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EFFECT OF REMOVAL OF SOME PHOTOSYNTHETIC ORGANS ON YIELD COMPONENTS IN DURUM WHEAT (*Triticum aestivum* L.)

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Abstract

This research was carried out in experimental field of Field Crops Department of Agricultural Faculty of Namik Kemal University in randomized split block design with three replications per treatment during 2004-2005 and 2005-2006. The objective of this study was to find out the contribution rates of awn, flag leaf, 1st upper leaf blade, 2nd upper leaf blade and other leaf blades to main yield components in three durum wheat cultivars (cv. Kiziltan-91, Kunduru-1149, and Yelken-2000). The results of this experiment showed that removal of awn, flag leaf, 1st upper leaf blade, 2nd upper leaf blade, and other leaf blades reduced significantly spike weight, number of grains per spike, grain weight per spike, and 1000-grain weight except the number of spikelets per spike. It was concluded that the organs play an important role in grain yield in durum wheat during grain filling stage.

Keywords: Photosynthetic organs, yield components, durum wheat.

Introduction

Products of photosynthesis are highly used in grain filling after heading (Thorne, 1973). Contribution of different photosynthetic organs to grain yield reduces with distance of these organs from grain. The most of photosynthetic products are obtained from upper photosynthetic organs of wheat plant during grain filling period (Austin and Jones, 1975 Mahmood and Chowdhry, 1997). In addition, ears of cool season cereals are photosynthetically active and play an important role in providing saccharides during grain filling (Jiang *et al.*, 2006).

During the grain filling period, awns, flag leaf, first upper leaf, second upper leaf and third upper leaf are the potentially efficient photosynthetic organs in terms of economic production in wheat (Mahmood and Chowdhry, 1997). Contribution rate of flag leaf to daily photosynthetic products varies from 50 % to 60 %. However, contribution rate of ear to grain yield is associated with ear type (awned ear or awnless ear; compact ear or sparse ear). Contribution of glumes and awns to grain yield can be very high depending on environmental conditions (Evans and Rawson, 1970; Birsin, 2005). Photosynthetic activity of ear depends on the release of CO_2 as result of respiration of grains (Migus and Hunt, 1980).

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Awns are very close to grains and their photosynthetic activity is very high. Besides, they have a xeromorphic characteristic. Thus, awns may serve as a high photosynthetic organ during periods of drought stress and actually compensate for flag leaf photosynthesis reduced by drought stress (Genc, 1977; Koc *et al.,* 1985; Weyhrich *et al.,* 1995). Therefore, awned cultivars of cool season cereals have more stable yields under warm and dry climatic conditions (Jiang *et al.,* 2006).

The main objective of this experiment was to determine the effects of the removal of main photosynthetic organs on the yield components, such as spike weight, number of spikelets per spike, number of grains per spike, grain weight per spike, and 1000-grain weight of durum wheat cultivars under the agro-climatic conditions of Tekirda during 2004-2005 and 2005-2006.

Materials and Method

An experiment was conducted at Experimental Field of Agricultural Faculty, Namik Kemal University in Tekirda, Turkey at latitude 40° 36’-40° 31’ and longitude 26° 43’-28° 08’and altitude 10 m during 2004-2005 and 2005-2006 growing seasons. The soil texture was slightly acidic (pH *6.5),* saltless (0.04 %), low in lime (0.63 %) and organic matter (1.66 %) content with adequate potassium and phosphorus. Climatic data during the growing period are shown in Table 1 below:

Table 1. The climatic data of the experimental area during the growing periods.

Months	Rainfall (mm)		Temperature (°C)		Relative humidity (%)	
	2004-2005	2005-2006	2004-2005	2005-2006	2004-2005	2005-2006
November	27.7	105.2	11.4	9.7	80.8	82.4
December	45.5	91.2	7.7	7.3	84.0	83.1
January	62.7	26.2	6.1	2.4	84.0	83.0
February	74.9	76.9	4.2	4.4	84.0	86.8
March	20.9	101.6	7.6	8.0	74.1	87.9
April	12.7	9.5	12.2	12.4	76.3	82.9
May	78.2	14.1	16.9	17.2	76.2	81.1
June	13.0	29.0	20.5	21.6	76.5	78.0

The experiment was laid out in a randomized split block design with three replications. Durum wheat cultivars viz. Kiziltan-91, Kunduru-1149, and Yelken-2000 were used in the experiment. Each cultivar was sown in a main plot (5 m^2)

consisting of 6 rows. The seeding rate was 500 seeds per square meter of plot. The cultivars were planted in mid November each year. A total of 130 kg N/ha and 50 kg P/ha were applied at sowing, tillering, and preanthesis periods in both years.

Following treatments were used and data were collected from 10 randomly selected plants at heading stage (59 stage of Zadoks scale):

T_1= Control (intact plants)

T_2= All leaf blades removed

T_3= All leaf blades and awns removed

T_4= Except flag leaf blade, other leaf blades removed

T_5= Except flag leaf blade and 1st upper leaf blade, other leaf blades removed

T_6= Except flag leaf blade, 1 upper leaf blade and 2nd upper leaf blade, other leaf blades removed

T_7= Only awns removed

T_8= Only flag leaf blade removed

T_9= Flag leaf blade and 1st upper leaf blade removed

T_{10}= Flag leaf blade, 1 upper leaf blade and 2nd upper leaf blade removed

Data were recorded from sample plants on spike weight, number of spikelet per spike, number of grains per spike, grain weight per spike and 1000-grain weight at maturity (92. stage of Zadoks scale). Data so collected were analyzed by using the analysis of variance techniques (Steel and Torrie, 1984) and Least Significant Different (LSD) Test was used to see the significance of treatment means (Düzgüneş *et al.*, 1987).

Results

Effects of 10 different treatments on spike weight, number of spikelets per spike, number of grains per spike, grain weight per spike, and 1000-grain weight are given in Table 2 and 3.

The results show that the spike weight was 3.54 g in 2005 and 2.95 g in 2006. Number of spikelets per spike was not statistically significant among the treatments, it was 22.75 in 2005 and 22.42 in 2006. Number of grains per spike was 49.97 in 2005 and 48.63 in 2006. Grain weight per spike was 2.79 g in 2005 and 2.35 g in 2006. Thousand-grain weight was 50.47 g in 2005 and 49.56 g in 2006. At heading stage, the crop received more rains, especially in May 2005 than in May 2006 (Table 1). Therefore, mean values of yield components obtained from 2004-2005 growing period were higher than those of 2005-2006 growing period.

Table 2. Yield components of wheat as affected by the removal of some photosynthetic organs in 2005.

Treatment	Spike weight (g)				Number of spikelet per spike				Number of grain per spike				Grains weight per spike (g)				1000-grain weight (g)			
	Cultivars			Mean	Cultivars			Mean	Cultivars			Mean	Cultivars			Mean	Cultivars			Mean
	Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000	
T.-1	4.57 a	4.22bc	4.34 b	4.37 a	23.07	23.27	22.07	22.80	57.20 ab	58.00 a	56.90abc	57.37 a	3.57 b	3.63ab	3.69 a	3.63 a	60.12 b	54.58def	64.61 a	59.77 a
T.-2	2.71 r	3.06 op	2.62 r	2.80 h	23.13	23.17	22.07	22.79	41.60 t	44.17 qr	45.00pq	43.591	2.09 q	2.19 p	2.37 n	2.22 i	43.50pqr	42.20 rs	44.73nop	43.48i
T.-3	2.35 s	2.65 r	2.35 s	2.45i	23.13	23.07	22.00	22.73	41.00t	41.00t	41.80 st	41.27k	1.79 s	1.93 r	2.15pq	1.96 k	37.80t	40.97 s	42.92 qr	40.56 k
T.-4	3.60 kI	3.68jk	3.72jk	3.67 e	23.00	23.07	22.00	22.69	52.47ghi	52.93fgh	50.00jk	51.80 e	2.941	2.81 j	2.84j	2.86 e	53.24 fg	48.52 kI	51.76 hi	51.17 e
T.-5	3.77hij	3.85ghi	4.04def	3.89 d	23.07	23.00	22.00	22.76	54.00 ef	53.73 fg	52.00 hi	53.24 d	3.03 h	3.07 h	3.22fg	3.11 d	55.35 de	50.40 ij	55.65 d	53.80 d
T.-6	4.01efg	4.05def	4.17 cd	4.08 c	23.07	23.10	22.07	22.74	55.73cd	55.50 cd	55.20 de	55.48 c	3.16 g	3.25ef	3.30de	3.23 c	57.30 c	52.95 gh	57.47 c	55.91 c
T.-7	4.25 bc	4.15cde	4.23 bc	4.21 b	23.10	23.13	22.07	22.77	56.50bcd	56.53bed	56.00bed	56.34 b	3.28ef	3.49 c	3.37 d	3.38 b	58.32 c	54.07efg	58.68 c	57.02 b
T.-8	3.91fgh	3.48Im	3.76 ij	3.72 e	23.13	23.07	22.00	22.73	46.83mno	51.33 ij	49.20 kI	49.12 f	2.73k	2.65 I	2.641	2.67 f	53.41 fg	46.00mn	51.16i	50.19 f
T.-9	3.00pq	3.24n	3.43m	3.22f	23.13	23.13	22.20	22.82	44.20qr	47.07mn	48.l0lm	46.46g	2.30o	2.52m	2.55m	2.46g	47.171m	45.00no	49.75jk	47.31 g
T.-10	2.88 q	4.16 no	2.98 pq	3.01 g	23.00	23.13	22.07	22.73	43.20 rs	45.57opq	46.30nop	45.02 h	2.17 p	2.35 n	2.50 m	2.34 h	45.57 n	44.00 oq	47.00 m	45.52 h
LSD	CV.: -			T.: 0.086	CV.: - 0.077			T.:	CV.: - 0.815			T.: 0.841	CV.: - 0.029			T.: 0.045	CV.: - 0.750			T.: 0.806
(P≤0.05)	CV. x T. : 0.1464				CV. x T. : -				CV. x T. : 1.4669				CV. x T. : 0.0732				CV. x T. : 1.4062			

Table 3. Yield components of wheat as affected by the removal of some photosynthetic organs in 2006.

Treatment	Spike weight (g)				Number of spikelet per spike				Number of grains/spike				Grain weight/spike (g)				1000-grain weight (g)			
	Cultivars			Mean	Cultivars			Mean	Cultivars			Mean	Cultivars			Mean	Cultivars			Mean
	Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000		Kiziltan-91	Kunduru-1149	Yelken-2000	
T. -1	3.56e	4.43a	4.02b	4.01 a	22.13	23.40	21.83	22.46	52.93 cd	56.20 ab	56.95 a	55.36 a	2.60e	3.41 a	3.21 b	3.07 a	50.90i	59.20 a	56.00cd	56.00cd
T.- 2	2.15r	2.59o	2.63 no	2.45 h	22.33	23.33	21.60	22.39	43.17 pq	43.00 pq	45.33 mn	43.83i	1.64 r	2.14lm	2.02 no	1.94 h	41.50 r	50.13 i	44.90no	44.90no
T. -3	1.75 s	2.40 p	2.30 q	2.15i	22.20	23.37	21.73	22.43	41.83 qr	41.00r	43.20 op	42.01k	1.38 s	1.90 p	1.76 q	1.68i	40.43 s	45.30n	36.l0t	36.l0t
T. -4	2.70mn	2.91 i	2.90 ij	2.84 e	22.17	23.30	21.27	22.24	48.00 ij	47.50 ijk	51.47 ef	48.99 e	2.08mn	2.41ghi	2.40ghi	2.30 e	45.57mn	54.70 ef	49.00j	49.00j
T. -5	2.84jk	3.11 h	3.31 g	3.09 d	22.33	23.60	21.67	22.53	49.83gh	50.33 fg	52.43cde	50.87d	2.23 kI	2.46 fg	2.53 ef	2.41 d	46.471	56.30 c	52.20 h	52.20 h
T. -6	2.961	3.47 f	3.72 d	3.38 c	22.47	23.37	21.20	22.34	51.80 de	52.33cde	53.33 c	52.49 c	2.41ghi	2.57 e	2.81 d	2.59 c	48.33jk	57.83 b	54.77ef	54.77ef
T. -7	3.05 h	3.83 c	3.84 c	3.57 b	22.50	23.23	21.40	22.38	52.07cde	54.90 b	55.23 b	54.06b	2.53 ef	2.76 d	3.05 e	2.78 b	49.13j	58.67ab	55.23de	55.23de
T .-8	2.66mn	2.86j	2.85j	2.79e	22.50	23.43	21.73	22.56	47.33jk1	46.33kIn	48.73 hi	47.47f	2.15 Im	2.56e	2.42 gh	2.38d	44.30op	54.37fg	48.43jk	48.43jk
T. -9	2.59o	2.71Im	2.78kI	2.69 f	22.40	23.23	21.57	22.40	46.00 Im	45.00mn	47.46 ijk	46.15g	2.02no	2.36 hi	2.33 ij	2.24 f	43.47pq	53.80 g	47.97k	47.97k
T. -10	2.38 p	2.64mno	2.70mn	2.57 g	22.57	23.30	21.47	22.44	44.53 no	44.23nop	46.33kIm	45.03h	1.97 op	2.26jk	2.20 kI	2.14 g	42.67 q	52.60 h	46.40Im	46.40Im
LSD	CV.: - 0.029			T.: 0.046	CV.: 0.482			T.:	CV.: 0.727			T.: 0.781	CV.: 0.037			T.: 0.048	CV.: 0.661			T.: 0.488
(P≤0.05)	CV. x T. : 0.0732				CV. x T. : -				CV. x T. : 1.3617				CV. x T. : 0.0896				CV. x T. : 0.8521			

T_1= Control(intaet plants). T_2= All leaf blades removed. T_3= All leaf blades and awns removed. T_4= Except flag leaf blade. other leaf blades removed, T_5= Except flag leaf blade and l'tupper leaf blade, other leaf blades removed, T_6= Except flag leaf blade, 1t upper leaf blade and 2nd upper leaf blade, other leaf blades removed, T_7= Only awns removed. T_8= Only flag leaf blade removed, T_9= Flag leaf blade and 1st upper leaf blade removed. T_{10}= Flag leaf blade. 1st upper leaf blade and 2nd upper leaf blade removed.

Spike weight

Considering the mean values of intact plants (control) in the experimental plots as 100%, reduction rates of spike weight depending on the removal of some photosynthetic organs are shown in Fig. 1.

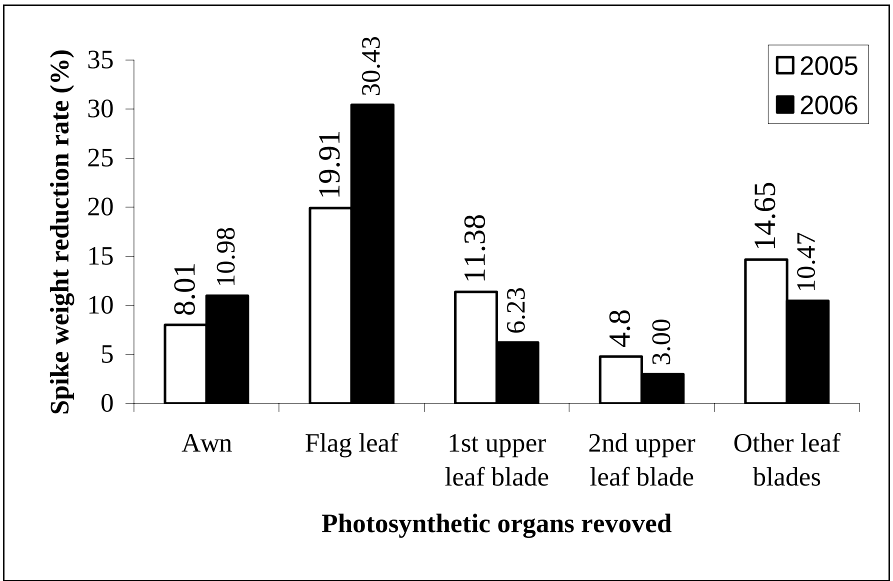

Fig. 1. Reduction rates of spike weight due to removal of some photosynthetic organs in 2005 and 2006.

In the first experimental year (2005), removal of awns, flag leaf blade, 1st upper leaf blade, 2nd upper leaf blade, and other leaf blades caused decrease in spike weight by 8.01%, 19.91%, 11.83%, 4.80%, and 14.65%, respectively (Fig. 1). In 2006, spike weight was reduced by 10.98 % due to awns removal. Besides, the removal of flag leaf blade, 1st upper leaf blade, 2nd upper leaf blade and other leaf blades reduced spike weight by 30.43%, 6.23%, 3.00%, and 10.47%, respectively.

In 2006, crop received inadequate rainfall after heading. Older leaves of wheat plant dropped due to drought stress. Therefore, flag leaf photosynthesis occurred for longer time. Contribution of flag leaf to spike weight in 2006 was more than its contribution in 2005. Awns, a xeromorphic trait, performed more effectively in photosynthesis, especially in heat and drought conditions. Thus, their contribution to spike weight in 2006 was higher than that in 2005.

Number of spikelets per spike

According to results of variance analysis, effects of treatments on number of spikelets per spike were not statistically significant in both the years 2005 and

2006 (Table 2 and 3). Therefore, change rates of number of spikelets per spike depending on some photosynthetic organs removal were not calculated.

Number of grains per spike

When the mean values of intact plants (control) in the experimental plots were considered as 100 %, reduction rates of number of grains per spike depending on some photosynthetic organs removal are shown in Fig. 2.

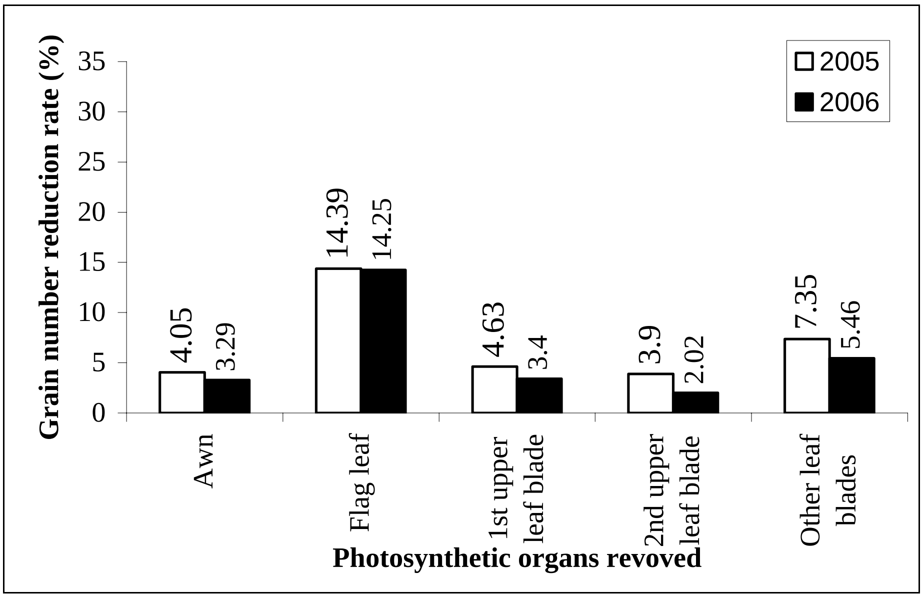

Fig. 2. Reduction rates of number of grains per spike due to removal of some photosynthetic organs in 2005 and 2006.

Fig. 2 shows that removal of awns reduced the number of grains per spike by 4.05 % in 2005. Flag leaf blade, 1st upper leaf blade, 2nd upper leaf blade, and other leaf blades removal reduced the number of grain per spike by 14.39 %, 4.63, %, 3.90 %, and 7.35 %, respectively, in 2005 during the year. In the second experimental year (2006), reduction rates of number of grains per spike due to removal of awns, flag leaf blade, 1st upper leaf blade, 2nd upper leaf blade and other leaf blades were 3.29%, 14.25%, 3.40%, 2.02% and 5.46%, respectively.

Grain weight per spike

As mean values of intact plants (control) in the experimental plots were accepted as 100%, reduction rates of grain weight per spike depending on some photosynthetic organs removal are shown in Fig. 3.

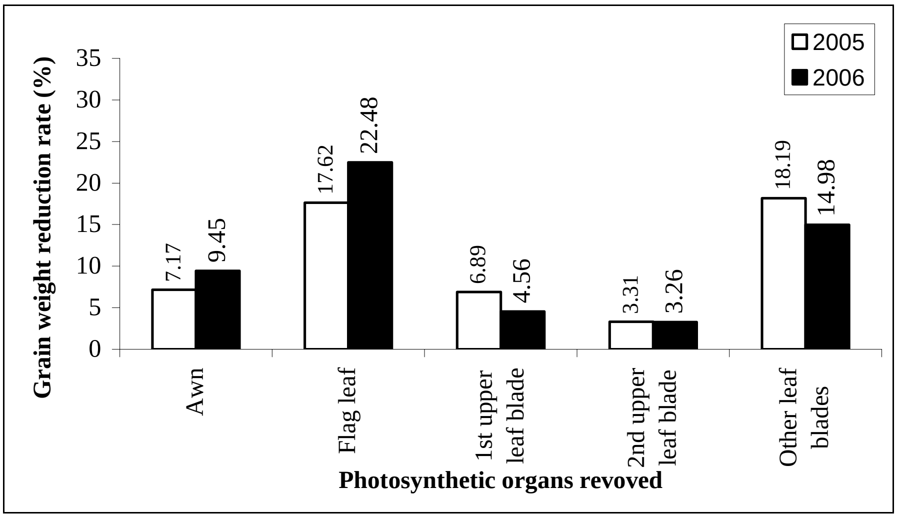

Fig. 3. Reduction rates of grain weight per spike due to removal of some photosynthetic organs in 2005 and 2006.

Based on the results of first year (2005), due to awns removal reduction rate of grain weight per spike was 7.17% (Fig. 3). Flag leaf blade removal caused a reduction of 17.62 % in grain weight per spike. As 1st upper leaf blade, 2nd upper leaf blade and other leaf blades were removed, grain weight per spike was reduced by 6.89%, 3.31%, and 18.19 %, respectively. According to results of the second year (2006), grain weight per spike was reduced by 9.45 % due to awns removal. As flag leaf blade was removed, reduction rate of grain weight per spike was 22.48 %. Besides, removal of 1st upper leaf blade, 2nd upper leaf blade, and other leaf blades caused reduction of grain weight per spike by 4.56%, 3.26%, and 14.98 %, respectively.

As the rainfall was higher in 2005 than in the fallowing year at heading stage, the contribution of awns and flag leaf blade to grain weight per spike was higher in 2006.

1000-grain weight

As mean values of intact plants (control) in the experimental plots were considered as 100 %, reduction rates of 1000-grain weight depending on some photosynthetic organs removal are shown in Fig.e 4.

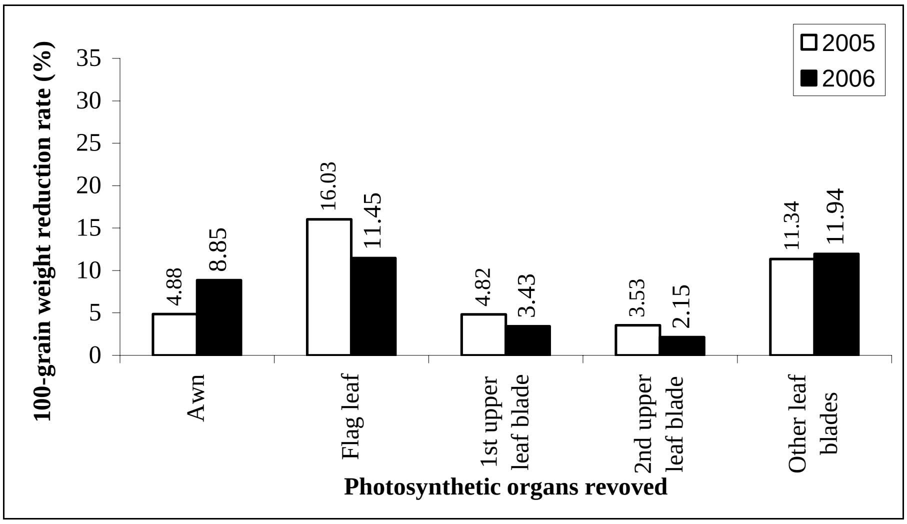

Fig. 4. Reduction rates of 1000-grain weight due to removal of some photosynthetic organs in 2005 and 2006.

As seen in the Fig. 4, removal of awns, flag leaf blade, 1st upper leaf blade, 2nd upper leaf blade and other leaf blades resulted in the decrease in 1000-grain weight by 4.88%, 16.03%, 4.82%, 3.53%, and 11.34%, respectively, in 2005. 1000-grain weight was reduced by 8.85 % due to awns removal in 2006. Due to the removal of flag leaf blade, 1st upper leaf blade, 2 upper leaf blade and other leaf blades, 1000-grain weight was reduced by 11.45 %, 3.43 %, 2.15% and 11.94%, respectively during the year. Contribution of awns to 1000-grain weight in 2006 was higher than that in 2005 since rainfall was less in 2006 at heading stage.

Discussion

The results of this study showed that removal of awns, flag leaf blade, 1st upper leaf blade, 2nd upper leaf blade significantly reduced main yield components of durum wheat. These organs are the most important photosynthetic organs for wheat. Their contribution rates to main yield components vary depending on both ecological conditions and genotypes. Besides, the awns on main yield components are very effective under drought stress, especially at heading stage. Kriedemann (1966) pointed out that the contribution made by ear photosynthesis to grain yield was found to vary from 10 % to 44 % depending on the technique used and environmental conditions. It was reported that a large amount of awns in the ear was a drought adaptive attribute in cereals (Blum, 1985). Olugbemi and Bush (1987) stated that awns increased photosynthetic rates of the ears. Araus *et al.* (1993) found that in durum wheat, if flag leaves (blade plus sheath) and ears were kept in the dark from one week after anthesis to maturity, grain weight was reduced by 22.4 % and 59.0 %, respectively. Mahmood and Chowdhry (1997) emphasized that removal of flag leaf resulted in 16.4%, 14.8%, 34.5%, and 20.0 % reduction in seed set percentage, number of grains per spike, grain weight per spike, and 1000-grain weight, respectively. Reduction in these traits as a consequence of the removal of 3rd nodal leaf and awns was also significant. Katsileros *et al.* (2002) reported that the removal of awns reduced yield and its components significantly, while the removal of the flag leaf had the same effect but of smaller magnitude. The 50 % reduction in the number of kernels per spike increased significantly the 1000-kernel weight which, however, did not prevent a reduction in total yield. Motzo and Giunta (2002) found that awns increased the ear surface from 36% to 59%, depending on their length. Awns positively affected grain yield, with an average increase of 10 and 16%. The effects of awns on grain yield and kernel weight strongly depend on the genetic background, on awn length and environmental conditions during grain filling. Birsin (2005) raported that grain number per spike was reduced by 12.4% to 12.8% as the flag leaf was removed. It was also reduced by 5.1% to 5.5% with the removal of second upper leaf blade. Besides, as awns were removed, grain weight per spike was reduced by 8.8% to 13.1% and it was reduced by 4.4% to 8.7% with the removal of second upper leaf blade. Bhutta (2006) pointed out that flag leaf area that had significant correlation with grain yield could be used as selection criteria to identify drought-tolerant wheat genotypes. Li *et al.* (2006) stated that in wheat, the leaves particularly the flag leaves have been considered to be the key organs contributing to higher yields. Besides, their results suggested that awns play a dominant role in contributing to large grains and high grain yield in awned wheat cultivars, particularly during the grain filling stage.

Conclusion

A review of the results has made it clear that flag leaf blade, 1st upper leaf blade and 2nd upper leaf blade were the most important photosynthetic organs of durum wheat during the grain filling stage. Besides, awns performed an effective role in photosynthesis, especially under the drought conditions. Spike weight, number of grains per spike, grain weight per spike, and 1000-grain weight were significantly reduced due to removal of these photosynthetic organs in wheat. It is concluded that the flag leaf should be utilized as an important morphological trait to increase yield in durum wheat.

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