Türkiye Tarımsal Araştırmalar Dergisi
dergipark.gov.tr/tutad

Research Article

Turk J Agric Res
2017, 4(1): 1-9
© TÜTAD
ISSN: 2148-2306
e-ISSN: 2528-858X
doi: 10.19159/tutad.300398

Identification of Water Usage Efficiency for Corn (*Zea mays* L.) Lines Irrigated with Drip Irrigation Under Green House Conditions as Per Plant Water Stress Index Evaluations

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Received: 29.02.2016 **Accepted:** 21.12.2016

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Abstract: The present study was conducted as a greenhouse study under Çukurova conditions during the years 2011-2012. Two different dent corn lines (5A2-B and 22K) were used as the plant material of the experiments. Crop water stress index (CWSI) values determined through leaf canopy temperature measurements performed ahead of irrigations were used to find out water use efficiencies. Experiments were conducted in randomized blocks-split plots experimental design with three replications. Drip irrigation was used for irrigations and two different irrigation programs were created as of I_{100} (supplying 100% of depleted water in every seven days) and I_{75} (applying 75% of depleted water. The amount of irrigation water applied for in the interaction of I_{100} irrigation and corn lines (5A2-B and 22K) in the first and second year were respectively varied between 253.0-274.0 and between 238.0-261.0 mm, seasonal plant water consumptions varied between 294.0-305.0 and between 284.6-302.6 mm, kernel yields varied between 2950.0-2990.0 and between 3130.0-3186.0 kg ha^{-1}. With regard to (in the interaction irrigation treatments x corn lines), the lowest and the highest CWSI values were observed in the interaction full irrigation (I_{100}) and of the line 22K as 0.22 and in deficit irrigation treatment (I_{75}) of the line 5A2-B as 0.41 in the first year; in full irrigation treatment (I_{100}) of the line 22K as 0.20 and in deficit irrigation treatment (I_{75}) of the line 5A2-B as 0.36. The greatest and the lowest chlorophyll contents (in the interaction irrigation treatments x corn lines) were respectively observed in I_{100} treatment of the line 22K as 58.3 spad and in I_{75} treatment of the line 5A2-B as 50.9 spad in the first year; in I_{100} treatment of the line 22K as 59.1 SPAD and in I_{75} treatment of the line 5A2-B as 55.1 spad. While the effects of irrigation treatments on average dry matter contents of the lines were not found to be significant, significant differences were observed in water use efficiency and kernel yield of dent corn lines ($p<0.01$). Current findings revealed that 22K dent corn line was prominent with regard to CWSI and chlorophyll content and the relevant line was also able to use available water holding capacity with an optimum efficiency. Therefore, it was concluded that the dent corn line (22K) could be used in further researches to improve water efficiencies.

Keywords: Corn lines, crop water stress index (CWSI), water use efficiency

1. Introduction

Following wheat and barley, corn has the third largest cultivation area in Turkey. Mediterranean region has the greatest corn cultivation areas with a 34% share in country production and it is followed by Southeastern Anatolia (28.7%) and Aegean region (15.1%) (Anonymous, 2015). Significant increases have recently been observed in corn cultivated lands together with an increase in irrigable lands. In Turkey, corn is used in animal feed, starch, glucose, cooking oil and recently in bioethanol production.

Corn is a C4 crop. Although it can use carbon dioxide, solar radiation and water more efficiently than C3 crops, it is more sensitive to water stress and the amount of water required throughout the growing season is different from the other cereals (Huang et al., 2006). Productivity response to water stress is different for each crop and is expected to vary with the climate. Many factors need to be considered in order to obtain a good measure of actual stress levels, but leaf temperature is the most important factor (Smith et al., 1985; Stockle and Dugas, 1992; Erdem et al., 2006). Kırnak and Demirtaş (2002) indicated decreased growth, leaf water potential, leaf relative moisture content and chlorophyll content with water stress treatments. Researchers also reported decreased photosynthesis rates, transpiration rates, stomal conductance and water use efficiencies with drought stress. The damage exerted on plants under drought stress resulted in decreased leaf water contents and resultant stomal closure and ultimately increased leaf temperatures (Farooq et al., 2009). Gençoğlan and Yazar (1999) indicated that plant canopy temperature was influenced by ambient temperature, plant phenological status and soil moisture deficit. It was indicated in a previous study that plant cover temperature measurements may be employed as a useful selection criteria since they well respond to selections and have high genetic correlation with yield (Yıldırım, 2005). According to Yıldırım (2005) inferred from Singh and Kanemasu (1983), “if the genotypes of a cultivar exhibit different responses to water stress, then leaf and plant cover temperature may serve as an indicator for the resistance of that genotypes to drought”. Transpiration slows down when the plant water intake decreased through decreasing soil moisture content, and then leaf stomas gradually close up. In this case, incoming solar energy is used to increase leaf surface temperature rather than being used in transpiration. When the leaf temperature went above ambient temperature, transpiration completely slow down. Then, the difference between plant canopy temperature and ambient air temperature can be used as an indicator of stress to be used in assessment of moisture content in plant root zone. In breeding researches for drought and temperature resistance, plant cover temperature and leaf chlorophyll content can easily be determined with portable and cheap devices (Reynolds et al., 1996). Çamoğlu et al. (2011) indicated that leaf moisture content and chlorophyll-meter values could reliably be used to identify water stress. Crop water stress index was developed through the relationship between vapor pressure deficit and the difference between canopy and ambient air temperature (Yazar, 2009). Leaf temperature decreases as long as plants transpire and goes below the ambient air temperature. By using this physical attribute and psychrometric measurements, crop water stress index (CWSI) values are determined (Jackson, 1982). Since the agricultural lands are not able to be enlarged anymore, the only way to increase the productions is to increase the yield per unit area. It is possible to increase crop production 5 folds with irrigation. However, ever-depleting water resources and spoiled water quality enforced the water users to apply water deficits in agriculture which is the greatest water user sector. Use of water-saving technologies and selection of crop and plant species with higher water efficiencies are evident strategies to be applied in prevention of soil and water resources and meeting the food demand of ever-increasing world population (Sarımehmetoğlu, 2007). A decrease in water resources and an increase in future temperatures have been forecasted as a result of climate change and resultant global warming. Therefore, selection research should be carried out for high yield varieties. The studies about the selection of high yield and quality dent corn lines with optimum water use efficiencies and able to adapt arid and semi-arid climate conditions are quite limited. Thus, the present study was conducted to determine water use efficiency and CWSI values of two different dent corn lines (5A2-B and 22K), of which the resistance to corn cob worm (*S. nonagrioides*) and corn borer (*O. nubilalis*) have already been proved and to identify the line to be used in further breeding researches to improve water use efficiencies.

2. Materials and Methods

The present research was conducted over the experimental fields of Çukurova Agricultural Research Institute between the years 2011-2012. Experiments were conducted under greenhouse conditions. The research site is located at 36°56' N latitudes and 35°18' E longitudes with an average altitude of about 20 m. The texture was silty-loam. The site has a plain and almost flat topography. According to the results of the analyses, irrigations were performed when 69 mm of the available water holding capacity in 0-90 cm soil profile was depleted. Irrigation water quality class was C_2S_1 and irrigation water does not pose any problems in terms of water quality. The research site has dominant Mediterranean climate with hot and dry summers and warm and rainy winters. Climate data of the research site was taken from the portable climate station placed within the research site and from Adana Regional Directorate of Meteorology (Anonymous, 2013). The warmest months are July and August respectively with average temperatures of 30.3 and 30.5 °C and the coldest months are January and February with an average temperature of 10 °C. Generally, winter rains are prevailing in Adana province. Annual average precipitation is about 700 mm. However, precipitation does not present an even distribution throughout the year. The experimental site has a semi-arid climate. The climatic variables for the experimental years are provided in Table 1. Experiments were conducted in randomized blocks-split plots experimental design with 3 replications. Irrigation treatments were placed in main plots and dent corn lines were placed in subplots. Details about experimental treatments are provided below:

I_{100}: Full irrigation (FI) and the control treatment in which depleted water were supplied fully to bring the soil moisture to field capacity. I_{75}: Deficit irrigation (DI) treatment in which 75% of full irrigation was supplied.

Plants were partially subjected to water stress through not carrying out irrigation during each of the indicated development periods. Following the sowing, full irrigation was performed in all treatment plots to ensure homogeneous germination and emergence. Then, experimental treatments were initiated. Two different dent corn lines (5A2-B and 22K) were used as the plant material. Sowing was performed on December 20 2010 and harvest was performed on 2nd of July, 2011 in the first year and sowing was performed on December 22 2011 and harvest was performed on 7th of July, 2012 in the second year. In both years, livestock manure was applied at sowing as to have 9 kg da^{-1} pure phosphorus and 25 kg pure nitrogen. Half of nitrogenous fertilizer was applied at sowing and the other half was applied when plants reached forty centimeters (40 cm long). When the kernel moisture contents decreased approximately by 15%, harvest was performed manually. Harvested cobs were husked and kernels were granulated in a corn granulation machine. Kernels were weighted to get kernel yield per plot.

Table 1. Climatic data of the experimental area in the growing periods of (2011-2012) and from 1962 to 2010

Years	Months	MMT (°C)	MT (°C)	MMiT (°C)	MH (%)	MWS (m s^{-1})	MDS (h)	TR (mm)	MST (°C)
1962-2010	January	14.4	7.7	2.8	79.8	1.0	8.1	191.8	8.6
	February	15.9	9.5	4.8	88.7	1.1	9.1	133.0	9.5
	March	18.9	11.4	5.2	80.4	1.1	11.6	183.8	16.0
	April	25.5	16.1	8.7	77.3	1.0	12.3	43.8	20.8
	May	29.6	20.2	12.4	73.1	1.0	11.4	90.2	21.8
	June	34.6	25.3	17.3	74.2	1.0	10.1	10.0	19.9
	July	33.4	30.5	23.4	70.7	1.1	12.3	10.2	30.8
	August	35.0	30.3	27.0	70.9	1.0	11.4	8.0	31.8
2011	January	17.5	11.3	-1.2	67.5	1.0	8.3	188.9	10.6
	February	11.6	9.9	7.2	87.6	1.0	9.2	136.2	17.4
	March	21.1	12.0	4.7	74.7	1.1	10.3	184.4	21.3
	April	26.4	19.2	8.6	71.8	1.0	10.9	182.1	22.6
	May	26.6	18.7	11.0	87.4	1.1	11.2	75.6	20.5
	June	32.4	24.3	19.1	82.0	1.0	11.3	7.5	24.6
	July	33.2	31.1	24.4	67.7	1.1	12.4	0.6	31.3
	August	34.0	31.0	24.5	63.4	1.0	11.8	2.7	32.6
2012	January	16.8	6.3	4.8	82.2	1.6	8.0	207.8	10.0
	February	12.6	9.4	5.5	90.3	1.7	9.1	134.6	14.3
	March	15.9	10.1	3.4	76.7	1.7	10.0	181.2	18.9
	April	23.0	16.3	12.7	74.3	1.8	10.9	144.6	21.0
	May	24.9	16.6	13.1	82.6	1.6	10.2	93.4	22.9
	June	29.0	23.4	18.2	71.9	1.6	11.0	9.0	25.0
	July	31.1	28.6	23.5	76.9	1.7	9.6	2.0	28.9
	August	31.0	29.2	23.2	74.8	1.8	10.3	1.3	31.0

MMT: Mean maximum temperature, MT: Mean temperature, MMiT: Mean minimum temperature, MH: Mean humidity, MWS: Mean wind speed, MDS: Mean daily sunshine, TR: Total rain, MST: Mean 50 cm soil temperature

Irrigations were performed with drip irrigation method. Soil moisture samples were taken from the mid-sections of each plot from 0-30, 30-60 and 60-90 cm layers. Samples were weighted to get wet weights. Then, soil samples were oven-dried at 105 °C until a constant weight to get dry weights. Dry weight-based moisture contents were calculated with Equation 1;

$$Pw = (WW-DW) / DW \times 100 \quad (1)$$

Where, Pw is dry weight-based moisture (%), WW is wet weight of the soil sample (g) and DW is dry weight of the soil sample (g). Dry weight-based moisture content of each layer was then converted into depth of water by using Equation 2;

$$d = \frac{P\ w\ x\ A}{1\ 0} \quad (2)$$

Where d is moisture content of soil layer in depth (mm), as is bulk density of the soil (g cm^{-3}) and D is layer depth (cm). Total moisture content (dT) was computed for 90 cm soil profile by summing up water depths calculated for each layer as below;

dT = d(0-30)+ d(30-60) + d(60-90)

Volume of water to be supplied to each plot was calculated by multiplying the total quantity of water with the plot areas by using Equation 3;

$$V = dT \times A \quad (3)$$

Where V is volume of water to be supplied to each plot (L) and A is plot area (m^2).

Following water balance equation was used to calculate plant water consumptions (Zeleke and Wade, 2012).

$$ETa = P + I - Rf - Dp \pm \Delta S \quad (4)$$

Where, ETa is evapotranspiration (mm); P is precipitation (mm); I is irrigation water (mm); Rf is runoff flow (mm); Dp is deep percolation (mm) and ± ΔS is the variation in soil moisture between the beginning and end of the period (mm). Since soil moisture level was brought to field capacity in each irrigation, deep percolation (Dp) was assumed to be zero. In addition, since there were seepage reducing dikes around the trial plots, runoff flow values (Rf) were not included in calculations.

The principles specified in Güngör et al. (2006) were used to determine the amount of water to be used in each plot. The water use efficiency (WUE) was calculated as the yield (kg ha^{-1}) divided by seasonal evapotranspiration (mm) (Howell et al., 1990).

Crop water stress index (CWSI) measurements were performed when the plant cover ratio was approximately 80% and the measurements were taken before and after irrigation. Infrared thermometer was used to define the plant canopy temperatures, air temperatures and vapor pressure deficits, while Psychrometric thermometer was used to take the wet-bulb and dry-bulb thermometer measurements. Measurements continued until physiological maturity. The CWSI was calculated by using the empiric method suggested by Idso et al. (1982);

$$CWSI= [(Tc-Ta)- LL] / UL- LL \quad (5)$$

Where, Tc is canopy temperature (°C); Ta is air temperature (°C), LL is Lower Limit where there is no water stress in plant (the threshold value where plant transpiration takes place at potential rates, UL is Upper Limit where plants are totally under stress (the threshold value where it is assumed that the plant no longer undergoes transpiration). Chlorophyll content was determined with a portable chlorophyll-meter (Minolta SPAD-502, Osaka, Japan). Chlorophyll measurements were made on the same leaves and plants before and after irrigations. To assess the leaf chlorophyll contents (spad value) of the reference object, a 0-1 range was used. When the value is close to one, the chlorophyll content increases; however, when it is about zero, the content decreases.

All the data acquired through these methods were subjected to Analysis of Variance (ANOVA). Significant treatments were compared with LSD (Least Significant difference) tests.

3. Results and Discussions

3.1. Crop water use

The evapotranspiration, water use efficiency (WUE), CWSI, chlorophyll content and irrigation water quantities for combined years (2011 and 2012) are provided in Table 2. Irrigation water was applied seven times (between 34 and 53 mm) in research years. In the first year, the total amount of applied water varied between 253.0-274.0 mm for the interaction of FI (I_{100}) irrigation and (5A2-B and 22K) corn lines. The seasonal ET was found to be between 294.0-305.0 mm for the interaction of FI (I_{100}) irrigation and (5A2-B and 22K) corn lines. The ET values varied from 220.0 to 235.0 mm in the interaction of DI (I_{75}) treatment and (5A2-B and 22K) corn lines respectively. In the second year, the total amount of applied water varied between 238.0-261.0 mm for the interaction of FI (I_{100}) irrigation and (5A2-B and 22K) corn lines. The seasonal ET was found to be between 284.6-302.6 mm for the interaction of FI (I_{100}) irrigation and (5A2-B and 22K) corn lines. The ET values varied from 210.1 to 226.6 mm in the interaction of DI (I_{75}) treatment and 5A2-B and 22K corn lines respectively. The water consumption values of the first year were higher than the second year since the first year was warmer than the second year (Table 1). Just because of increasing irrigation water, the ET values also increased. The second-year climate conditions were more favorable for the soil-water environment of corn lines. Compared to full irrigation, seed yields significantly decreased in deficit irrigation treatment of all corn lines. Kernel yields increased with decreasing water deficits.

In present study, water deficit affected the seed yields substantially. Therefore under deficit water resources, irrigation water must be divided into two equal parts and be applied at cob formation and milk stages. In addition, some researchers (Payero et al., 2006; Sezen et al., 2011) explained this relation using a second-order equation. There was a significant linear relation between grain yield and seasonal evapotranspiration.

Table 2. Kernel yield, CWSI, chlorophyll content and WUE values of dent corn lines

Treatments	Kernel yield (kg ha^{-1})**	CWSI**	Chlorophyll content (spad)*	Dry matter (kg ha^{-1})	Irrigation water (mm)	ET (mm)	WUE (kg da^{-1}-mm)**
2011 (First year)							
Irrigation treatments							
I_{100} (FI)	2970.0 a	0.24 b	56.48 a	16471.0	263.5	299.5 a	0.99 b
I_{75} (DI)	2623.0 b	0.35 a	52.16 b	16203.0	198.0	227.6 b	1.14 a
Average	2800.0	0.29	54.32	16337.0	230.8	263.5	1.06
CV (%)	1.18	2.67	0.75			1.53	1.69
LSD (0.05)	4.65	0.24	0.56	ns		4.82	0.029
Varieties							
5A2-B	2915.0	0.33 a	52.78 b	14828.5	263.5	257.0 b	1.04
22K	2678.3	0.25 b	55.86 a	14506.6	198.0	270.1 a	1.09
Average	2796.6	0.29	54.32	14667.5	230.8	263.5	1.06
CV (%)		10.00	0.96			1.32	
LSD (0.05)	ns	0.04	0.72	ns		4.75	ns
Varieties x irrigation treatments							
I_{100}x5A2-B	2990.0 a	0.27 c	54.60 b	16710.0	253.0	294 b	1.01 c
I_{100}x22K	2950.0 a	0.22 d	58.30 a	16350.0	274.0	305 a	0.97 d
I_{75}x5A2-B	2370.0 c	0.41 a	50.90 d	16230.0	190.0	220 d	1.07 b
I_{75}x22K	2880.0 b	0.29 b	53.40c	16060.0	206.0	235 c	1.22 a
Average	2800.0	0.29	54.30	16340.0	231.0	263.5	1.06
CV (%)	0.28	2.67	0.75			1.53	1.69
LSD (0.05)	6.61	0.083	1.03	ns		9.15	0.045
2012 (Second year)							
Irrigation treatments							
I_{100} (FI)	3160.0 a	0.24 b	57.55a	16750.0	249.5	294.0 a	1.08 b
I_{75} (DI)	2691.0 b	0.35 a	56.25b	16300.0	187.5	218.3 b	1.23 a
Average	2930.0	0.29	55.69	16525.0	218.5	256.1	1.16
CV (%)	0.14	0.98	0.19			0.63	0.96
LSD (0.05)	1.72	0.004	0.17	ns		2.26	0.015
Varieties							
5A2-B	2800.0	0.34 a	55.56 b	15415.0	249.5	247.3 b	1.13
22K	3050.0	0.26 b	58.23 a	15361.0	187.5	265.0 a	1.17
Average	2162.0	0.30	56.80	15388.0	218.5	256.1	1.15
CV (%)		9.83	0.53			0.61	
LSD (0.05)	Ns	0.039	0.42	ns		2.13	ns
Varieties x irrigation treatments							
I_{100}x5A2-B	3186.0 a	0.25 c	56.00 c	16790.0	238.0	284.6 b	1.11c
I_{100}x22K	3130.0 b	0.20 d	59.10 a	16710.0	261.0	302.6 a	1.03 d
I_{75}x5A2-B	2410.0 d	0.36 a	55.10 d	16390.0	179.0	210.1 d	1.14 b
I_{75}x22K	2970.0 c	0.26 b	57.30 b	1621.0	196.0	226.6 c	1.31 a
Average	2924.0	0.27	56.80	16525.0	218.5	256.0	1.68
CV (%)	0.14	0.98	0.19			0.63	0.96
LSD (0.05)	0.93	0.069	0.28	ns		3.67	0.024

CWSI: Crop water stress index, ET: Plant water consumption, WUE: Water use efficiency, ns: Not significant, Mean values followed with one or more of the same letters in each column were not significantly different at $^{*}P<0.05$ and $^{**}P<0.01$, CV: Variation coefficient

3.2. Kernel yield and water use efficiency

Irrigation regime significantly affected kernel yields ($p<0.01$) (Table 2). In the first year in the interaction of I_{100} irrigation and corn line 5A2-B produced the best kernel yield (2990.0 kg ha^{-1}) and corn line 22K gave the lowest kernel yield (2950.0 kg ha^{-1}). In the interaction of I_{75} irrigation and corn line 22K (2880.0 kg ha^{-1}) produced the best yields, while corn line 5A2-B (2370.0 kg ha^{-1}) gave the lowest kernel yield. In the second year the interaction of I_{100} irrigation and corn line 5A2-B, produced the best kernel yield (3186.0 kg ha^{-1}) and corn line 22K gave the lowest kernel yield (3130.0 kg ha^{-1}). In the interaction of I_{75} irrigation and corn line 22K (2880.0 kg ha^{-1}) produced the best yield, while corn line 5A2-B gave the lowest kernel yield (2410.0 kg ha^{-1}) (Figure 1).

The smaller the amount of water, the lower the kernel yield is, and vice versa. In I_{75} treatment group, all corn lines were irrigated equally, but there was a significant difference between the kernel yields of 5A2-B and 22K corn lines.

Figure 1. Kernel yields of corn lines

Especially, 19% higher yield was obtained from 22K compared to 5A2-B. The primary reason for decreased yields in I_{75} treatments was reduced number of kernels because of water stress.

The WUE values were significantly affected by irrigation treatments (Table 2). In the first year for in the interaction of I_{75} irrigation and corn line 5A2-B, the lowest value was obtained (1.07 kg da^{-1}-mm) and the highest values were obtained for corn line 22K (1.22 kg da^{-1}-mm). In the interaction of I_{100} irrigation and corn line 22K the lowest value was obtained (0.97 kg da^{-1}-mm) and the highest value was obtained for corn line 5A2-B (1.01 kg da^{-1}-mm). In the second year for in the interaction of I_{75} irrigation and corn line 5A2-B the lowest value was obtained (1.14 kg da^{-1}-mm) and the highest values were obtained for corn line 22K (1.31 kg da^{-1}-mm). Among the I_{100} treatments, the lowest value was obtained for corn line 22K (1.03 kg da^{-1}-mm) and the highest value was obtained for corn line 5A2-B (1.11 kg da^{-1}-mm). Present findings were quite similar to the findings of Erdem et al. (2006). In another study, Demir et al. (2006) reported WUE values as between 0.5-1.0 kg da^{-1}-mm. The differences may be resulted from plant species, environmental conditions, plant density, irrigation program and cultural practices (Brown, 2003).

The average CWSI values are provided in Table 2. The differences in CWSI values were found to be significant ($p<0.01$). In the first year, the highest CWSI values were obtained for corn line 5A2-B (0.41) of I_{75} treatments and the lowest value was obtained for corn line 22K of I_{100} treatments. In the second year, the highest CWSI values were obtained for corn line 5A2-B (0.36) of I_{75} treatment and the lowest value was obtained for corn line 22K (0.20) of I_{100} treatments. The CWSI values in June and July were slightly higher than those determined during the vegetative period (the first year; Figure 2a and 2b, the second year; Figure 3a and 3b). This can be explained by the fact that the average air temperature in June and July was somewhat higher than in the other months. The values obtained for the days are presented in Figure 2a and 2b and Figure 3a and 3b. The figures showed that the CWSI values increased with increasing water deficit and were the highest before the irrigation. Soil moisture decreases when an increase in air temperature leads to an increase in temperature of plant canopy; that is why the CWSI values become higher. Köksal (1995) reported under Çukurova conditions that CWSI values for I_{100} treatments were between 0.13-0.43, while the values for rain-fed treatments were between 0.42-0.73. Ödemiş and Baştuğ (1999) reported that in order for CWSI values to decrease after irrigation, certain time was required, and this period was between four and five days. These researchers emphasized that as the water level decreases the plant experiences water stress, and thus CWSI values go up. Şimşek and Gerçek (2005) stated that CWSI values varied according to amount of water and in general high CWSI values led to plant degradation. Orta et al. (2002) conducted a research to determine water stress index under Tekirdağ conditions and to assess the relation between the plant stress index and yield. Each of the test subjects was irrigated using different amounts of water. The optimum CWSI values were between 0.44 and 0.48. These proportions are indicators for determining the correct time of irrigation. Moreover, the relation between the CWSI and yield was as follows: $Y= 8.28-7.36\times CWSI$. There were small differences between CWSI values, even when they have been determined by researchers to be equal. It was considered that this was due to differences in the reaction of hybrids to decreasing soil moisture levels. CWSI (i.e., the threshold for a yield decrease) values may vary depending on the irrigation program, soil type of the experimental field and weather conditions in the experimental year. In addition, results vary depending on the type of the plant material and the planting method.

Effects of irrigation treatments on chlorophyll contents were found to be significant ($p<0.01$). In the first year, the highest chlorophyll content was obtained from I_{100} treatment of corn line 22K with a SPAD value of 58.3 and the lowest chlorophyll content was detected in I_{75} treatment of corn line

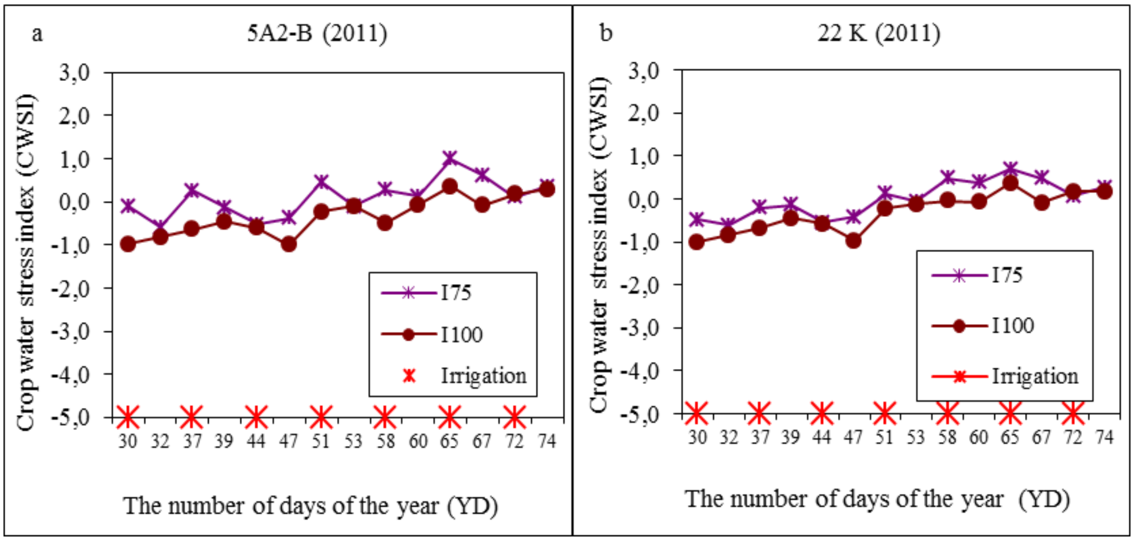

Figure 2. 2011, (a) Water stress for 5A2-B plants, (b) Changes during the vegetation period for 22K plants

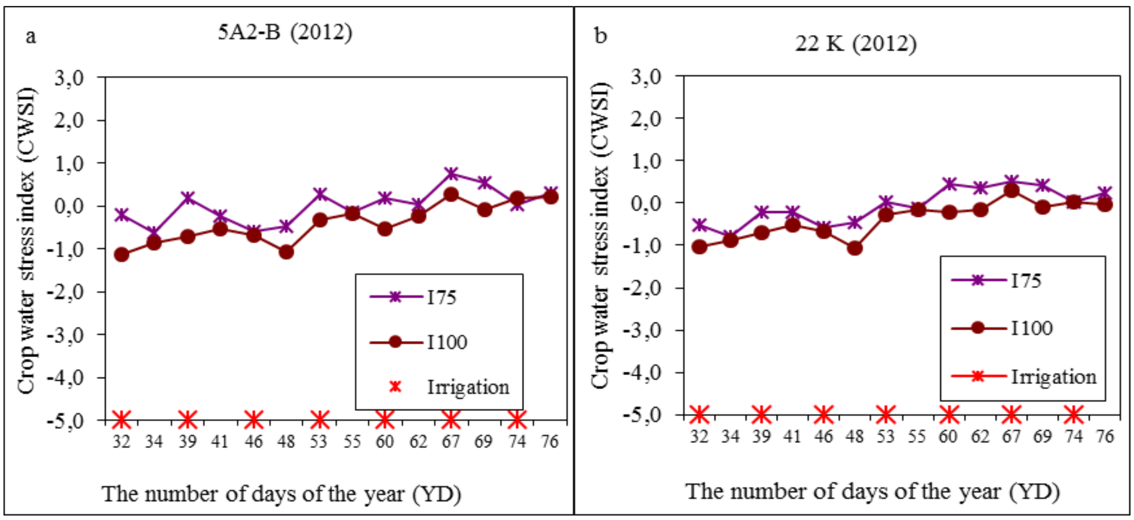

Figure 3. 2012, (a) Water stress for 5A2-B plants, (b) Changes during the vegetation period for 22K plants

5A2-B with a spad value of 50.9. In the second year, the highest chlorophyll content was found in I_{100} treatment of corn line 22K with a spad value of 59.1 and the lowest chlorophyll content was detected in I_{75} treatment of corn line 5A2-B with a spad value of 55.1. The chlorophyll values increased significantly with increasing irrigation water. The highest value in the irrigation periods, excluding the vegetative periods, was obtained in the I_{100} group, which received the highest amount of irrigation water, and the lowest value was obtained in the I_{75} group, which received no irrigation water, except in January. In the vegetative period, the chlorophyll values were not completely distinctive with respect to the irrigation status. This can be explained by the fact that irrigation of the subjects was newly started in the mentioned period, so the plants experienced no stress yet. In the other periods, there were four groups among the subjects, both before and after the irrigation, and discrepancies appeared in chlorophyll values depending on the stress level among the subjects in the harvest season. When the changes in the subjects were analyzed by the growth periods, it could be noticed that the chlorophyll values generally decreased in the late vegetative periods. When examining the study periods together, it could be concluded that the chlorophyll values in plants suffering from extreme water stress decreased dramatically in time. It has been emphasized by many researchers (Fernandez et al., 1997; Demirtaş and Kırnak, 2009) that, depending on the amount of applied water, chlorophyll content of the leaves could vary; in particular, plants have the rate of their chlorophyll synthesis reduced under water stress.

In this study, the chlorophyll meter values varied based on the amount of chlorophyll in leaves, depending on irrigation status.

4. Conclusions

Drought is one of the most important abiotic stress factors affecting the CWSI and physiological structure of plants, especially in semi-arid climate zones such as the present research site. In the first year, corn line 22K had the lowest CWSI value with 0.22 and corn line 5A2-B had the highest CWSI values with 0.41. In the second year, corn line 22K had the lowest CWSI value with 0.20 and corn line 5A2-B had the highest CWSI value with 0.36. There was no immediate relation between the yield and CWSI and chlorophyll content. Identifying plant types tolerant to water stress, developing new types and generating germplasm tolerant to drought may help in finding solutions for global droughts. In both years of deficit irrigation treatments, the water use efficiencies of corn line 22K were higher than that of corn line 5A2-B. It can be concluded that corn line 22 K used irrigation water with an optimum efficiency. Therefore, despite low efficiency values, corn line 22K can be recommended to farmers in regions with similar climates and especially to farmers with limited irrigation opportunities. For higher kernel yields, at least four irrigations can be recommended and these irrigations are recommended to be applied at before flowering period, in flowering period, before cob formation period and in cob formation period. Agricultural water management is the most important issue in water-deficit areas since agriculture is the largest freshwater using sector throughout the world. In regions with water shortages, mostly groundwater is used for irrigation and the water level gradually depletes due to excessive water withdrawals from these reservoirs. Finally in present study, corn line 22K was identified as an outstanding line with regard to CWSI, chlorophyll content and water use efficiency. However, still further research is needed for more specific recommendations.

Acknowledgements

The authors would like to thank TAGEM and East Mediterranean Agriculture Research Institute for their financial support and technical assistance.

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