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Effect of Planting Date on Yield, Plant Water Stress Index and Water Usage Rate of Sunflower (*Helianthus Annuus*) Genotypes in Semi-Arid Cukurova of Turkey

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Abstract: The aim of this study is to identify the effect of the different sowing dates on the sunflower efficiency and the efficiency of elements, plan t water consumption, plant water stress index and water usage rate. The study was conducted to determine the effect of the different planting dates on yield and the yield components of 6 sunflower genotypes in the semi-arid Cukurova region of Turkey, all through the periods of the year 2012 to 2013. In this research, two different planting dates were examined and Evapotranspiration (ET), as the average of two years in the first and second growing seasons was found to be 567 mm and 578 mm, respectively. On at wo years average, the amount of irrigation water was determined as 524 mm. ET, Water Use Efficiency (WUE), Irrigation Water Use Efficiency (IWUE), Chlorophyll Content (CC), Crop Water Stress Index (CWSI), and grain yield were significantly affected. Results showed that thermal stress accelerated flowering and physiological make-up time. The highest CWSI values were determined as 0.67 in genotype No.1 and the lowest values are between genotypes No.4 or No.5,which is given as 0.22 and 0.27 respectively.

Keywords: Irrigation, plant water stress index, sowing dates, sunflower genotypes

Çukurova Koşullarında Ekim Tarihinin Ayçiçeği Genotiplerinin (*Helianthus Annuus*)Verim, Bitki Su Stres İndeksi ve Su Kullanım Randımanı Üzerine Etkileri

Öz: Bu çalışmada, 2012 ve 2013 yıllarında Çukurova koşullarında homozigot hale gelmiş (durulmuş) 6 adet ayçiçeği genotipi üzerine ekim tarihinin, bitki su tüketimine, su kullanım etkinliğine, bitki su stres indeksi ve klorofil içeriği üzerine etkileri araştırılmış ve elde edilen verilerin ışığında sıcak iklim koşullarına en uygun genotip belirlenmeye çalışılmıştır. Vejetasyon süresi boyunca ortalama bitki su tüketimi birinci ekim zamanı denemesinde (567 mm), ikinci ekim zamanı denemesinde (578 mm), uygulanan ortalama sulama suyu miktarı ise birinci ekim zamanı denemesinde ve ikinci ekim zamanı denemesi için (524 mm) olarak belirlenmiştir. Bitki çiçeklenme süresi, fizyolojik olum süresi, bitki su tüketimi (ET), su kullanım randımanı, sulama suyu kullanımı randımanı, klorofilmetre değeri (KO), bitki su stres indeksi (CWSI), 1000 tane ağırlığı ve dane verimi istatistiksel olarak önemli düzeyde değişmiştir. Araştırma sonucunda ekim tarihinin çiçeklenme ve fizyolojik olum süresini benzer şekilde etkilediği söylenebilir, ortalama CWSI değerleri ikinci ekimde en yüksek No.1 genotipinde 0.67 ve en düşük de No.4-No.5 genotiplerinde sırasıyla 0.22 ve 0.27 olarak elde edilmiştir.

Anahtar Kelimeler: Ayçiçeği, bitki su stresi indeksi, ekim tarihi, sulama

1.Introduction

The deficit of vegetable oil is one of the most significant problems of the vegetable oil industry in Turkey. The production is far from meeting Turkey's demand for vegetable oil, so Turkey is vegetable oil producing country and an oil seed importer. The continuous increase in population would lead to further oil consumption and because the levels of production does not change with population increase, an increase in imports would be inevitable. Sunflower cultivation fields, especially in Adana province, have continuously increased in the last five years. This increase was identified as 19.5 ha of the cultivated land with a production output of 54.9 tons, and an average of 2.3 t ha^{-1} yields in year 2005; and 28.9 ha of cultivated land with a production output of 81.5 ton and an average of 2.9 ton ha^{-1} yields in year 2006. Thus, it could be argued that sunflower cultivation lands and its production have a tendency to increase every year. However, Cukurova region, a region which suffers most from the effects of global warming, is included in the Akdeniz basin as the one that will suffer the most effect of global warming.

The average sunflower yield in Adana is 3.5 ton ha^{-1}, however, this rate of yield has risen up to 4.0 ton ha^{-1} in cooler climates, such as the region of Thrace. The role of the cooler climate in Thrace is significant in this difference. A study by Munjal and Rana (2003) indicated that genotypes with smaller leaf area were effective, since they could form a more upright plant canopy, as well as a low canopy temperature and high stoma conductivity properties, which all played an important role in plant tolerance against high thermal stress, during the grain filling process. In a study conducted by CIMMYT scholars (Reynolds et al. 2001), high and significant genetic correlations were found between the yield and the morphological properties. Raising the daytime/nighttime temperatures from 18/13°C to 30/25°C resulted in 30% - 60% weight loss in grain. During the grain filling phase, an increase in temperatures result in a decrease in grain filling rate and in grain filling period (WardlawandMoncur 1995; Kazi et al. 2002). Gibson and Paulsen (1999) reported that, when daytime/nighttime temperatures increased from 20/20°C to 35/20°C after flowering, under controlled conditions, the yield, grain count, and grain weight decreased by 78%, 63%, and 29%, respectively.

The critical periods of flowering and grain filling, generally fall into a high temperature season in late planting. The decrease in the yield in late planting when compared to normal planting, demonstrates the effect of the temperature (Singh and Kanemasu 1983; Ortiz et al. 1994; Stone and Nicolas 1994; Siddique et al. 2000; Bahar et al. 2008). Ucak et al. (2010) stated that frequent irrigation could extend pollination period and increase the yield without waiting for the development of plant species that are tolerant to abiotic stress during pollination, through breeding, and the consumption of 50% of the favorable moisture during pollination.

High temperature is one of the most important abiotic stress factors limiting the yield of sunflower. Thus, to cope with that problem, the objective of this study is to determine sunflower genotypes that are tolerant to high temperatures, and then, to determine the effect of different planting dates on their yield, crop water use, water use efficiency, as well as some yield components.

2.Material and Methods

This study was conducted using the divided parcels experimental design in randomized complete blocks,with three replications, under the field conditions of Eastern Mediterranean Agronomic Institute research and experimentation field, Adana,during year 2012 and 2013. The research site is situated 20 m above the sea level and is located on 36° 56′ N longitude and 35° 18′ E latitude, with a typical Mediterranean climate. In the study, genotypes with normal Sanbroand Tunca (No.1 and No.2), Sanay mid oleic and 10 TR 054 (No.3 and No.4) and high oleic P64 H 34 and Oleko (No.5 and No.6) fatty acid characteristics, were used as plant material. Soil of experimental site is Arıklı series, characterized with clay content on the alluvial deposits of old river terraces (Bicer 1987). The study field contains high level of lime content, and is separated from Arpacı and Mürsel series that were located in the same physiographic unit by its color, clay content and deep crack formations (Dinc et al. 1995). The soil of the experiment location was slightly alkaline, with very low organic matter (1.94%), and adequate potassium content. The soil contained 49.3 kg ha^{-1} of plant-useful P_20_5, which was favorable for sunflower cultivation. The field capacity and permanent wilting point for a 90 cm soil depth and the effective root zone were 402 mm and 261 mm, respectively. Monthly average temperatures during the two years of the study were about 22 °C and the total amount of precipitation was 32 mm in the study period (Anonymous 2013). Precipitation over the years of the experiment was higher in the month of May and in September for several years, and lower in other months. The temperature during the research period was quite similar with that of other years. However, relative humidity was around 15% in all the months which was an optimum period for sunflower cultivation.

In the study, planting was performed on April 5, 2012 and April 20, 2013. Parcel length was 7.20 m, row spacing was 70 cm and intra row distance was 30 cm, and the total parcel area was (0.7 m x 7.20 m x 4 rows) 20 m^2. Seeds were sown with a seed drill to a depth of about 4 cm, and 250 kg ha^{-1} 20-20-0 compound fertilizer was used in the experiments. During the growth period, soil moisture content of the control treatment was measured using the gravimetric method and three irrigation exercises were performed when there is 50% water consumption from the available water capacity, through the crop root zone depth. In the first experimental year, 55 days after the seeding (15 May 2012), in the second experimental year, 54 days after the seeding (29 May 2013), 121 mm of irrigation water was applied to 0-90 cm soil depth for all the parcels. To irrigate the experimental parcels, 3 m x 3 m of wetting diameter, under 0.2 MPA pressure, and a 75 L h^{-1} flow rate sprinklers were used. In the second and third irrigation, drip irrigation system was used. In addition, a barrier circled the area where all the parcels were located, and no water entry or exit was allowed into the experimental parcels. The quality of the irrigation water was C_2S_1, which did not pose a problem for the irrigation of sunflower plants. Samples from each 30 cm of the 90 cm soil profile were taken, to determine the amount of irrigation water needed to be applied on the parcels. The principles proposed by Gungor et al. (2006) were considered, in order to determine the amount of water used in the parcels. Water Use Efficiency, WUE were calculated by dividing yield (kg ha^{-1}) to seasonal evapotranspiration (mm), and the unit irrigation water applied (mm), respectively (Howell et al. 1990). Evapotranspiration was calculated using the following water budget equation (Garrity et al. 1982).

$$ET=P+I-Rf-Dp\pm\Delta S \qquad (1)$$

Where, ET- is Evapotranspiration (mm), P- is Precipitation (mm), I- is Irrigation (mm), Rf- is Runoff (mm), Dp- is Deep Percolation (mm), and ΔS- is the changes in soil moisture content in the root zone or the storage difference between the beginning and the end of the season (mm).

The plant water stress index was determined using the principles found by Gencoglan (1996). Crop Water Stress Index (CWSI) was calculated using the following equation as suggested by Idso et al. (1982).

$$CWSI=[(Tc-Ta)-LL]/UL-LL \qquad (2)$$

Where, CWSI- is the Crop Water Stress Index, Tc- is the Temperature of canopy (°C), Ta-is the air temperature (°C), LL- is the Lower Limit (the limit value in which the plants transpire at the potential pace), where there is no stress on the plant, and UL- is the Upper Limit (the limit value in which the plants are assumed not to transpire) where the plants are completely under stress. Chlorophyll content was measured indirectly by a portable chlorophyll meter device (Minolta SPAD- 502, Osaka, Japan). Chlorophyll measurements were conducted on the same leaves and plants before and after the irrigation.

The harvest was performed in the middle of two rows, out of the four rows, so the two plant rows on the other side would be ignored. The harvest parcel area (0.7 m x 6.9 m) was 4.83 m^2.The harvest was performed on September 23, 2012 and 29 September, 2013, respectively. During the trial, the required maintenance work and cultural practices were performed according to the standard procedures. In the assessment of the research data, JUMP statistics software package was used.

3.Results and Discussion

Water consumption and irrigation water applied. Evapotranspiration or crop water use, irrigation water usage, Crop Water Stress Index (CWSI), chlorophyll content and the proportional irrigation quantities arepresented in Table 1. Irrigation water during the years of study were applied 3 times between 87 mm and 137 mm; the total amount of irrigation water used was 524 mm. Seasonal Evapotranspiration (ET) were found to be 567 mm-578 mm, and as the average of two working years on the condition that the figures differed in the genotypes, which were fully watered. Depending on the increasing irrigation water, the seasonal ET values also increased. This was due to the fact that plants continued to benefit from the moisture in the soil, even though the precipitation during the period of vegetation has decreased and accurate irrigation practices in the area have ceased.

Especially during the pre-flowering and flowering periods (NYD 175), high temperatures resulted in low crop yield and quality. For an increased yield, consumption of more than 50% of the consumable moisture should not be allowed during the late vegetative, flowering and grain filling periods of the sunflower plant (Doorenbos and Kassam 1986). It can be revealed that second year trial provided a better environment for the development of sunflower plant when the data for both trial years was compared. Due to the temperatures, grain yield decreased in second plantings for all genotypes, when compared to the initial plantings. Grain filling rate decreased due to the increase in temperatures during the grain filling phase, while the grain filling duration decreased (Wardlaw and Moncur 1995; Ginkel et al., 2004). In a study by Gibson and Paulsen (1999), it was reported that the increase in daytime/nighttime temperatures from 20/20°C to 35/20°C post-flowering, under controlled conditions resulted in a decrease of 78% in the yield, 63% in grain number, and 29% in the grain weight. The study findings demonstrated that excessive temperatures affected grain yield statistically, within a significance level of 99% (Table 1). An assessment of the years of research done together showed that the highest grain yield in the first planting was obtained with No.5 genotype as 3.82 kg ha^{-1}, and the lowest grain yield was obtained with No.2 genotype as 3.16 kg ha^{-1}. In the second planting, the highest grain yield was obtained with No.5 genotype as 3.48 kg ha^{-1}, and the lowest grain yield was obtained with No.2 genotype as 2.793 kg ha^{-1}.

Table 1. Sunflower yield, genotypes, CWSI, chlorophyll content, applied water, evapotranspiration, WUE

Subject	Genotypes	Grain yield (kg ha^{-1})	Crop water stress index (CWSI)	Chlorophyll content (spad)	Irrigation water (mm)	ET (mm)	WUE (kg m^{-3})
First planting	No.1-OLEKO	3533c	0.44a	43.7j	524	560	0.63c
	No.2-P64H34	3163d	0.30c	45.8g	524	553	0.58f
	No.3-SARAY	3568c	0.17d	47.9f	524	564	0.63c
	No.4-10 TR 054	3284cd	0.11e	48.5e	524	574	0.57g
	No.5-TUNCA	3818a	0.13e	54.20b	524	586	0.66a
	No.6-SANBRO	3646b	0.21c	55.80a	524	567	0.64b
LSD (0.05)		9.5	0.30	0.24			0.45
Second planting	No.1-OLEKO	3335c	0.67a	41.21	524	571	0.58f
	No.2-P64H34	2793f	0.54a	43.2k	524	565	0.50j
	No.3-SARAY	3394b	0.43b	44.74ı	524	576	0.59e
	No.4-10 TR 054	3169d	0.22c	45.32h	524	587	0.54h
	No.5-TUNCA	3480a	0.27c	49.87d	524	594	0.60d
	No.6-SANBRO	2981e	0.29c	51.45c	524	599	0.51ı
LSD (0.05)		3.9	0.30	0.24			0.006

**Means shown with identical letters in the same column are statistically similar based on LSD test within the error limit of P<0.05.*

As the temperatures increase, the grain yield decreased. Significant differences were found between the yield in genotype No.5 and genotype No.2 due to the thermal effect. It could be stated that the decrease in the yield in the second time trial was as a result of the increase in the vegetative and generative development, and wilting was due to the thermal stress; the decrease in the grain count per table was due to the shortening of the pollination phase; and lower grain weight. The decrease in the yield in late planting compared to regular planting, demonstrated the effect of the temperature (Ortiz Ferrara et al. 1994).

Gajendra and Giri (2001) studied the effects of irrigation (full blossom in mustard, table formation and flowering periods in sunflower) and nitrogen doses (40 and 80 kg ha^{-1}) on sunflower performance in India during the periods of 1995-1996 and 1996-1997, in different plantation times (October 19-November 17, 1995 and October 16-November 18 1996). They determined that early planting was of better quality than late planting, irrigation did not affect the yield parameters in both crops, however, the nitrogen dose caused significant differences in grain yield. The lowest Water Use Efficiency (WUE) values were obtained by genotype No.4 (0.57 kg m^{-1}) at the first trial, and the highest values were obtained by genotype No.5 (0.66 kg m^{-3}). In the second trial, the lowest WUE values were obtained by genotype No.2 (0.50 kg m^{-3}), and the highest values were obtained by genotype No.5 (0.60 kg m^{-3}).Thus, it could be stated that genotype No.5 utilized the irrigation water to an optimum level when compared to other genotypes. It could be argued that these differences were due to the type and variety of the plant, regional climatic conditions, crop density, implemented irrigation program, and cultural operations (Goksoy et al. 2004; Demir et al. 2006); Kazemeini et al. 2009; Sezen et al. 2012).

Crop Water Stress Index (CWSI) and Chlorophyll-Meter (CM)

The data used for CWSI were collected through leaf canopy temperature readings between 12:00-14:00 hours which was the maximum, and the meteorological data for the field of study between the period of 20.05.2012 (DOY 140) to 02.07.2012 (DOY 182) in the first year of the study and between 25.05.2013 (DOY 145)-07.07.2013 (DOY 187) in the second year of the study. The Lower Limit (LL)and the Upper Limit (UL) equations are given in Figure 1(a) for the study years. Figure 1(a) demonstrates that for the Lower Limit (LL) equation, it was assumed that there was no water stress, and the plant which is in evapotranspiration, was determined as Tc-Ta =0.0.68-1.150 VPD (R^2 =0.766). The cross-sectional values for the LL line were found to be positive. Idso et al., (1982) indicated that, the cross-sectional value can not be lower than zero, and this is as a result of the fact that, there would still be a positive evaporation from the leaves towards the atmosphere, even when vapor pressure deficit and VPD is lowered to zero by saturation in the atmosphere. Thus, based on the LL equation, it could be revealed that there was a positive evaporation towards the atmosphere during the whole measurement period, as mentioned in the previous studies conducted by Gençel (2009).

The Upper Limit (UL) equation that assumes the plant is completely under water stress was determined as Tc-Ta = -2.357+1.115 VPG (R^2=0.824). Since the slope was ignored due to the fact that, it was too small in the UL equation, the differences between the canopy temperature and the ambient temperature were calculated as 0.54-0.34 ºC, for the first and second years of the research. Although, the CWSI values measured for the trail subjects that were planted at different times, varied mainly between 0 (no water stress) and 1 (maximum water stress), some values gave negative figures. Negative CWSI values occurred due to the fact that measurement values used in calculations were below the LL line, as seen in Figure 1(a).

Mean CWSI values (LSD) determined for different planting periods in the years of research are presented in Table 1. Obtained CWSI values demonstrated statistical differences depending on the planting times. Table 1 shows that mean CWSI values determined for planting periods combined for the years of research were the highest in genotype No.1 in the first planting (0.44) and the lowest in genotypes No.4 and No.5 (0.11 and 0.13, respectively). It varied between those two figures in the other genotypes. It obtained the highest in No.1 genotype in the second planting (0.67) and the lowest in genotypes No.4 and No.5 (0.22 and 0.27, respectively). It varied between these two figures in the other genotypes. It was determined that the CWSI values identified for all irrigation programs during the months of July and August, were partially higher than the CWSI values identified during the vegetation phase as seen Figures 1(b) and (c). This could be related to the fact that the temperatures during the months of July and August, especially in the first year of sunflower cultivation were higher compared to the previous months. The graph which shows the CWSI values determined based on the days of measurement during the genotype cultivation period, demonstrates that, CWSI values, which increase based on the severity or excess of the water limitation applied, tended to be at maximums prior to irrigation, albeit, it decreased after the irrigation.

Generally, the decrease in soil moisture before irrigation causes an increase in plant canopy temperatures, hence, resulting in high CWSI values. Köksal (1995) discovered the CWSI values for the subject with the highest water intake as 0.13-0.43 and for the subject with the lowest water intake as 0.42-0.73, under Cukurova conditions. Odemiş and Bastug (1999) reported that a certain period of time is needed after irrigation for the CWSI value to decrease, and this period is between 4 and 5 days. As the water content of the soil decreased, the plants under go water stress, and hence, an increase in CWSI value is observed. Simsek et al. (2005) stated that CWSI values varied based on the amount of irrigation and that, generally high CWSI values resulted in the loss of crop yield.

Orta et al. (2002) conducted a study to determine the Crop Water Stress Index (CWSI) in sunflowers under Tekirdağ province conditions and to scrutinize the relationship between the crop stress index and the yield. For each trial subject, different irrigation water amounts were applied. The trial covered two years with different study subjects. The trial studied T1, T3, and T5 trial subjects during the initial year and T1, T2, T3, T4, and T5 trial subjects during the second year. In the study, 100% of the irrigation required for the sunflower plant was implemented in T1; 75% was implemented in T2; 50% was implemented in T3; 25% was implemented in T4; and 0% was implemented in T5. The result showed that, Crop Water Stress Index (CWSI) values were determined and the CWSI value to obtain a high yield was indicated and utilized in the irrigation programming. As a result, researchers concluded that CWSI value could be used as a criterion to determine the irrigation time that will be suitable to obtain the highest yield when CWSI values reached 0.44 and 0.48. Threshold CWSI values obtained by the studies that was mentioned above demonstrated partial difference among the studies.

At the end of this study, it is possible to argue that the genotype with the lowest CWSI was the genotype No. 5, and even under high temperatures genotype No: 5 produced optimum yield (3818 kg ha^{-1}) when compared to others, and genotype No: 2 was sensitive to high temperatures and aridity and was affected negatively, hence the yield dropped (2793 kg ha^{-1}). Thus, it could be suggested that the plantation of variety (No.2) should not be conducted during the days of pollination with high temperatures.

The maximum chlorophyll content was found in the first planting trial of genotypes No.5 and No.6, which stood at (54.20 and 55.80 spad, respectively); and the lowest chlorophyll content was identified in genotype No.2 (41.21 spad). Chlorophyll values were not distinctive between the subjects during the vegetative period. This could be linked to the fact that plants were not completely under thermal stress, during the above-mentioned period. There was a tendency in the second planting trial, where the leaf chlorophyll content of the plants, under thermal stress were low, whereas, in the first planting trial, the leaf chlorophyll content of the plants under thermal stress were high. The variations between the subjects depended on the growth periods, which also showed that chlorophyll values decreased generally during the late vegetative period. A combined evaluation of the years of the study demonstrates that chlorophyll values for plants under thermal stress rapidly decreased in elapsed time. Several previous studies also indicated that chlorophyll rates in the leaves differed between the pre-irrigation and post-irrigation, and the plants lowered their chlorophyll rates due to thermal stress before the irrigation (Fernandez et al. 1997; Demirtas and Kırnak 2009). The findings of this study corresponds with previous studies in the sense that, the chlorophyll-meter values that vary based on the chlorophyll content in leaves differed between pre-irrigation and post-irrigation, based on the genotypes.

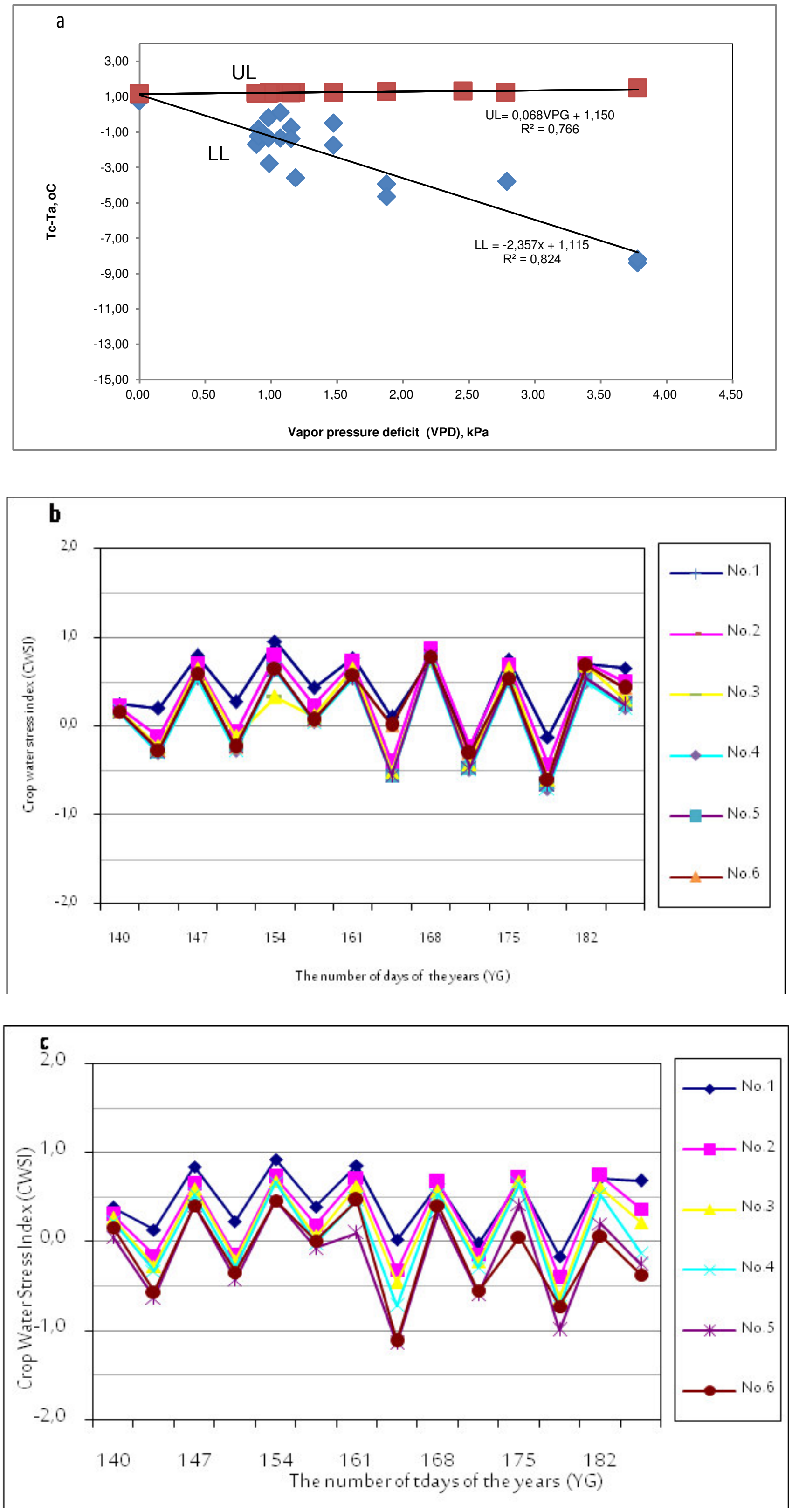

Figure 1. (a) The relationship between (LL) and (UL) limits of crop water stress index. (b) the first planting, and (c) the second planting during the vegetation period.

4.Conclusion

Genotype grain yield, leaf chlorophyll content (spad), canopy temperature, or crop water stress index were scrutinized based on plant water use in this study spanning two years. It could be argued that temperature is one of the most significant of all the abiotic stress factors in Çukurova, that caused physiological changes in the plants. Thermal stress, in addition to the fact that it affects the growth and development of the plant negatively, it also affects the crop yield significantly. Acceleration in vegetative and generative development, premature wilting in the leaves, and a tendency for an increase in plant water use were observed in the second planting season due to thermal stress. Thus, it could be argued that thermal stress promoted premature flowering, although, flowering date and physiological maturity period are closely related to the genetic properties of the genotypes.

As a result of the study, we discovered that the reasonably heat tolerant genotypes No. 4 and No.5 (based on 0-0.5 scale) could be used by other researchers in future sunflower agronomy studies. It is possible to state that, in both time trials, the genotypes with the lowest CWSI were the genotypes No. 4 and 5, genotype No.5 produced optimal yield even under high temperatures when compared to others (3818 kg ha^{-1}), genotype No. 2 was sensitive to high temperatures, hence, was affected negatively, thus, its yield dropped (2793 kg ha^{-1}). Therefore, it could be suggested that this variety should be planted so that the pollination should not occur during warm days under Çukurova or similar climates worldwide.It could be revealed that genotypes No.4 and No.5 utilized irrigation water more efficiently when compared to other genotypes. As a result, it could be stated that crop water stress index and chlorophyll content values could be used as assessment criteria to determine heat tolerant genotypes.

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