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The Effect of Different Irrigation Water Levels on Productivity and Other Parameters for After-Crop Corn Plant: A Case Study from Turkey's Southeastern Anatolia Region

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***Abstract* — This study has been performed as a field study to determine the possible reactions on productivity of 3 different levels of irrigation (I100, I70, I35) for seeded corn plant, which has four different grow types under the climatic conditions of Siirt district in Turkey's southeastern in 2014. In conclusion, for the types with full irrigation (I100), the total average irrigation water amount has been defined as 718 mm and average seasonal plant water consumption has been defined as 751 mm. With full irrigation, the yield from the species (S1, S2, S3 and S4) were 7171, 6945, 6735, 6525 kg/ha respectively. Depending on the climate conditions and the applied water deficiency, plant water consumption, plant water stress index, chlorophyll meter value, seed productivity, leaf area index and plant size, stub size have changed significantly. As plant water stress index (CWSI) increased, the above mentioned parameters have decreased. From the pre-irrigation infrared thermometer observations, the threshold CWSI value, when the corn seed yield begins to drop, has been defined as 0.31. It is possible to say that CWSI values can be utilized to momentarily define irrigation timing and water stress.**

Keywords — Agricultural Drought, Deficit Irrigation, The water-yield relationship

I. Introduction

The homeland of the corn, Zea mays L., plant is the American continent, and its worldwide spread began after the discovery of this continent. It is known that corn arrived to Turkey during 1600's [1]. Playing an important role in human and livestock nutrition, corn is ranked third most planted grain in the world, following wheat and brown rice, and second most produced grain, following wheat.

Corn is an important industrial raw material, used for making starch, syrup, sugar, beer and alcohol [2]. In Turkey, the total corn plantation area is 500.000-600.000 ha, production level is 1.850.000-4.200.000 ton, and average yield is between 364-741 kg/da [3]. Even though Turkey has suitable ecologies to grow corn, it is true to say that ecology suitable corn species are not used in many corn growing areas, thus actual yield potentials cannot be achieved. Humphreys et al. [4] have examined the effectiveness of sprinkling, furrow and drip irrigation methods on corn in Australia. For the purpose of their studies, Pioneer 3153 hybrid type corn has been used, and in all three irrigation methods, irrigation started after 40% of the soil's useful water was consumed. Drip irrigation laterals have been placed at the centre of corn rows, at a depth of 20 cm underground. The total amounts of applied water for sprinkling furrow and drip irrigation methods were 620 mm, 600 mm and 510 mm respectively, and in drip irrigation method, compared to sprinkling and furrow methods, 21.5% and 17.6% less water was used, respectively. Seed yield (in 12% humidity) was achieved as 1150 kg/da in drip irrigation, 1030 kg/da in sprinkling irrigation, and 990 kg/da in furrow irrigation. For this reason, this study has been performed as a field study to determine the possible reactions on productivity, of 3 different levels of irrigation (I100, I70, I35) for seeded corn plant, which has four different grow types under the climatic conditions of Siirt district in Turkey's southeastern.

II. Material and Method

A. Material

This study has been carried out at the agricultural experiment zone in Southern of Turkey (Siirt District) during the corn plant growing season in 2014.

In this research, Hybrid seed corn species with 4 different growing types have been used as plant material. The three times repetitive study was based on randomized blocks divided parcels experimental design and irrigation method was drip irrigation. Irrigation program was scheduled weekly. Seven irrigation applications took place during the study year and water content of soil was monitored through gravimetric method. In the research area, it has been observed that some climate data give in Table 1.

Table 1.Some climate data of research field [5]

Months	Min. Temperature (^{0}C)	Max. Temperature (^{0}C)	Average Temperature (^{0}C)	Total Rain (mm)	Humidity (%)
June	19.2	40.2	32.3	9.4	35.0
July	23.5	44.0	37.2	2.0	27.7
August	23.2	43.4	37.0	1.3	26.9
September	18.9	39.5	32.4	3.5	31.8

B. Method

This study was performed under after crop conditions at Siirt University, Faculty of Agriculture research and experiment area in 2014. The experiment was based on randomized blocks divided parcels experimental design with three repetitions. For seeding purposes, the plan was to have 4 rows in each parcel, with an interval of 70 cm between rows, row top 20 cm, and parcel size 2.1 x 5 = 10.5 m^2. Seed bed has been prepared to allow ridge seeding, and soil was irrigated after seeding. To meet the amount of water required by the plant during growing period; drip irrigation method was employed every 7 days. The main parcels, irrigation subjects and sub parcels of the study consisted of different types.

A: Main Parcels: (Irrigation Levels I35, I70, I100,) I100: Full irrigation, where 100% (I100, control subject) of the water consumed weekly at a 90 cm soil profile and I70: Deficient irrigation subject, where 70% of the full irrigation has been applied and I35: Deficient irrigation subject, where 35% of the full irrigation has been applied.

B: Sub Rows: 4 pieces of seed corn species. Irrigation has been performed at a level that it would provide sap/life line to all subjects to ensure a homogeneous outlet right after seeding; and to bring all subjects to field capacity, when 50% of the soil profile moisture is consumed until the plants grow 6-8 leafs. All subjects have been irrigated on the same day, by making I100 irrigation subject the control parcel.

Observations and Measurements to be acquired from the Study

Measurements and yield value calculations of the plant have been made by taking into account the Ministry of Agriculture and Rural Affairs' Technical Regulations on Measurement Experiments of Agricultural Values [6].

Seed yield per decare (kg/da)

After removing two rows from the sides of each parcel, as edge effect, the remaining 10 m long corns shall be harvested manually. All measurements related to the plant shall be made over the two central rows. The harvested product shall be weighed and then the moisture ratio shall be defined by using a moisture measurement device. Following this, it will be rectified to achieve 15% moisture level and calculated in kg/da [7].

Plant water stress index (CWSI)

Plant Water Stress Index (CWSI) measurements shall start when the plants cover the soil surface by approximately 80%, and measurements will be made before and after irrigation. Infrared thermometer will be used to define plant crown temperatures, air temperatures and vapor pressure deficit of air, while psychrometer thermometer will be used to start wet-bulb and dry-bulb thermometer measurements, and measurements shall continue until physiologic maturity is achieved.

Calculation of the Plant Water Stress Index (CWSI): Defining the plant water stress index (CWSI) shall be done by the empiric method suggested by Idso et al [8]. Based on this method, CWSI has been defined with the following equation 1.

$$CWSI= [(Tc\text{-}Ta) - LL] / UL\text{-}LL \quad (1)$$

In the equation: Plant Water Stress Index (CWSI), Tc, crown temperature (°C); Ta, air temperature (°C); LL, lower limit, where there is no water stress in plant (the border value where plant transpiration takes place at potential speed); UL, upper limit, where plants are totally under stress (border value, where the plant is assumed to having no transpiration). Chlorophyll content has been defined by using a portable chlorophyll meter device, indirectly measuring the chlorophyll amount in the leaf. Chlorophyll measurements were made at different periods during the whole growing season, on the leaf closest to the tasselling of 10 corn plants chosen randomly at each parcel, between the hours of 12:00 - 14:00, in a non-windy, clear weather. 0-1 scale shall be used for expressing the leaf chlorophyll contents (spad) of the above mentioned subjects, where chlorophyll content increases when approaching to one (1), and decreases when approaching to nought (0).

Leaf area index (LAI)

In this study, leaf areas shall be measured by making use of the below given equation, for which, details have been proposed by Stewart and Dwyer [9]. 3 plants from 2nd and 5th rows of all parcels shall be cut from soil surface and sampled.

Total leaf area of a leaf cut from a plant shall be proportioned to the area allocated to a plant, in order to calculate the leaf area index (LAI).

YA = Wm x L x 0.743 ………………………..………. (2)

In the equation, Wm: Maximum with of leaf (cm), L: Leaf size (cm).
Leaf area index (LAI) is to be calculated by using the below equation.

LAI = YA/ BA …………………………………....... (3)

In the equation, LAI: Leaf area index, YA: Leaf area (cm^2), BA: Plant area (cm^2)

Some parameters measured in plants

Tasselling growing duration (days): The duration it takes for approximately 50% of the plants to grow tasselling from the date of seeding is said to be the tasselling growing duration. Plant size (cm): Before harvesting, 10 plants from the harvest area have been randomly selected and the distance from soil level to tasselling tip has been measured to calculate the average size. Stem diameter (mm):10 plants have been randomly selected from the two central rows; stem diameter has been measured from 10 cm above soil surface by using calipers, before getting an average value [7].

Evaluation of Data

All the data acquired through these methods have been subjected to an analysis of variance in randomized blocks, in accordance with divided blocks (strip wise) experimental design. Based on the analysis of variance results, the statistically important applications have been compared to LSD (Least Significant difference) test.

III. Discussion

Irrigation findings

In the study area, the total amount of irrigation water applied to the full irrigated (I100) irrigation subject of the species, have been respectively 718 mm, 503 mm, 251 mm for I100, I70 and I35 irrigation subjects, and seasonal plant water consumption has been defined as 751 mm for S1 species, the highest value, and the lowest value was in S4 specie with 736 mm, while the remaining species had values ranging between these two. With full irrigation, (I100) the yield from the species (S1, S2, S3 and S4) were 7171, 6945, 6735, 6525 kg/ha respectively. In previous studies based on corn plant water-yield relations, it has been reported that when the deficient moisture in soil is fully covered for, the amount of applied irrigation water is between 310-1206 mm [10, 11, 12]. For their research, Gençoğlan and Yazar [10] have provided for all of the deficient moisture in the soil profile when irrigating (I100 irrigation subject) corn plant under Çukurova conditions in Turkey, and for the first year they irrigated 6 times, and 7 times for the second year, with a total of 752 and 823 mm irrigation water respectively. For their studies irrigating corn plant under Şanlıurfa conditions in Turkey, Şimşek and Gerçek [11] have applied irrigation water through the vegetation period, with the amount ranging between 814-1116 mm for the first year, and 843-1206 mm for the second year. Generally speaking, the amounts of irrigation water applied by the above mentioned researchers is higher, even if slightly, than the amount of irrigation water applied for the purposes of this study. These slight differences may be associated with soil characteristics, plant type, climatic differences, amount of precipitation and differences in temperature values during study years, corn being grown as main crop or after crop, etc. Regarding the total irrigation water applied to corn plant during the growing season, and the related water consumption values; Çamoğlu et al. [13] total irrigation water (SS) amounts and plant water consumption (ET) values under Çanakkale conditions (Turkey) in 2007 were 50-373 mm and 271.6-483.2 mm respectively, and 53-389 mm and 201.4-423.0 mm in 2008. Pandey et al. [14] reported 641-668 mm for irrigation subject with no water deficit applied.

Generally speaking, the irrigation water and the calculated water consumption amounts applied by the above mentioned researchers are slightly lower or higher than the irrigation water and water consumption values of this study. These slight differences may be associated with soil characteristics, plant type, climatic differences, amount of precipitation and differences in temperature values during study years, corn being grown as main crop or after crop, inclusion or exclusion of life line water to the total irrigation water etc. Among the irrigation subjects of the study, highest water usage efficiency has been observed in I35 irrigation subject genotype no 2 (1.24 kg/m^3), and placed in the 1st group (A). And the lowest water usage efficiency has been observed in I70 irrigation subject genotype no 4 (0.86 kg/m^3) and placed in the last group. The other genotypes were placed between these two groups with different rates. The reason for the water usage efficiency value for I35 irrigation subject to be higher could be associated with the fact that deficient irrigation water has been applied through the growing season.

Findings related to plant water stress index (CWSI) and chlorophyll content

The equations for the lower limit (LL), deemed to have no plant water stress and the upper limit, where the plant is deemed to be fully under water stress have been provided in Figure 1 (a, b, c, and d section)

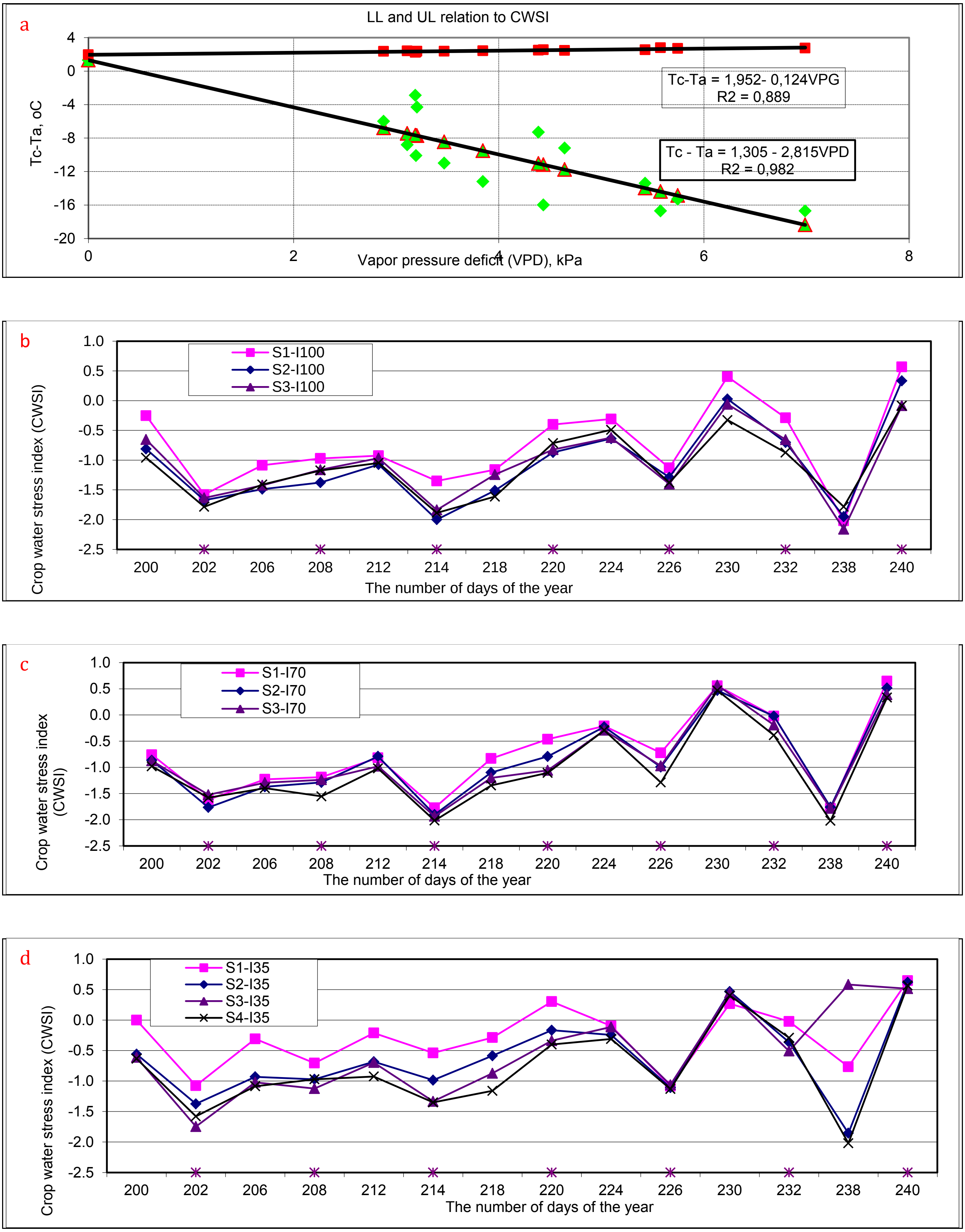

Figure 1.(a) Plant water stress limit lower (LL) and upper (UL) limit, (b)Water stress for full watered (I100), (c) Plant Water stress for deficit watered (I70) during the vegetation, (d) Plant Water stress for deficit watered (I35) during the vegetation while the changes through vegetation period for I100, I70, and I35 have

been given in Figure 1. As it can be seen in Figure (a) the low limit (LL) equation, where no plant water stress is present, regarding the first year of the study has been determined as Tc-Ta = 1.305-2.815VPD (R^2 = 0.982). In the equation, the inter section values of the LL line have been defined as positive.

Idso et al. [8] have reported that inter section value cannot be lower than 0, and this is caused by the fact that even when it is saturated in atmosphere and VPD is brought to zero, there is a positive water steam flux from the leaf to the atmosphere. In this case, according to the LL equation, and as discussed in previous studies on this subject, it can be understood that there was a positive water steam flux from the leaf to the atmosphere during the whole time [15, 16]. The upper limit (UL) equation, on the other hand, has been defined as Tc-Ta = 1.952 + 0.124 VPG (R^2=0.889).

The inclination in UL equation was too small, therefore it was neglected and as such, crown temperature and air temperature difference in UL has been defined as 1.1 ºC. The CWSI values measured in irrigation subjects were mostly between 0 (no water stress) and 1 (state of maximum stress). During the vegetation period in the study area, the highest CWSI value has been determined in I35 irrigation subject genotype no 4 (0.56). The lowest CWSI value, on the other hand, has been defined in I100 irrigation subject genotype 1 (0.27). The threshold CWSI value, when the corn seed yield becomes decreasing, determined by the pre-irrigation infrared thermometer observations, has been defined as 0.31. At the beginning of the vegetative period, CWSI and chlorophyll values were similar for all species, but towards the end of the vegetative period and mid-generative period, CWSI values inclined to increase, while chlorophyll contents inclined to decrease. This can be associated to the fact that the majority of available water in soil was used by the corn plant to grow seed, thus, leaving less water to convey to the leaves (Figures 3). Chlorophyll values measured in full irrigated and deficiently irrigated locations were mostly between 58 and 64 spad values, however some of these values dropped to as low as 54 spad (Table 2). Ç1-Ç2-Ç3-Ç4 symbolizes the S1-S2-S3-S4 varieties.

Table 2.Chlorophyll content during the period of the type of vegetation changes

Chlorophyll Activity Measurements				
Maize Varieties	Vegetative Period	Before Flowering	Flowering Period	After Flowering
Ç1	60,7	65,37	64,10	60,10
Ç2	59,4	63,45	63,40	59,80
Ç3	55,3	60,10	62,00	56,20
Ç4	53,9	58,60	58,00	55,30
Average	57,325	61,88	61,875	57,85

The lowest chlorophyll value has been acquired through measurements taken before irrigation, during a day with maximum temperature (42ºC). During the trial, the measured chlorophyll values for corn genotypes during vegetative period, regarding irrigation subjects, were 53.9 spad in S4, and 55.3 spad in S3, while the highest value was observed in S1 species, with 65 spad value. In other genotypes, these values varied between the above mentioned values. Chlorophyll values measured in I35 irrigation subject have been slightly lower than the chlorophyll values measured in I100, which could be associated with the fact that evapotranspirasyon and temperature values during July and August, when deficient irrigation is applied, are higher when compared to the full irrigation subject. If the root zone soil water content is high, chlorophyll content is high, but it shows an inclination to decrease when soil water content is getting lower [17]. As a conclusion to this study, the authors can suggest that leaf chlorophyll content may change due to factors such as plant and soil type, irrigation program, location of measurement etc.

Yield and some yield parameters

Though changing by irrigation subjects, the highest yield in the experiment has been observed in I100 irrigation subject S1 species 7171 kg/ha, and place in Group A. The lowest yield, on the other hand, has been observed in I35 irrigation subject Ç4 species 3173 kg/ha, and placed in the last group. As it can be seen in Table 3, there are noticeable differences between yield values, measured per irrigation subjects and species. It can be said that these differences are due to species with different maturity groups (FAO), genetic richness of genotype, climate conditions of the study area, plant prevalence, irrigation method and program, as well as cultural methods employed [18]. Among the leaf area indexes in irrigation subjects, defined in genotypes, the lowest value was I35 irrigation subject 3.17 in S4, while the highest value was 5.21 in irrigation subject I100, S1. The other values in other genotypes ranged between these values. Çamoğlu et al. [13] reported that leaf area index and chlorophyll content may noticeably decrease, depending on the irrigation program and the region of planting (Table 3). Ç1-Ç2-Ç3-Ç4 symbolizes the S1-S2-S3-S4 varieties.

Table 3.The values of some yield parameter related to maize varieties

Irrigation levels	Varieties	Tasselling time (day)**	Plant height (cm)**	First corncob height (cm)**	Stem (stalk) Thickness (mm)**	Leaf Area Index (LAI)**	Corncob length (cm)	Corncob diameter (mm)	Irrigation (mm)	Consumption of Plant water (ET)	Yield (kg/ha)**	Water use efficiency
I_{100}	Ç1	62.33a	225c	70.33a	24.3a	5.21a	20.70	20.66a	718	751	7171a	0.96
	Ç2	61.32a	242.2a	65.66b	21.33b	4.74b	20.20	20.20a	718	742	6945b	0.94
	Ç3	60.3 b	232.2b	56.33e	21.2b	4.60c	20.10	20.50a	718	733	6735c	0.92
	Ç4	56.3f	217e	55.00e	21.3b	4.53d	19.20	19.10b	718	739	6525d	0.88
I_{70}	Ç1	61.0b	221d	67.33b	22b	3.7e	19.20	18.5b	503	531	5146e	0.97
	Ç2	59d	227.4b	64c	19.0e	3.67e	20.20	16.73d	503	527	5063e	0.96
	Ç3	59.3c	224c	54.66e	17.6f	3.39g	20.00	15.63e	503	514	4780f	0.93
	Ç4	55.4g	223c	54.0e	20.33d	3.35g	19.05	15.43e	503	519	4480g	0.86
I_{35}	Ç1	58.3d	213f	64.0c	20.7c	3.66e	19.10	18.13c	251	294	3670h	1.25
	Ç2	57.3e	219d	60.33d	18.66e	3.51f	18.20	16.43d	251	283	3520ı	1.24
	Ç3	59d	229.7b	53.0f	16.6g	3.33g	17.90	15.46e	251	269	3280j	1.22
	Ç4	54.3g	214f	51.33f	21.66b	3.17h	18.00	15.33e	251	277	3173j	1.14
C. V. (%1)		1.10	2.60	2.67	3.10	1.40	2.12	2.16			2.37	
LSD (0.05)		1.12	6.23	2.65	4.79	0.10	NI	0.67			11	

**: $p < 0.01$; Averages indicated by similar letter in the same column aren't statistically different from each other within $P < 0.05$ error limit according to LSD test; NI: Not important

According to the study results, on condition that they may change per irrigation subjects, largest and smallest plant size ranges between 242-213 cm; stem height 70-51cm; stem diameter 20.7 mm-15.4 mm; tasselling growing duration (days) 62 days and 55 days.

It has been reported that, depending on ambient conditions, there will be a significant decrease in stem yield when water stress and drought condition are more severe [19]. Our findings, though slightly lower, are generally in line with some of the previous studies, indicating yield values changing per region and species. This could be the result of applied cultural methods and ecologic characteristics. In corn production, yield is the most important economic factor. However, yield displays differences, depending on genetic potentials of species, as well as environment and planting techniques [20, 21, 22].

IV. CONCLUSION

Irrigation program was scheduled on a weekly basis. Irrigation was done by drip irrigation method. Seven irrigation applications took place during the study year and water content of soil was monitored through gravimetric method. For the types with full irrigation (I100), the total average irrigation water amount has been defined as 718 mm and average seasonal plant water consumption has been defined as 751 mm. With full irrigation, the yield from the species (S1, S2, S3 and S4) were 7171, 6945, 6735, 6525 kg/ha respectively. Following the statistical analysis on species and irrigation methods, meaningful statistical relations have been defined between yield and other parameters. Generally speaking, the average yield of corn plant can be somewhere around 1000 kg/da, however, in this study, the yield value was around 700 kg/da, which could be explained by the fact that at times, the temperature rose to 42°C, particularly during the pollination period, and relative humidity fall below 65%.

As a result of this effect, CWSI values increased, while yield values decreased. In other words, during pollination, annual climatic parameters displayed differences; temperatures rose above normal values (42°C) and humidity fall below normal values (65%), which all lead to a decreased level of yield. In conclusion, depending on the climate conditions and the applied water deficiency, plant water consumption, plant water stress index, chlorophyll meter value, seed productivity, leaf area index and plant size, stub size have changed significantly. As plant water index increased, the above mentioned parameters have decreased. From the pre-irrigation infrared thermometer observations, the threshold CWSI value, when the corn seed yield begins to drop, has been defined as 0.31. It is possible to say that CWSI values can be utilized to momentarily define irrigation timing and water stress. However, according to the study findings, it is advisable in Siirt climate conditions not to apply deficit irrigation, or to apply a maximum deficit of 10% during vegetative development duration, as well as applying drip irrigation, due to the fact that water resources are scarce. It is also possible to suggest that similar studies should continue in Siirt region for many years to come.

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