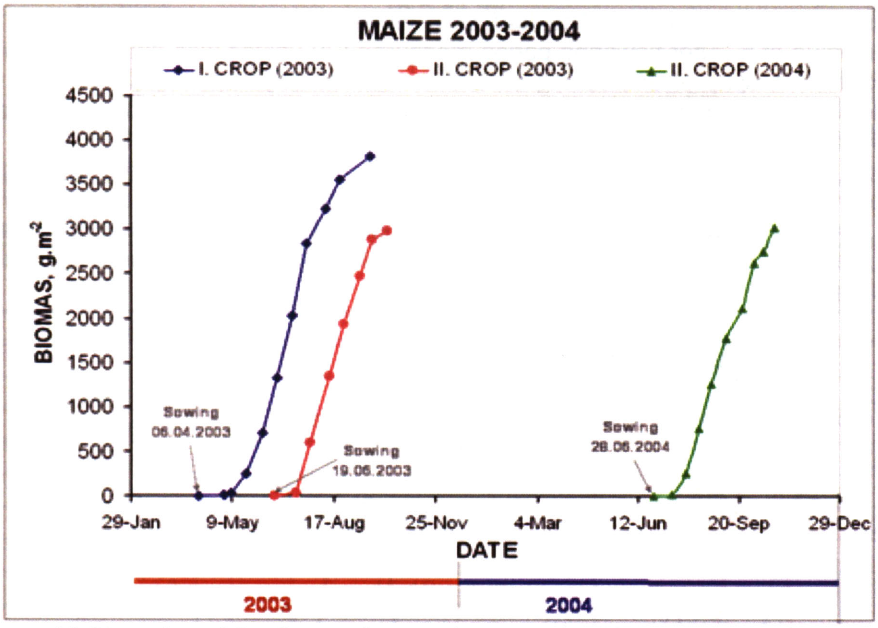

Figure 11.Changing of the first and second crop maize biomass during the growing period of the 2003 and 2004

Biomass results indicated that first crop corn increased the biomass values significantly from 3000g/m^2 to 3800 g/m^2. This could be resulted from the higher temperatures that second crop maize is exposed.

3.2.4. Yield and Yield Components for maize crop

At the end of the first crop maize growing season, total soil surface crop production was 3817 g for each square meter, and grain yield was calculated 1865 g as given in Table 6. Harvest Index value was calculated as 48.8% and each grain mass of taken 5757 grains was weighted as 326 mg in the year of 2003.

In the second crop maize biological yield and grain yield comparing with the first crop maize were taken 22% (2982 g m-2) and 14% (1612 g m-2), respectively. Because of decrease in biological yield was higher than decrease in grain yield, Harvest Index was calculated higher as 11%. In the second crop maize, the decrease in grain yield was because of the decrease in grain weight.

Table 6. Biological Yield, Grain Yield and Yield Components of First and Second Crop Maize

	Biological Yield ($g\ m^{-2}$)	Grain Yield ($g\ m^{-2}$)	Harvest Index(%)	Grain Weight (mg)	Grain Number m^{-2}
First Crop	3817 (±231)	1865 (±120)	48.8 (±0.45)	326 (±10.8)	5757 (±480)
Second Crop	2982 (± 94)	1612 (±21)	54.0 (±0.49)	276 (±6.2)	5862 (±289)
Change	-%22	-%14	+%11	-%15	+%2

3.2.5. Leaf Area Index for maize crop

Leaf area index values followed the similar trend in both years and for both first and second crop maize. In the Seyhan plain study, the leaf area index of the first crop maize increased slowly at the beginning of the growing period and then reached as a value of 1 (LAI=1) after 5 weeks from the planting in the year of 2003 (Figure 12). The leaf area index reached maximum value at the flowering period as a value of 6. After flowering period measured LAI values was approximately the same as before and then in spite of decreasing on LAI in the 105 days later after planting, with passing the physiological maturation period of grain (124 days of the day after planting) plants activations were still effective.

In the second crop maize experiment at the Seyhan plain study, the measured leaf area index was higher than the first one and reached the highest value until the flowering period (22 days of day after planting, LAI=1) in the year of 2003 as shown in Figure 12. The LAI value approximately 6.7 which is higher than first crop maize and than after physiological maturation the plant activity functions decreased rapidly.

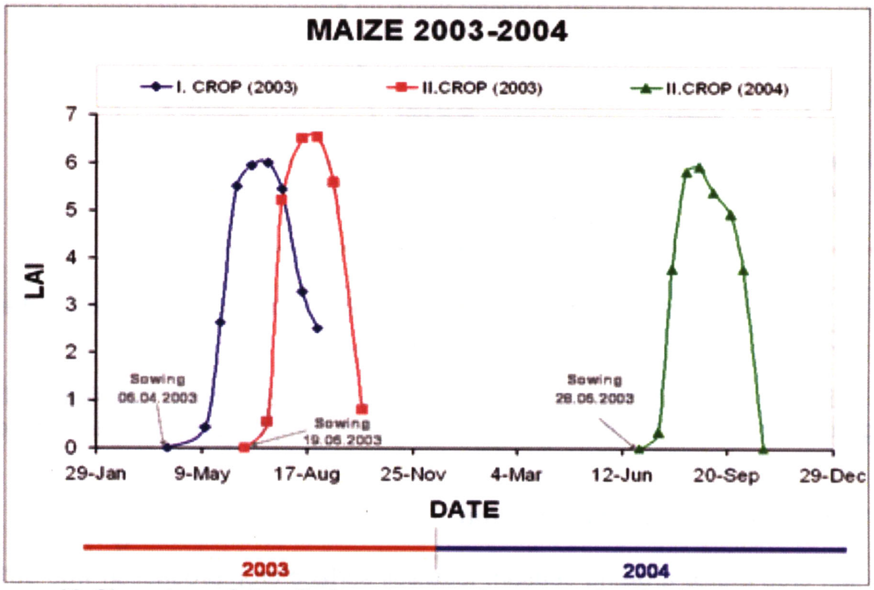

Figure 12.Changing of the first and second crop maize leaf area index the during the growing period of 2003 and 2004

In the Cukurova University, Agricultural Structures and Irrigation department experimental area study, changing of leaf area index by time for maize crop in the year of 2004 also given in Figure 12. It was obtained maximum LAI value for second crop maize after 57 days from sowing in pollination period and found as 5.92.

3.3. The Results of SWAP Simulation Model for Wheat and Maize Crops

In the study, the results of the SWAP simulation model for the wheat and maize crops are given in the Table 7 and 8, respectively.

Table 7. Water Balance Components for Wheat

	1994-2003 (Observed)		2070-2079 (Created)
Precipitation mm	531.1±184.7	-4.0%	510.6±209.5
Evapotranspiration, mm	373.9± 30.6	-10.9%	333.0±24.2
Irrigation, mm	74.8 ± 72.8	-9.9%	67.4±1.37
Biomass, ton/ha	16.5 ±1.39	-13.1%	14.33 ± 1.37
Yield, ton/ha	5.11 ±0.73	-5.5%	4.83 ± 0.7
Growing period, days	183.4 ±6.3	-8.7%	167.4 ± 5.4

Table 8. Water Balance Components for Maize

	1994-2003 (Observed)		2070-2079 (Created)
Precipitation	47.5±23.8		24.9±18.0
		-47.6%	
Evapotranspiration,	399.9± 29.8		393.1±33.9
mm		-1.7%	
Irrigation,	371.1 ± 49.4		383.3±44.2
mm		+3.3%	
Biomass,	27.5 ±1.53		20.6± 1.34
ton/ha		-25.1%	
Yield, ton/ha	15.19 ± 1.29		10.48 ± 1.0
		-31.0%	
Growing period, days	115.2 ± 3.6		105.9 ± 0.7
		-8.1%	

The results show that duration of growth period for maize and wheat becomes shorter by about 10 and 16 days, respectively and results in lower biomass and yield in the future. ET and irrigation amount slightly decreases due to shorter growing days except slight increase in irrigation amount for maize.

4. Conclusions

Previously discussed results in this work led to the following conclusions, inferences and suggestions:

Wheat production may have some damages with higher temperature and less rainfall. Higher temperature caused to the shorter wheat growing period. Reduction of wheat vegetation growth and yield from less fertility, while higher concentration of CO_2 could be enhance photosynthesis of crops with higher vegetation production. Increasing irrigation water requirements for wheat crop in summer could be reason of the higher temperature. The conventional rain-fed wheat depends on rainfall in winter from November to May.

Second crop maize yield decreased due to the decreased grain weight caused by short growing period. Future maize grain yield decreases due to increased temperatures are to be expected more drastically under rain-fed condition. Maize grain yield reductions due to increased temperatures will occur even under irrigated conditions. Maize grain weight increases were not sufficient to compensate for the reduced grain number. This indicates to an adverse effect of high temperatures also on grain growth.

This study is expected to provide important information for scientists, institutions and producers that work on soil and water management.

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