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The Relationship Between Flag Leaf Senescence and Grain Yield of Some Durum Wheat Varieties under Drought Stress During Grain Filling Period

Murat TİRYAKİOĞLU[a]

[a]*Mustafa Kemal University, Agricultural Faculty, Field Crops Department, Hatay,TURKEY*

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Corresponding Author: Murat TİRYAKİOĞLU, E-mail: mtiryaki27@gmail.com, Tel: +90 (532) 522 08 68
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ABSTRACT

This study aimed at investigating genotypic differences in the leaf area duration of durum wheat genotypes during grain filling periods and their relation to grain yield under two different irrigation conditions. The experiments were designed randomized complete block design for four replication in 2009/2010 and 2010/2011. Irrigation levels in main plots, cultivars were included in the sub plots. The study gathered data of six genotypes with similar anthesis times in Antakya/Hatay-Turkey. During the growth period, the two groups of plants received general management techniques and 60 kg ha^{-1} phosphorus and 80 kg ha^{-1} nitrogen (ammonium sulphate) fertilizer. Two different irrigation regimes were applied; the control group received full irrigation until reaching physiological maturity, while the experiment group was not irrigated after anthesis but instead received rainfall characteristic of WANA (West Asia North Africa). Results showed that flag leaf area (FLA) and lower leaf area (LLA) were not significantly related to spike grain yield (SGY) under control conditions. Flag leaf area duration (FLAD) was not related to grain yield, while the increase in lower leaf area duration (LLAD) reduced grain yield. Meanwhile, a positive relation was observed between FLA and SGY under experimental conditions, since SGY significantly increased according to the increase of FLAD. Moreover, high FLAD positively contributed to grain filling under both the conditions, while high LLAD partly contributed only under control conditions. These results suggest that the genotypes with low leaf number or short plant height and low tillering capacity should receive significant irrigation, while genotypes with middling plant height should be planted during conditions of drought stress. Under both the sets of conditions genotypes must have high FLAD.

Keywords: Flag leaf area; Lower leaf area; Leaf area duration; Drought stress; Grain yield; Wheat

Bazı Makarnalık Buğday Genotiplerinde Dane Dolum Dönemindeki Kuraklık Stresinde Bayrak Yaprak Yaşlanması ile Tane Verimi İlişkisi

ESER BİLGİSİ
Araştırma Makalesi
Sorumlu Yazar: Murat TİRYAKİOĞLU, E-posta: mtiryaki27@gmail.com, Tel: +90 (532) 522 08 68
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ÖZET

Çalışmada, bazı makarnalık buğday çeşitlerinde dane dolum dönemindeki kuraklık stresinde yaprak alan sürekliliği ile dane verimi arasındaki ilişki incelenerek, çeşitler arasında bu unsurlar yönünden herhangi bir farklılığın olup olmadığı araştırılmıştır. Çalışma, çiçeklenmesi aynı zamanda gerçekleşmiş altı adet çeşitle Antakya/Hatay koşullarında 2009/2010 ve 2010/2011 yetiştirme sezonunda yürütülmüştür. Deneme her iki yıl tesadüf bloklarında bölünmüş parseller deneme desenine göre dört tekrarlamalı kurulmuştur. Uygulamada sulama seviyeleri ana, çeşitler alt parsellerde yer almıştır. Fosforun tamamı ekimle birlikte (60 kg P_2O_5 ha^{-1}) tiriple süper fosfat şeklinde toprağa uygulanmıştır. Azot ise amonyum sülfat formunda ve ekim, kardeşlenme ve sapa kalkma dönemlerinde (30+30+20 kg N ha^{-1}) verilmiştir. Sulama uygulaması, fizyolojik oluma kadar sulama (I_1: tam sulama-konrtol) ve çiçeklenmeye kadar sulama (I_2: WANA: (West Asia North Africa) yağış rejimi) olarak iki farklı şekilde gerçekleştirilmiştir. Çalışma sonucunda; I_1 koşularında bayrak yaprak alanı (BYA), ile başak dane verimi (BDV) arasında önemli ilişki tespit edilememiştir. Benzer sonuç bayrak yaprak alan sürekliği (BYAS) ile dane verimi arasında da gözlenmiştir. I_2 koşullarında BYA ile BDV arasındaki ilişki, olumlu olmuştur. Sonuç olarak yüksek BYAS'ye sahip olma, her iki sulama koşulunda da danede madde birikimine olumlu etki yapmıştır. Bu sonuçlara göre, kuraklık stresi olmayan koşullarda bitkide yaprak sayısı daha az olan dolayısıyla kısa boylu ve az kardeşlenen, su tresi olan koşullarda ise orta boylu genotip modeli önerilebilir. Ancak her iki koşulda da bitki, bayrak yaprak alanı sürekliliği yönünden yüksek değere sahip olmalıdır.

Anahtar Kelimeler: Bayrak yaprak alanı; Alt yaprak alanı; Yaprak alan sürekliliği; Kuraklık stresi; Dane verimi; Buğday

1. Introduction

During the period of wheat spike growth, the important moment of assimilation that supplies carbon for the grain depends on the amount and quality of light on the surface of the green area after anthesis. This assimilation area normally decreases due to natural senescence and various stresses. At this time, the growing grain requires more carbon, and assimilation becomes essential for the survival of the plant (Blum 1998).

The leaf water potential decreased earlier (Royo et al 2004; Guóth et al 2009) and at a higher rate in the sensitive than in the tolerant cultivars (Entz & Fowler 1990; Yang et al 2001; Guóth et al 2009). Drought stress substantially increasd absisic acid (ABA) but reduced zeatin (Z) + zeatin riboside (ZR) concentrations in leaves (Yang et al 2003). In leaf tissue increased depending on the concentration of ABA is nitrogen and non structure carbohydrates is carried out transport of grains (Yang et al 2003). It also begins to decrease in chlorophyll content and photosynthesis rate drops (Yang et al 2001).

The contribution of dry matter (DM) to both the flag leaf (FL) and lower leaves (LL) allow the areas to either remain green for a definite period or continue to change according to the rate of senescence (Fischer & Kohn 1966; Borrell et al 2000; Blake et al 2007). However, data of only the size of the leaf area and its stay-green period cannot sufficiently determine the total efficiency of photosynthesis. In this situation, the leaf green area and its green period have a special function that increases the importance of green area duration (Mohiuddin & Croy 1980; Blake et al 2007), thus these factors affect the weight of the grain and its productivity. As a result, it is clear that this effect varies according to many factors, such as drought stress during grain filling (Yang et al 2001).

The grain DM accumulated in the share of LL is lower than its share from the FL. In fact, some stress conditions (e. g., droght stress) or cultural practices, such as excessive plant density, were not important contributors. LL contributes to the impotence of grain DM, while stress factors linked to premature aging (Finnan et al 1998; Öztürk 1999; Gelang et al 2000; Sahahand & Paulsen 2003; Valentinuz & Tollenaar 2004) or non-sparse planting (Borras et al 2003) are due to shadowing by the FL.

Therefore, a positive and significant relationship exists between leaf area and leaf area duration. According to Dokuyucu et al (1996), a positive and significant relationship also exists between FLA and FLAD. However, the size during flag leaf duration is also associated with a low yellowing rate. During leaf area duration, there is the large leaf area on the one hand, while on the other hand there is also what should be considered a late yellowing property.

This study thus aimed at determining changes of aging in leaves and the elements of aging during the period of grain development in order to examine both the relationship between grain yields and whether there were any differences among the genotypes under conditions of drought stress.

2. Material and Methods

A study investigate 2 years was conducted at Antakya/Hatay (36° 15´ N, 36 13´ E; D 80 m) in 2009/2010 and 2010/2011. This region is called WANA (West Asia North Africa).

The soil in the study region consists of clay and mainly alluvium material and forms either flat or lightly sloping land. It has low organic matter with light alkali character. Before planting, total nitrate in the 600 mm profile was 0.86 mg during the first year and 0.76 mg during the second year. The experiments were designed randomized complete block design with four replications in first and second year. Irrigation levels in main plots, cultivars were included in the sub plots. The study was performed on six cultivars (i. e. of CIMMYT origin; Amanos-97, Ceylan-95, Fırat-93, Gediz-75, Harran-95, and Zenit (Italian origin) whose anthesis occurred on the same day (Koç et al 2002). These cultivars were sown on 27 November during the first year and on 10 December during the second year. Sowing was performed in eight lines of 6 × 1.2 m, each 0.2 m apart. The seeds were sown with a planter at 450 seeds m^{-2}. Whole phosphorus (60 kg P_2O_5 ha^{-1}) was mixed with the soil as triple superphosphate, while nitrogen in the form of ammonium sulphate was given during planting, tillering and stem elongation (30 + 30 + 20 kg N ha^{-1}). To germination properly after planting, 45.3 mm (20.3 + 25.0) and 50.5 mm (24.7 + 25.8) of water were given via a sprinkler irrigation system during the first and second years, respectively. After germination, the time and the amount of water were considered, as well as the PAN evaporating values and amount of rain. When the amount of water in the soil reached 50% field capacity, a decreased amount of water was added to the soil by irrigation (Table 1). The irrigation activities were performed in one of two ways; the control group received irrigation until

Table 1- Rainfall occurred in both vegetation (first and second year) period and the amount of irrigation at I_1 and I_2 (mm)

Çizelge 1- Birinci ve ikinci yıldaki yağış ve her iki koşulda (I_1 ve I_2) yapılan ilave sulama miktarları (mm)

Irrigation times	*2009/2010*					*2010/2011*					
	*Rain**	*Irrigation*		*Irrigation + rain*		*Irrigation times*	*Rain**	*Irrigation*		*Irrigation + rain*	
		I_1	I_2	I_1	I_2			I_1	I_2	I_1	I_2
November	150.0	0.0	0.0	150.0	150	November	0	15.8	15.8	15.8	15.8
December	290.1	0.0	0.0	290.1	290.1	December	207.4	0.0	0.0	207.4	207.4
January	188.7	0.0	0.0	188.7	188.7	January	85.3	0.0	0.0	85.3	85.3
February	99.6	0.0	0.0	99.6	99.6	February	128.0	0.0	0.0	128.0	128
March	42.9	19.5	19.5	62.4	42.9	March	81.2	0.0	0.0	81.2	81.2
April	15.1	48.1	0.0	63.2	15.1	April	45.9	20.2	0.0	66.1	45.9
May	9.2	65.8	0.0	75.0	9.2	May	13.2	58.9	0.0	72.1	13.2
Total	795.6	133.4	19.5	929.0	795.6		561.0	94.9	15.8	655.9	576.8

*, total rainfall between two time periods

physiological maturity (I_1: No drought stress), while the experiment group received irrigation only until anthesis (I_2: Drought stress after heading).

During the period from anthesis to maturity, the thermal period [i. e. growth degree day [GDD]] was calculated with the following formula (1):

$$GDD = \Sigma Td;\ Td = (T_{max} + T_{min}) / 2 - Tb \quad (1)$$

Where; *Td,* signifies average daily temperature; T_{max}, signifies the highest temperature recorded during the day; T_{min}, signifies the lowest temperature recorded during the day and *Tb* signifies the lowest temperature at beginning of growth. In this study, Tb= 0 was assumed (Bauer et al 1985). Anthesis for 50% of the plants during the first growing season began on April 12 and during the second growing season on April 19.

Figure 1(a) shows the change in the thermal period (°C day) and the slope lines during the first and the second growing seasons, while Figure 1(b) shows those changes from anthesis to maturity. During anthesis, 200 plants (mean stem) were marked in each plot. While analysing the first sample according to Zadoks Growing Scale (ZGS) (Zadoks et al 1974) and considering the grain development period of varieties, samples with ZGS of 65, 71, 80, 85, 88, and 91 were taken during both the years. For each sample, 20 main stems (ms) were cut at soil level, and leaf areas were measured by leaf area meter (Li-3100, LI-COR Biosciences, Lincoln, NE, USA). During the grain maturity period, the amount of grains in each spike, the spike grains number (SGN), single grain weight (SGW), and the spike grain yields (SGY) were calculated.

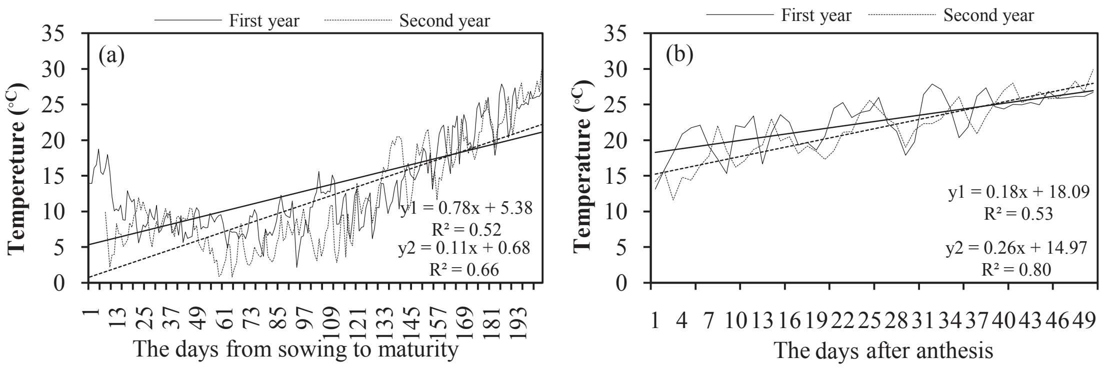

Figure 1- Change of the thermal period (°C day) and the slope lines during first and second growing season (a) and from anthesis to maturity (b) in the experiment years

Şekil 1- Her iki deneme yılında ekimden tam oluma (a) ve çiçeklenmeden tam oluma (b) kadarki süreçte termal periyottaki (°C day) değişim ve eğim çizgileri

2.1. Statistical analysis

Data collected from the samples were subjected to separate or combined variance analysis using SPSS (SPSS Inc., Chicago, IL, USA) according to the randomized complete block design. During grain filling, the leaf area was measured at different time points. First, the graphical bent function of the flag and lower leaves was used depending on the course of time to determine the decrease in the green area. This process was practised for testing according to different functional equations (i. e. direct, cubic and quadratic). At the end of the tests, the senescence functional bent was determined by way of a cubic model ($f(x) = ax^3 + bx^2 + cx + d$). With this equation, the following parameters of leaf senescence were calculated.

Green Area Duration (GAD): These data were calculated by considering the anthesis (t_1) and the time that the green area became spoiled (t_3) according to the bent function for the flag and lower leaves. The integral of the time interval between them was found by calculating as under:

$$\int_{t_1}^{t_2} f(x)dx = F(c) - F(a) \quad and \, (t_1 = 0) \rightarrow F(x) = F(t_3) \qquad (2)$$

$$F(x) = 3a\frac{x^4}{4} + 2b\frac{x^3}{3} + c\frac{x^2}{2} + dx \qquad (3)$$

Senescence Period (SP): The senescence period (SP) was calculated according to the number of days from anthesis (t_1) to the time when the green area was non-existent (t_3).

$$SP = t_3 - t_1 \Rightarrow SP = t_3(t_1 = 0) \qquad (4)$$

The data obtained were subjected to the variance analysis and means were compared by LSD tests. Additionally, correlation coefficients were determined among the characters studied..

3. Results and Discussion

3.1. The flag and lower leaves areas

Both flag leaf area (FLA) and lower leaves area (LLA) were found to differ by year. In both the leaf areas, higher values were measured during the first year than in the second year (Table 2) (Figure 2). Droughts during the grain filling period in the I_2 application did not cause differences in FLA and LLA values compared to the I_1 application. These results in the study of different irrigation practices have been completed before the commencement of the development stemmed from plant leaves.

For FLA values, no statistical difference was determined among irrigation activities between years (Table 2), which could derive from maximum FLA, for when FLA took its final form, a different watering technique was not being used and thus all plants grew under similar conditions.

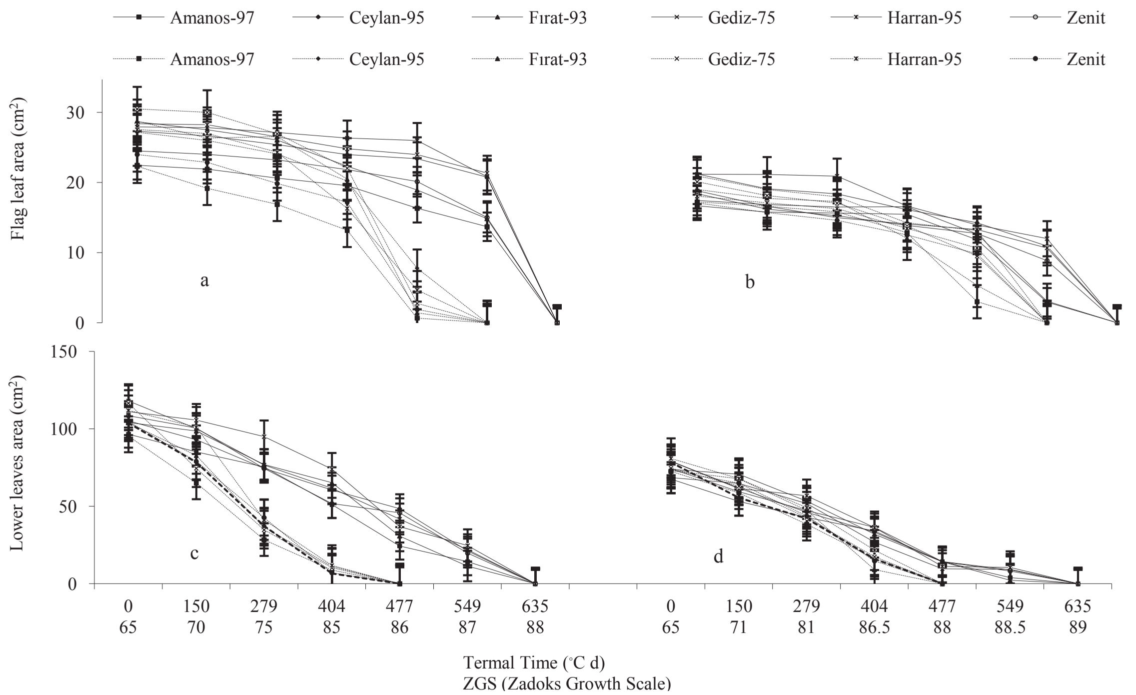

Figure 2- Six durum wheat cultivars grown under two different irrigation regime (I_1 and I_2), the change of flag leaf area (a- b) and lower leaves area (c-d) senescence from anthesis to maturity in first (a and c) and second (b and d) year

Şekil 2- İki farklı sulama rejminde (I_1 ve I_2) altı makarnalık buğday çeşidinin çiçeklenmeden oluma kadarki dönemde bayrak yaprak (a-b) ve alt yaprak alanlarındaki (c-d) birinci (a-c) ve ikinci (b-d) yıl değişim seyri

Although the FLA developed differently among the species, three groups could be distinguished over the study period of two years. Ceylan-95 (28.0-21.4 cm^2 ms^{-1}) and Gediz-75 (29.3-20.8 cm^2 ms^{-1}) had the highest FLA during both the years, while Amanos-97 (22.3-16.8 cm^2 ms^{-1}) had the lowest FLA. The FLA of Fırat-93 (28.1-17.9 cm^2 ms^{-1}) became noticeable as the cultivar whose FLA fluctuated most.

Genotypic differences similar to FLA were significant regarding LLA, while irrigation and interaction were insignificant (Table 2). LLA values changed from 117.2-96.8 cm^2 ms^{-1} during the first year to 78.7-70.7 cm^2 ms^{-1} during the second year. The highest LLA value was obtained from Gediz-75 and Harran-95 during the first year and from Harran-95 and Ceylan-95 during the second year. The lowest LLA value appeared in Amanos-97 (96.8 cm^2 ms^{-1}) during the first year and in Zenit and Gediz-75 during the second year. No significant differences occurred among irrigation regimes, for they ceased after LLA had reached its maximum.

3.2. Senescence period in the flag and lower leaves

The flag leaf senescence period (SP_f) lasted longer during the first year (28.7 days) than during the second year (26.5 days) (Table 2). The difference between the years varied according to drought stress (I_1) and the non-existence of drought stress (I_2). The senescence period for the I_2 group decreased during both the years compared to the I_1 group. During the first year, the decrease occurred at a rate of 14.5%, while it decreased during the second year at 11.1%.

SP_f occurred at nearly the same time in all samples, though during the second year differences were statistically significant (Table 2).

Table 2- Six durum wheat cultivars grown under two different irrigation regime (I_1 and I_2) average values of the flag leaf area, lower leaves area and senescence period from anthesis to maturity in first and second year and according to the comparison groups of LSD test

Çizelge 2- İki farklı sulama rejminde (I_1 ve I_2) yetiştirilen altı adet makarnalık buğday çeşidinde çiçeklenmeden ölüme kadarki dönemde bayrak yaprak alanı, alt yapraklar alanı ve yaşlanma sürelerine ait ortalama değerler ve LDS karşılaştırma testine göre oluşan gruplar

Genotypes	*FLA (cm^2)*			*SPf (day)*			*LLA (cm^2)*			*Spl (day)*		
	I_1	*I_2*	*Avr.*	*I_1*	*I_2*	*Avr.*	*I_1*	*I_2*	*Avr.*	*I_1*	*I_2*	*Avr.*
First year												
Amanos-97	22.5	22.1	22.3 c	30.9	26.3	28.6	97.6	96.0	96.8 c	30.1 c	24.1 e	27.1 bcd
Ceylan-95	28.8	27.2	28.0 a	31.2	26.8	29.0	103.5	104.6	104.1 b	31.2 a	23.8 e	27.5 b
Fırat-93	27.9	28.4	28.1 a	30.7	26.3	28.5	105.5	105.0	105.3 b	30.1 c	24.1 e	27.1 cd
Gediz-75	28.4	30.3	29.3 a	31.2	26.5	28.8	117.2	117.1	117.2 a	31.1 a	24.7 d	27.9 a
Harran-95	25.2	27.4	26.3 b	30.8	26.6	28.7	111.2	116.6	113.9 a	30.5 bc	23.2 f	26.9 d
Zenit	27.3	23.9	25.6 b	31.2	26.5	28.8	109.7	105.1	107.4 b	30.9 ab	24.0 e	27.5 bc
Average	26.7	26.6	26.6	31.0	26.5	28.7	107.5	107.4	107.4	30.7	24.0	27.3
Second year												
Amanos-97	16.4	17.1	16.8 c	27.5 d	24.5 h	26.0 d	74.4	72.4	73.4 bc	26.5 b	20.9 c	23.7 b
Ceylan-95	21.5	21.2	21.4 a	28.4 b	25.2 e	26.8 a	79.3	77.7	78.5 a	28.2 a	20.8 c	24.5 a
Fırat-93	17.2	18.6	17.9 b	27.5 d	24.8 g	26.2 c	73.9	76.5	75.2 ab	26.7 b	20.4 d	23.6 b
Gediz-75	21.5	20.1	20.8 a	28.6 a	25.0 f	26.8 a	67.9	74.4	71.2 c	28.0 a	20.9 c	24.5 a
Harran-95	18.7	18.0	18.3 b	28.1 c	25.0 f	26.5 b	76.8	80.6	78.7 a	27.9 a	20.9 c	24.4 a
Zenit	18.3	17.0	17.7 bc	28.1 c	25.0 f	26.5 b	66.9	74.6	70.7 c	27.8 a	20.8 c	24.3 a
Average	18.9	18.7	19	28.0	24.9	26.5	73.2	76.0	74.6	27.5	20.8	24.2
	1.y	2.y		1.y	2.y		1.y	2.y		1.y	2.y	
Lsdirrig.	ns	ns		ns	**		ns	ns		**	**	
Lsd gen.	1.5 **	1.1 **		ns	0.1 **		4.67 **	3.86 **		0.4 **	0.3 **	
Lsdint.	2.2 **	ns		ns	0.10 **		ns	ns		0.5 **	0.4 **	
CV	5.6	5.8		1.6	0.3		4.26	5.07		1.4	1.1	

**, P<0.01; *, P<0.05; ns, non significiant; FLA, flag leaf area (cm^2 ms^{-1}); LLA, lower leaves area (cm^2 ms^{-1}); SP_f, senescence period of flag leaf (day); SP_l, senescence period of lower leaves (day).

SP for the lower leaves (SP_l) was negatively affected due to drought stress that occurred after anthesis and decreased at the rate of 21.8% during the first year and 24.4% during the second year, depending on the severity of drought stress. Although the decrease in SP_f occurred at similar rates during both the years, in SP_l the decrease occurred at a higher rate during the first year than during the second. This difference may have been caused by early higher temperatures during GFD (Figure 1). It was noticeable that the lower leaves had been negatively affected regarding flag leaf after high temperatures occurred during the first year.

The response of the genotypes to SP_l was different for each year. During the first year, the highest value was obtained from Gediz-75 (27.9 days), while the lowest was obtained from Harran-95 (26.9 days). Gediz-75 and Ceylan-95 had the highest value and Fırat-93 the lowest during the second year.

3.3. Flag and lower leaves area duration

The flag leaf area duration (FLAD) and lower leaves area duration (LLAD) both resulted from the areas being continually photosynthetically active. FLAD and LLAD were studied in three phases of 10 days each from the beginning of anthesis, though the third phase was generally shorter than 10 days.

During the first year, under I_1 conditions FL senescence ranged from 31.0 to 30.7 days, hence, the change in the FLAD and its relation to grain yield (Table 3).

Table 3- Average values six durum wheat cultivars grown under two different irrigation regime (I_1 and I_2) for the flag leaf area duration from anthesis to maturity in first and second year and according to the comparison groups of LSD test ($FLAD_{(F10)}$, over this period is the first ten days of flag leaf area duration; $FLAD_{(S10)}$, over this period is the second ten days of flag leaf area duration; $FLAD_{(T10)}$, over this period is the third ten days of flag leaf area duration; $FLAD_{(t)}$, total flag leaf area duration (cm^2 d))

Çizelge 3- İki farklı sulama rejminde (I_1 ve I_2) yetiştirilen altı adet makarnalık buğday çeşidinde çiçeklenmeden ölüme kadarki dönemde her iki yıldaki bayrak yaprak alan sürekliliği ve LSD karşılaştırma testine göre oluşan gruplar

	First year											
Genotypes	*FLAD(F10)*			*FLAD(S10)*			*FLAD(T10)*			*FLAD(t)*		
	I_1	*I_2*	*Avr.*	*I_1*	*I_2*	*Avr.*	*I_1*	*I_2*	*Avr.*	*I_1*	*I_2*	*Avr.*
Amanos-97	210 f	208 f	209 e	206 d	159 e	182 e	137 e	37 j	87 e	558	402	480 e
Ceylan-95	273 bc	261 cd	267 c	260 a	238 b	249 b	154 d	67 f	111 c	687	566	627 c
Fırat-93	280 b	281 b	280 b	269 a	241 b	255 ab	204 b	56 gh	130 b	751	578	664 b
Gediz-75	273 bc	318 a	296 a	265 a	259 a	262 a	225 a	61 fg	143 a	764	626	695 a
Harran-95	248 de	278 b	263 c	234 bc	226 c	230 c	164 c	52 hı	108 c	646	556	601 c
Zenit	233 e	234 e	234 d	239 b	195 d	217 d	156 d	46 ı	101 d	628	476	552 d
Average	253	263	258	245	220	233	173	53	113	672	534	603
	Second year											
Amanos-97	163 d	174 cd	168 c	147 d	121 f	134 c	46 c	13 g	30 e	356 de	308 h	332 d
Ceylan-95	191 b	189 b	190 a	174 b	163 c	169 a	71 a	31 d	51 a	436 b	384 c	410 a
Fırat-93	172 d	186 b	179 b	157 c	129 ef	143 b	49 c	16 g	32 d	378 c	330 fg	354 bc
Gediz-75	207 a	184 bc	196 a	187 a	148 d	168 b	72 a	25 f	48 b	467 a	357 de	412 a
Harran-95	171 d	173 cd	172 bc	143 d	144 d	143 c	73 a	28 de	51 a	387 c	346 ef	366 b
Zenit	167 d	162 d	165 c	143 d	131 e	137 c	65 b	27 ef	46 c	375 cd	320 gh	348 c
Average	179	178	178	158	139	149	63	23	43	400	341	370
LSD	1.y	2.y		1.y	2.y		1.y	2.y		1.y	2.y	
Irrigation	**	ns		**	**		**	**		**	**	
Genotypes	11.7 **	8.3 **		8.6 **	50.6 **		6.0 **	2.3 **		27.0 **	13.9 **	
Interaction	16.5 **	11.7 **		12.1 **	7.9 **		8.5 **	3.3 **		ns	19.6 **	
CV	4.4	4.5		3.6	3.7		5.2	5.3		4.4	3.7	

**, $P<0.01$; *, $P<0.05$; ns, non significiant

FLAD values and their interactions in both I_1 and I_2 irrigated conditions (except during 10 days during the second year) were statistically significant (Table 3).

Among the cultivars, the highest value of total flag leaf area duration ($FLAD_{(t)}$) occurred in Gediz-75 (695 cm^2 ms^{-1}) during the first year and in Gediz-75 (412 cm^2 ms^{-1}) and Ceylan-95 (40 cm^2 ms^{-1}) during the second year. The lowest value for both years occurred in Amanos-97 (480 - 332 cm^2 ms^{-1}) (Table 3). The FLA values of the cultivars were more often determinants on $FLAD_{(t)}$ than their senescence.

The difference between I_1 LLAD and I_2 LLAD values increased from anthesis to maturity and differed in value depending on I_1 and I_2 conditions. The values of I_2 conditions compared to I_1 conditions decreased at the rate of 7.90, 47.84, and 94.12% for first, second and third period, respectively, and the total decrease was 27.97% (Table 4).

Cultivar Harran-95 showed the highest total lower leaves area duration ($LLAD_{(t)}$) during both the years, while Amanos-97 showed the lowest value during the first year and both Zenit and Amanos-97 during the second. Drought stress occurring during GFD similarly and negatively affected the LLAD of all genotypes in both the years (Table 4).

FLAD and LLAD were mainly mediated by the size of LA and was independent to change in irrigation types (Tables 3 and 4). The relations between LA and LAD were mainly determined by senescence.

Table 4- Six durum wheat cultivars grown under two different irrigation regime (I_1 and I_2) average values of the lower leaves area duration from anthesis to maturity in first and second year and according to the comparison groups of LSD test ($LLAD_{(F10)}$, over this period is the first ten days of lower leaves area duration; $LLAD_{(S10)}$, over this period is the second ten days of lower leaves area duration; $LLAD_{(T10)}$, over this period is the third ten days of lower leaves area duration; $LLAD_{(t)}$, total lower leaves area duration (cm^2 day^{-1}))

Çizelge 4- İki farklı sulama rejminde (I_1 ve I_2) yetiştirilen altı adet makarnalık buğday çeşidinde çiçeklenmeden ölüme kadarki dönemde her iki yıldaki alt yaprak alan sürekliliği ve LSD karşılaştırma testine göre oluşan gruplar

Genotypes	*LLAD(F10)*			*LLAD(S10)*			*LLAD(T10)*			*LLAD(t)*		
	I_1	I_2	*Avr.*	I_1	I_2	*Avr.*	I_1	I_2	*Avr.*	I_1	I_2	*Avr.*
	First year											
Amanos-97	918	777	847 d	676	306	491 c	251 e	15.7 f	133 e	1845	1098	1472 c
Ceylan-95	994	900	947 c	769	379	574 b	333 b	17.1 f	175 b	2096	1296	1696 b
Fırat-93	1011	918	965 c	766	402	584 b	287 d	20.8 f	154 d	2064	1341	1703 b
Gediz-75	1085	926	1005 b	786	356	571 b	322 bc	21.3 f	172 bc	2193	1303	1748 b
Harran-95	1104	999	1052 a	890	505	697 a	367 a	26.1 f	196 a	2361	1529	1945 a
Zenit	1028	919	974 bc	760	402	581 b	310 c	20.3 f	165 c	2098	1341	1719 b
Average	1024	906	965	774	392	583	312	20.2	166	2110	1318	1714
	Second year											
Amanos-97	569 d	536 e	552 c	308 a	151 ef	230 b	17.6 c	0.0 e	9 c	1039 bc	830 g	934 d
Ceylan-95	583 d	531 e	557 c	290 b	166 e	228 bc	37.6 a	0.0 e	19 a	1064 b	848 g	956 cd
Fırat-93	660 a	630 b	645 a	297 ab	139 f	218 bcd	14.2 d	0.0 e	7 c	1120 a	923 ef	1021 b
Gediz-75	616 bc	579 d	598 b	265 c	167 e	216 cd	24.0 b	0.0 e	12 b	1043 b	893 f	968 c
Harran-95	636 ab	634 ab	635 a	315 a	202 d	258 a	36.9 a	0.0 e	18 a	1140 a	995 cd	1068 a
Zenit	513 e	597 cd	555 c	268 c	155 ef	212 d	37.9 a	0.0 e	19 a	950 de	901 f	926 d
Average	596	585	590	291	163	227	28.0	0.0	14	1059	898	979
LSD	1.y	2.y		1.y	2.y		1.y	2.y		1.y	2.y	
Irrigation	**	ns		**	**		**	**		**	**	
Genotypes	37.4 **	21.0 **		23.8 **	12.5 **		8.7 **	2.3 **		63.4 **	31.8 **	
Interaction	ns	29.8 **		ns	17.7 **		12.3 **	3.3 **		ns	45.0 **	
CV	3.8	3.5		4.0	5.4		5.1	16.3		3.6	3.2	

**, P<0.01; *, P<0.05; ns, non significiant

Flag leaf senescence has started immediately after anthesis in grain filling duration. However, in the course of senescence, particularly in controlled conditions, startup has been very slow, after the twentieth day of the period of grain filling was accelerated. In drought conditions, especially in the first year, mainly from anthesis leaf senescence has developed faster than control. Guóth et al (2009) in their study of wheat, the early drought reduces leaf water potential and that this reduction occurs faster than those who reported that tolerant. Borerell et al (2000) in their study sorghum, grain filling period of drought control in the leaves have reported accelerated aging. The findings from both studies, this study is associated with the findings. Leaf water potential is low, increases the concentrations of ABA in leaves (Yang et al 2003; Yang & Zhang 2006; Guóth et al 2009). Accordingly, a reduction in chlorophyll content (Calderini et al 2001; Yang et al 2001; Yang et al 2003; Yang & Zhang 2006) and consequently becomes fall occurs in photosynthetic activity (Shah & Poulsen 2003; Yang & Zhang 2006; Guóth et al 2009). Increased concentration of ABA in leaves to pieces TNC also leads to deflection of the leaf tissue (Yang et al 2003; Yang & Zhang 2006). Senescence is accelerated due to this process experienced (Yang & Zhang 2006).

Aging has developed faster than the flag leaf in lower leaves. One of the reasons that the lower leaves before the flag leaf is formed due to the older leaves. Another reason, the lower leaves obscured by the flag leaf and still compete in terms of lower leaves is the presence of light in themselves (Hopkins 1966).

There were no significant relationships between FL and SGY under well-irrigated conditions. However, significant relationships were found during the first year in samples under water-stressed conditions, though during the second year slight relationships were observable only during the second phase (Table 5).

The relationship between $FLAD_t$ and SGY was similar to the relationship between FLA and SGY. There was no significant relationship between FLAD and SGY during any of the 10-day phases under well-irrigated conditions, while significant relationships between FLAD and SGY emerged under water-stressed conditions and increased until late grain filling. Several studies have reported relationships between FLAD and grain yield, though

Table 5- Relationship between flag leaf area duration and the grain yield parameters of durum wheat cultivars grown under two different irrigation regime (I_1 and I_2), in first and second year (LA, Leaf area; SP, senescence period; LAD, flag leaf area duration; $LAD_{(t)}$, total lower leaves are duration; NGS, number grain in spike; SGW, single grain weight; SGY, spike grain yield; F_{10}, first ten days; S_{10}, second ten days; T_{10}, third ten days)

Çizelge 5- İki farklı sulama rejminde (I_1 ve I_2) iki yıl süreyle yetiştirilen makarnalık buğdaylarda bayrak yaprak alan sürekliliği ile dane verimi ve parametreleri arasındaki ilişki

	First year											
	LA	*SP*	*LAD*			*LAD(t)*	*LA*	*SP*	*LAD*			*LAD(t)*
			First10	*Second10*	*Thirt10*				*First10*	*Second10*	*Thirt10*	
	I_1						I_2					
NGS	-0.18	0.20	-0.28	-0.27	-0.13	-0.25	-0.35	-0.12	-0.43 *	-0.38	-0.21	-0.40
SGW	0.13	-0.22	0.40	0.34	0.27	0.39	0.46 *	0.17	0.53 **	0.52 **	0.36	0.52 **
SGY	-0.10	0.13	0.02	-0.01	0.14	0.08	0.57 **	0.29	0.53 **	0.75 **	0.80 **	0.69 **
	Second year											
NGS	0.24	0.32	0.22	0.31	0.04	0.23	0.15	0.14	-0.09	0.12	0.13	0.06
SGW	-0.18	-0.24	-0.19	-0.30	0.07	-0.19	-0.15	0.06	-0.08	0.08	0.17	0.06
SGY	0.27	0.33	0.22	0.30	0.12	0.26	0.01	0.35	-0.25	0.38	0.54 **	0.25

**, P<0.01; *, P<0.05; LA, leaf area; SP, senescence period; LAD, flag leaf area duration; $LAD_{(t)}$, total leaf area duration their results often differ. While some studies have reported a significant relationship between FLAD and grain yield (Fischer & Kohn 1966; Mohiuddin & Croy 1980; Gelang et al 2000; Blake et al 2007), other studies have found the relationships to be insignificant (Devendra et al 1983; Miralles & Slafer 1995). The relationships between FLAD values for each phase and SGY showed increases near the end of grain filling, though increases depended on a high R^2 coefficient. In short, SGY increased with delayed senescence.

The increase at LLA negatively affected SGY under well-irrigated conditions, though a positive interaction existed under water-stressed conditions, suggesting a slight contribution of LLs to grain yield when grain filling occurred under water-stressed conditions (Table 6).

High $LLAD_t$ under well-irrigated conditions negatively impacted SGY, especially during the late grain filling period (Table 6). Slight relationships between $LLAD_t$ and LLAD with SGY during each phase under water-stressed conditions suggested that the stay-green period of LLA could contribute to grain yield.

This study also observed that SGY was high in genotypes with high FLAD under water-stressed conditions. The genotypes of Gediz-75 and Ceylan-95 exhibited high FLDA and SGY, while Amanos-97 exhibited the lowest values for FLDA and SGY. Meanwhile, Harran-95 exhibited the highest SGY under water-stressed conditions during the second year-a finding supported by FLAD and high LLAD during the first 20 days after anthesis.

4. Conclusions

It was also observed that the effects of FLA and FLAD on SGY were positive but insignificant when drought stress was not a problem in WANA's agro-climatic conditions, in which temperature rose and rainfall decreased between the heading and physiological maturity of wheat. However, SGY was negatively affected by increases in LLA and LLAD (Table 6). In the case of drought stress during grain filling, high FLA positively contributed to SGY, and moreover, long stay-green periods for FL showed a significant role on SGY, while LL showed no contribution. Furthermore, significant differences were observed among genotypes for

Table 6- Six durum wheat cultivars grown under two different irrigation regime (I_1 and I_2), the relationship between lower leaves area duration and the grain yield in first and second year (LA, Leaf area; SP, senescence period; LAD, lower leaves area duration; $LAD_{(t)}$, total lower leaves are duration; NGS, number grain in spike; SGW, single grain weight; SGY, spike grain yield; F_{10}, first ten days; S_{10}, second ten days; T_{10}, third ten days)

Çizelge 6- İki farklı sulama rejminde (I_1 ve I_2) iki yıl süreyle yetiştirilen makarnalık buğdaylarda alt yaprak alan sürekliliği ile dane verimi ve parametreleri arasındaki ilişki

	First year											
	LA	*SP*	*LAD*			*LAD(t)*	*LA*	*SP*	*LAD*			*LAD(t)*
			First10	*Second10*	*Thirt10*				*First10*	*Second10*	*Thirt10*	
	I_1						*I_2*					
NGS	-0.29	0.20	-0.54 **	-0.74 **	-0.55 **	-0.65 **	-0.48 *	0.41 *	-0.78 **	-0.89 **	-0.61 **	-0.86 **
SGW	0.14	-0.39	0.40	0.64 **	0.41 *	0.52 **	0.51 *	-0.35	0.78 **	0.83 **	0.59 **	0.83 **
SGY	-0.36	-0.06	-0.50 *	-0.59 **	-0.51 *	-0.56 **	0.29	0.18	0.27	0.01	0.04	0.15
	Second year											
NGS	-0.29	0.19	-0.75 **	-0.61 **	0.18	-0.81 **	-0.47 *	0.23	-0.69 **	-0.39	--	-0.73 **
SGW	0.23	-0.07	0.69 **	0.41 *	-0.03	0.71 **	0.54 **	0.11	0.55 **	0.67 **	--	0.72 **
SGY	-0.31	0.26	-0.64 **	-0.71 **	0.26	-0.74 **	0.28	0.62 **	-0.13	0.68 **	--	0.17

***, P<0.01; *, P<0.05*

FLAD and LLAD; the genotypes with high FLAD were benefitted by high SGY. The contribution of LLAD to SGY changed according to year and was not as important as FLAD on genotypes. These results suggest that the genotypes with low leaf number or short plant height and low tillering capacity should receive significant irrigation, while genotypes with middling plant height should be planted during conditions of drought stress. Under both the sets of conditions genotypes must have high FLAD. FLAD must thus be taken into account when obtaining highly adapted genotypes (Gediz-75 and Ceylan-95) during the breeding process under WANA (West Asia North Africa)'s agro-climatic conditions.

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