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Original article

Flag Leaf in Bread Wheat (*Triticum aestivum* L.) Genotypes and Association with Yield and Yield Component under Rainfed Condition

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Abstract

An experiment was carried out to assess of flag leaf fresh and dry weight of advanced bread wheat genotypes and relation with yield component. A total of 25 bread wheat genotypes were tested during the 2017-2018 cropping cycle in Trakia region, Turkey. The experiment was conducted in a randomized complete block design with four replications. Data on grain yield, flag leaf fresh and dry weight, days of heading, plant height, peduncle length, spike length, spike number per square meter, spikelet number per spike, kernel number per spike, and spike dry weight were investigated. There were significant differences (P<0.01, and P<0.05) among genotypes for grain yield. Mean grain yield was 7172 kg ha-1. The highest grain yields performed by cv Köprü (7781 kg ha-1) while the lowest by G9 (6124 kg ha-1). Ten flag leaf fresh and dry weights of the plant were weighted at heading growth stages (Z55). There were significant differences among genotypes for flag leaf fresh and dry weight. Flag leaf fresh weight was varied among genotypes from 3.25 g to 9.15 g and, the mean was 4.95 g. In the study, ten flag leaf dry weight was varied among genotypes from 1.36 g to 2.37 g and, the mean was 1.71 g. Flag leaf fresh and dry weight positively affected yield component in genotypes. There was a positive significant relation between spike length with flag leaf fresh (r=0.526**) and dry weight (r=0.529**). Flag leaf fresh (r=0.513**) and dry weight (r=0.568**) was also significantly positively associated with spikelet number per spike. Kernel number per spike was slightly significant positively correlated with flag leaf fresh weight (r=0.377) and significantly correlated with flag leaf dry weight (r=0.398*). Flag leaf positively affected and increased spike weight in genotypes and it was found a significant association among flag leaf fresh (r=0.489*) and dry weight (r=0.531**) with spike dry weight. Flag leaf fresh and dry weight was also slightly positively correlated with days of heading. Results showed that flag leaf fresh and dry weight can be used as an indirect selection in bread wheat for yield components under rainfed conditions.

Keywords: Bread wheat, Genotypes, Flag leaf, Yield component

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is economically one of the most important cereal crops in the world. Genetic improvement in wheat yields in dry areas has not been as easy as in more favorable environments or where water is not a limiting factor (Richards et al., 2001). All parts of a cereal plant contribute to spike development (Blade and Baker, 1990); however, the upper three leaves are of great importance to grain filling, which determines cereal yield potential (Sen and Prasad, 1996). Flag leaf is the importance part of plant, contributing to cereal yield formation during grain filling. This importance is differentially expressed under healthy and biotic stress conditions. Furthermore, defoliation seems to increase photosynthetic activity of the other leaves to avoid any interruption in grain filling. The contribution of leaves to wheat grain yield depends on the interaction of wheat genotype with the environment (El Wazziki et al., 2015). Wheat leaves, especially flag leaf, are important photosynthetic assimilation organs during jointing stage and anthesis. But the ear assumes a greater role than flag leaves in supplying assimilates to the grain when drought stress develops (Evans et al. 1972; Johnson and Moss 1976; Blum 1985). The flag leaf is considered to be the greatest contributor to grain yield for its short distance to spike and the fact that it stays green for longer than the rest of the leaves. Erect leaves are desirable for all environments, while for rainfed conditions, short and tough leaf blades were important to withstand the drought stress (Minhas et. al., 1978). Contrarily, a big flag leaf area might be used in combination with yield components to obtain maximum genetic advance (Smocek, 1969). Inconsistent results about the relationship between flag leaf characteristics and yield may be found in the literature as they range from strong to inexistent or genotype-dependent (Minhas et al. 1978, Briggs and Aytenfisu 1980, Singh and Singh 1992; Berdahl et al. 1972, McNeal and Berg 1977; Chowdhry et al. 1976). Although the flag leaf has traditionally been considered the main photosynthetic organ for grain filling (Evens et al., 1975), the ear also contributes. However, reports on the photosynthetic contribution of the ear to final grain weight vary widely, depending not only on species and genotypes, but also on growing conditions (Biscoe et al., 1975; Duffus et al., 1985). The relative contribution of ear photosynthesis to grain yield was more important under abiotic stress (Abbad et al. 2004; Tambussi et al. 2007; Zhang et al. 2013). Chlorophyll contents of non-leaf organs, such as ear, stem and leaf sheath, slowly decrease, and these organs still exhibit a certain degree of photosynthesis in the late grain filling (Lu and Lu 2004).

Some morphological traits, such as flag leaf, could be selection criteria in breeding programmes to obtain varieties with good yield stability. Therefore, the objective of this study is to investigate flag leaf fresh and dry weight of bread wheat genotypes and relation with yield and yield component under rainfed environment conditions.

MATERIAL and METHODS

The experiment was conducted during the 2017-2018 growing cycle in Trakia region, Turkey. The study was carried out in a randomized complete block design (RCBD) with four replications. Each plot was 6 meter long and had 6 rows, spaced 0.17 meters apart. Using a plot drill performed sowing and 500 seeds per square meter were used. A total of 25 bread wheat genotypes, five was local check, were tested. Data on grain yield, flag leaf fresh and dry weight, days of heading, plant height, peduncle length, spike length, spike number per square meter, spikelet number per spike, kernel number per spike, and spike dry weight were investigated.

***Days to 50% heading*:** The number of days from the date of 1 October up to the date when the tips of the spike first emerged from the main shoots on 50% of the plants in a plot.

***Plant height*:** The height of ten randomly taken plants was measured at harvest maturity from the ground level to the tip of the tallest spike in centimeter and averaged.

***Peduncle length*:** Ten randomly taken plants peduncle length were measured at harvest maturity in centimeter and averaged.

***Spike length*:** Ten randomly taken spikes were measured from base to the tip excluding the awns at harvest maturity in centimeter and averaged.

Number of spikes per square meter: The number of spikes per square meter was calculated by counting the spikes contained in 1 m^{-2} in central part in each plot.

Number of spikelet per spike: The average number of spikelets per spike is taken from ten spikes randomly selected from each plot.

Number of grains per spike: The average number of kernels in the main tillers in each of the ten spikes is taken randomly selected from each plot.

Spike dry weight (g): The sample of 10 spikes randomly selected from each plot in the stage of full maturity. Sample plants weighted and averaged for spike dry weights.

Flag leaf fresh and dry weight: Ten flag leaves from each plot and genotypes were removed at GS55 (Zadoks et al., 1974) growth stages and then weighted and averaged to obtain the flag leaves fresh weight (FLFW). For dry weight flag leaves (FLDW) were oven-dried at 70^{o}C to obtain the flag leaves dry weight.

To evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. The differences between genotype means of parameters were tested by the L.S.D test (0.05). Letter groupings were generated by using a 5% level of significance. Data were analyzed statistically for analysis of variance the method described by Gomez and Gomez (1984). The significance of differences among means was compared by using the L.S.D test. The regression equations were calculated according to Finlay and Wilkinson (1963), and Eberhart and Russell (1969). Regression graphs were used to predict the adaptability of genotypes and the correlations between the quality parameters were determined by Pearson's correlation analysis. The Zadoks Decimal Code (GS) was used to describe plant growth stages of cereals (Zadoks et al., 1974). The situation and main characteristics of the experimental sites and meteorological variables during the experiments are summarized in Table 1.

Table 1. Climate conditions in Edirne/Institute in 2017-2018 growing year.

Months	Rainfall (mm) Long year	Rainfall (mm)	Moisture (%)	Temperature °C		
				Min.	Max.	Mean
September 2017	34.0	34.2	57.8	6.8	35.9	21.3
October 2017	52.9	135.2	77.1	3.8	27.8	13.6
November 2017	72.4	71.6	75.7	-2.1	27.4	9.5
December 2017	61.7	119.6	85.1	-4.2	20.8	7.4
January 2018	48.1	55.6	88.1	-5.2	15.1	4.3
February 2018	46.9	101.8	89.5	-5.4	16.1	5.7
March 2018	52.2	145.6	88.8	-11.0	20.2	8.9
April 2018	51.0	3.0	61.3	2.6	31.7	16.6
May 2018	56.0	18.8	64.0	9.2	31.1	20.3
June 2018	41.5	148.4	66.4	11.7	34.8	22.6
Total/Mean	516.7	833.8	75.4	-11.0	35.9	13.0

RESULTS and DISCUSSION

The analysis of variance for yield, yield component, and flag leaf fresh and dry weight were performed and given in Tables 2, 3, and 4. The results of variance analyses showed that there were significant differences (P<0.01) among genotypes for parameters investigated (Table 2). There were significant differences among genotypes for grain yield and mean grain yield for 25 genotypes was 7172 kg ha^{-1}. The highest grain yields performed by genotypes Köprü (7781 kg ha^{-1}) while the lowest by genotype G9 (6124 kg ha^{-1}). Ten flag leaf fresh and dry weights of the plant in each genotype were weighted at the heading (Z55) growth stage.

Table 2. Sum of the square and mean square for yield components and morphological traits measured in 25 bread wheat genotypes grown under rainfed conditions

Characters	Sum of squares	Mean squares	F Ratio
Grain yield	177676.18	7403.17	3.369**
Flag leaf fresh weight	77.97	3.25	4.718**
Flag leaf dry weight	5.99	0.25	4.127**
Days of heading	263.00	10.96	1.405ns
Plant height	4069.76	169.57	12.919**
Peduncle length	856.92	35.71	18.015**
Spike length	36.46	1.52	5.686**
Spike number per square meter	215799.00	8991.63	5.017**
Spikelet number per spike	147.28	6.14	5.707**
Kernel number per spike	2510.45	104.60	3.889**
Spike dry weight	6.47	0.27	2.006*

* and ** indicate significances, ns: non-significant at $P<0.05$ and $P<0.01$, respectively.

The result of the analysis showed that it was found significant differences among genotypes for flag leaf fresh and dry weight. Flag leaf fresh weight was varied among genotypes from 3.25 g to 9.15 g and, the mean was 4.95 g. Flag leaf fresh weight of plants was weighted maximum in genotypes G17 (9.15 g), G21 (8.41 g), and G16 (8.37 g). Considerable variations existed in flag leaf dry weight investigated. Ten flag leaf dry weight was varied among genotypes from 1.36 g to 2.37 g and, the mean was 1.71 g. The highest flag leaf dry weight was found in genotype G17 (2.37 g), G16 (2.30 g), and G7 (2.24 g). Because of the fluctuation of rainfall mid-early genotypes generally are favorable in bread wheat in the Trakia region. Almost all genotypes were chosen in an attempt to represent a wide range of genetic variability, all of them having a similar date of heading, near the optimum in the region. In the study, days of heading ranged from 110.5 to 117.8 among genotypes, and the mean value was 113.8 days (Table 3). Plant breeders have tried to select and release intermediate varieties (Richards et al., 2001; Calderini et al., 1999).

Table 3. Flag leaf fresh and dry weight and yield component of genotypes in 2017-2018 cycle

No	Genotype	GY	FLFW	FLDW	DH	PH
1	Pehlivan	7704 a	5.56 jkl	1.46 ı-l	114.5 a-e	106.0 ab
2	G2	6765 def	5.82 ı-l	1.57 h-l	114.0 a-f	96.8 d-h
3	G3	7295 a-d	7.67 b-f	1.92 b-h	114.3 a-f	92.0 hı
4	G4	7610 ab	7.41 b-h	1.93 b-h	115.3 a-d	92.5 ghı
5	Selimiye	6990 b-e	4.95 l	1.41 kl	114.3 a-f	97.0 d-h
6	G6	7474 abc	7.60 b-g	1.94 b-h	114.0 a-f	92.0 hı
7	G7	6593 ef	8.16 a-d	2.24 abc	115.0 a-e	99.0 cde
8	G8	6879 cde	8.00 a-e	2.12 a-e	115.3 a-d	81.3 j
9	G9	6124 f	7.44 b-h	2.04 a-f	117.8 a	90.8 ı
10	Gelibolu	7543 ab	5.30 kl	1.36 l	110.5 f	97.8 c-f
11	G11	6864 cde	7.02 c-ı	1.82 d-j	113.3 b-f	99.5 cd
12	G12	6715 def	6.56 f-k	1.63 g-l	113.5 b-f	107.8 a
13	G13	7354 a-d	6.62 f-k	1.78 e-k	114.0 a-f	94.3 e-ı
14	G14	6560 ef	6.25 g-l	1.93 b-h	112.0 b-f	110.3 a
15	Saban	7576 ab	6.87 d-j	1.79 e-k	111.8 c-f	94.3 e-ı
16	G16	7142 a-e	8.37 abc	2.30 ab	112.3 b-f	100.3 cd
17	G17	7210 a-e	9.15 a	2.37 a	113.8 b-f	99.3 cde
18	G18	7259 a-d	7.30 b-h	1.86 c-ı	113.5 b-f	108.0 a
19	G19	7511 abc	6.21 h-l	1.45 jkl	115.0 a-e	93.0 f-ı
20	Köprü	7781 a	7.75 b-f	1.94 b-h	111.5 def	97.5 c-g
21	G21	7702 a	8.41 ab	2.20 a-d	115.8 ab	105.5 ab
22	G22	6782 def	7.10 b-ı	1.59 h-l	111.3 ef	93.0 f-ı
23	G23	7554 ab	7.50 b-h	2.01 a-g	115.3 a-d	96.3 d-h
24	G24	7329 a-d	8.11 a-d	2.18 a-e	115.5 abc	102.5 bc
25	G25	6992 b-e	6.68 e-j	1.70 f-l	113.3 b-f	95.8 d-ı
Mean		7172	7.11	1.86	113.8	97.7
CV (%)		6.5	11.6	12.9	2.45	3.71
LSD (0.05)		65.96	1.34	0.40	1.41	5.09

* and ** indicate significances at $P<0.05$ and $P<0.01$, respectively. GY: Grain yield (kg ha^{-1}), FLFW: Flag leaf fresh weight (g), FLDW: Flag leaf dry weight (g), DH: Days of heading, PH: Plant height (cm)

Plant height was recorded at harvest and measured from the ground to the tip of the spikes, excluding awns in both years. There was a significant difference among genotypes for plant height. With regard to genotypic effects, although genotypes G14, G18, and G12 exhibited the highest plant height, under rainfed condition, on the other hand, genotype G8, which was showed the lowest plant height (81.3 cm).

Table 4. Mean performance of the genotypes for yield component investigated in 2017-2018

No	Genotype	PL	SL	SNM	SNS	KNS	SDW
1	Pehlivan	35.5 b	8.8 ı-m	495.3 a	18.3 ef	32.6 k	1.96 de
2	G2	31.0 def	10.1 b-e	407.8 b-f	18.5 ef	53.1 a	2.49 a-d
3	G3	32.2 cde	9.1 g-m	373.3 e-h	19.3 de	39.4 e-k	2.22 a-e
4	G4	32.6 cde	9.1 g-m	463.3 ab	18.3 ef	36.9 g-k	2.30 a-e
5	Selimiye	33.0 cd	8.9 h-m	465.5 ab	18.5 ef	34.4 ıjk	1.82 e
6	G6	30.5 efg	9.2 f-m	401.3 c-f	18.5 ef	35.3 h-k	2.10 cde
7	G7	23.7 kl	9.3 e-l	330.3 hıj	20.7 a-d	47.7 a-e	2.11 b-e
8	G8	28.4 ghı	9.5 d-j	399.3 c-g	19.9 b-e	46.7 a-f	2.71 ab
9	G9	22.9 l	9.8 b-g	309.3 ıj	18.8 ef	42.4 c-ı	2.43 a-d
10	Gelibolu	29.5 f-ı	8.8 j-m	433.3 bcd	18.5 ef	41.8 c-j	2.13 b-e
11	G11	27.4 ıj	9.1 g-m	392.0 d-g	17.3 f	38.3 f-k	2.09 cde
12	G12	31.4 c-f	8.5 lm	400.5 c-f	19.2 de	36.5 g-k	1.99 de
13	G13	27.4 ıj	9.7 c-h	413.3 b-e	21.2 abc	48.5 a-d	2.61 abc
14	G14	27.4 ıj	8.7 lm	367.5 e-ı	19.6 b-e	43.2 b-h	2.44 a-d
15	Saban	30.3 e-h	9.5 e-k	451.8 abc	18.3 ef	40.1 d-k	2.06 cde
16	G16	32.1 cde	10.6 abc	350.5 f-j	21.7 a	45.6 a-f	2.71 ab
17	G17	32.2 cde	11.0 a	361.3 e-j	22.3 a	51.1 ab	2.79 a
18	G18	28.7 ghı	8.4 m	407.3 b-f	18.3 ef	33.7 jk	1.81 e
19	G19	26.0 jk	9.0 h-m	368.8 e-ı	18.4 ef	48.0 a-d	2.62 abc
20	Köprü	31.1 def	8.7 klm	383.3 d-h	19.5 cde	43.9 b-g	2.28 a-e
21	G21	33.6 bc	10.6 ab	304.3 j	21.3 ab	46.4 a-f	2.45 a-d
22	G22	32.0 cde	9.7 d-ı	374.5 d-h	19.0 def	45.0 a-g	2.23 a-e
23	G23	28.1 hıj	10.1 b-e	413.5 b-e	21.6 a	49.5 abc	2.61 abc
24	G24	37.9 a	10.0 b-f	373.5 e-h	17.3 f	49.9 abc	2.71 ab
25	G25	32.8 cd	10.4 a-d	340.0 g-j	17.4 f	39.3 e-k	1.95 de
Mean		30.3	9.45	391.2	19.26	42.76	2.31
CV (%)		4.6	5.3	10.8	5.3	12.1	15.6
LSD (0.05)		2.28	0.84	5.02	1.68	8.5	0.59

* and ** indicate significances at $P<0.05$ and $P<0.01$, respectively. PL: Peduncle length (cm), SL: Spike length (cm), SNM: Spike number per square meter, SNS: Spikelet number per spike, KNS: Kernel number per spike, SDW: Spike weight

Cereals grain yield is a complex interaction between its components such as the number of plants per unit area, number of spikes per plant, number of grains per spike, and grain weight. Numbers of grains per spike or the number of seeds/m2 are determined within the period from initiation of spikelets to anthesis (Fischer and Stockman, 1986). There were significant differences (P<0.01) among genotypes for peduncle length and genotype G24 had the longest peduncle length, while G9 the shortest one. The mean values of the genotypes were varied between 22.9 (G9) to 37.9 (G24) for peduncle length. There were significant differences (P<0.01) among genotypes based on spike length and ranged from 8.4 cm to 11.0 cm among genotypes and mean was 9.45 cm. Cultivar Pehlivan had the highest spike number per square meter (495.3) and followed by Selimiye and G4 (Table 4). Spikelet number per spike varied in genotypes from 17.3 to 22.3 and the mean was 19.26. The highest spikelet number was counted in genotypes G17, G16, and G23 (Table 4). Kernel number in the spike was measured and there was a significant difference among genotypes. G2 and G17 had the highest kernel numbers in spike (Table 4)

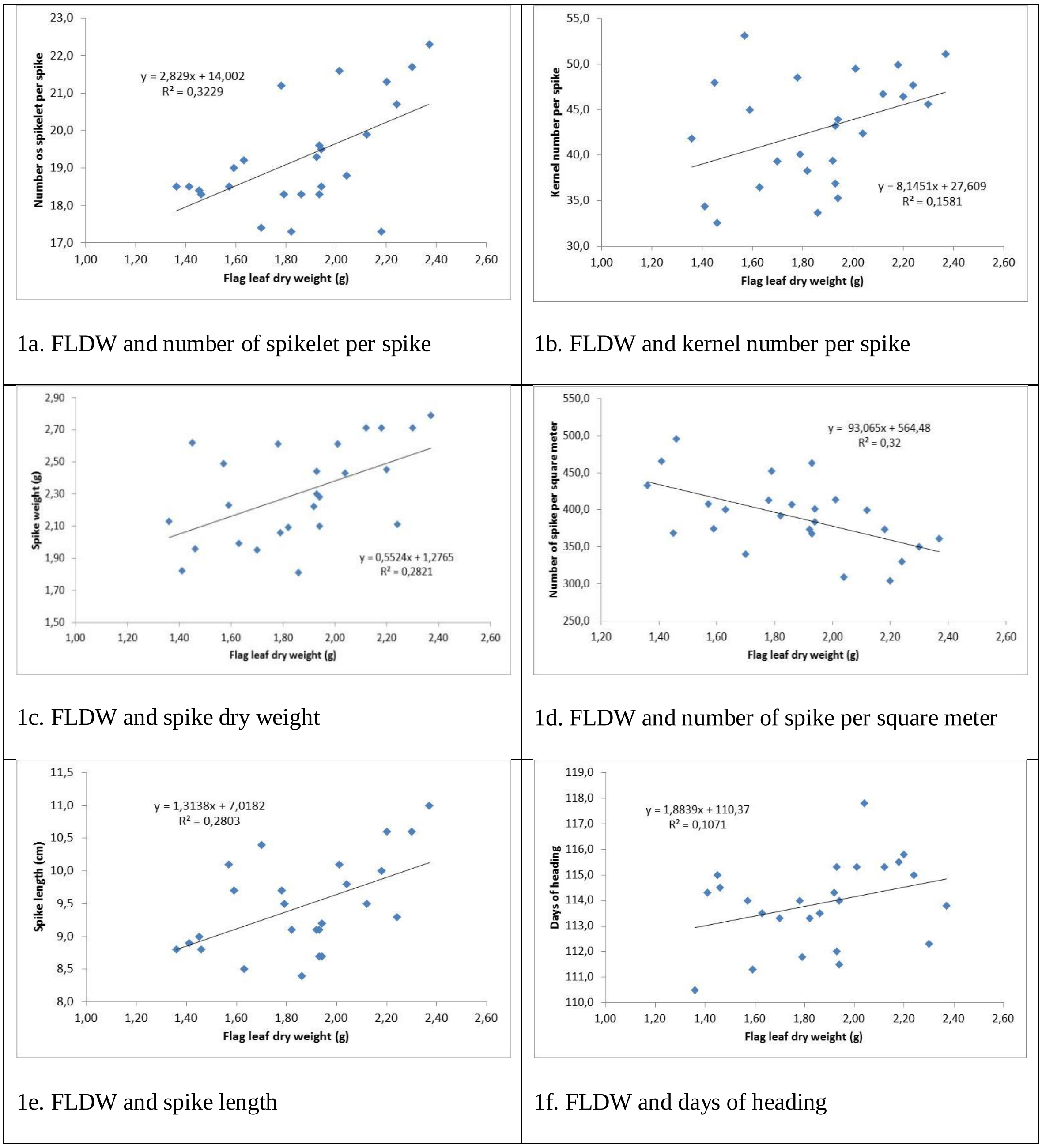
Table 5. Correlation coefficients between flag leaf with yield and yield component under rainfed conditions

Traits	GY	SNM	PH	DH	PL	SL	SNS	KNS	SDW	FLFW
SNM	0.418*									
PH	0.035	-0.022								
DH	-0.173	-0.236	-0.215							
PL	0.469*	0.298	0.248	-0.153						
SL	-0.034	-0.480*	-0.178	0.236	0.198					
SNS	0.052	-0.323	0.031	0.073	-0.172	0.480*				
KNS	-0.100	-0.465*	-0.191	0.127	-0.159	0.629**	0.515**			
SDW	0.014	-0.369	-0.255	0.268	-0.061	0.599**	0.546**	0.831**		
FLFW	0.037	-0.583**	-0.121	0.267	0.014	0.526**	0.513**	0.377	0.489*	
FLDW	-0.085	-0.566**	-0.012	0.327	-0.055	0.529**	0.568**	0.398*	0.531**	0.928**

**: $P<0.01$, *: $P<0.05$, GY: Grain yield (kg ha^{-1}), FLFW: Flag leaf fresh weight (g), FLDW: Flag leaf dry weight (g), SNM: Spike number per square meter, PH: Plant height (cm), DH: Days of heading, PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike, SDW: Spike weight (g).

Correlation coefficients were determined by Pearson's correlation analysis Correlation coefficients of flag leaf fresh and dry weight, with days of heading, plant height, peduncle length, grain yield, and its components were computed in 25 wheat genotypes (Table 5). In the study, no correlation was found between flag leaf fresh and dry weight with grain yield. In this experiment, it was found a slightly significant negative correlation between flag leaf fresh (r = -0.583**) and dry weight (r = -0.566**) with the number of spike per square meter. Flag leaf fresh and dry weight was slightly positively correlated with days of heading. Flag leaf fresh and dry weight positively affected yield component in genotypes. There was a positive significant relation between spike length with flag leaf fresh (r=0.526**) and dry weight (r=0.529**). However, flag leaf fresh and dry weight does not show any effect on peduncle length. Flag leaf fresh (r=0.513**) and dry weight (r=0.568**) was also significantly positively associated with spikelet number per spike. Kernel number per spike was slightly significant positively correlated with flag leaf fresh weight (r=0.377) and significantly correlated with flag leaf dry weight (r=0.398*). Flag leaf positively affected and increased spike weight in genotypes and it was found a significant association among flag leaf fresh (r=0.489*) and dry weight (r=0.531**) with spike weight. Results showed that flag leaf fresh and dry weight could be used in selection in bread wheat for yield component (Table 5).

The results of the Regression equation (R^2) were given in Figures 1. Regression analysis indicated that increasing in dry weight of flag leaf (FLDW) resulted in increased yield component of genotypes, and there was a positive association between yield component and FLDW except the number of spike per square meter (Figure 1a, b, c, d, e, f). The results showed that an increase in the number of spike per square meter decreased in FLDW in genotypes and there was a negative relation between FLDW and spike number per square meter (R^2=0.32). The higher weight of flag leaves led to an increase of the number of spikelet per spike (R^2=0.322), kernel number per spike (R^2=0.158), spike dry weight (R^2=0.282), length of the spike (R^2=0.280) in genotypes (Figure 1a, 1b, 1c, 1e, and 1f). There was also a positive association between FLDW and days of heading (R^2=0.107) (Figure 1f).



1a. FLDW and number of spikelet per spike

1b. FLDW and kernel number per spike

1c. FLDW and spike dry weight

1d. FLDW and number of spike per square meter

1e. FLDW and spike length

1f. FLDW and days of heading

Figure 1. Relationships between flag leaf dry weight with a yield component measured in the study. Each point represents the mean value of one genotype.

Conclusion

Flag leaf is an important part of the plant, contributing to cereal yield during the grain filling phase. The flag leaf is considered to be the greatest contributor to grain yield for its short distance to spike and the fact that it stays green for longer than the rest of the leaves. In this experiment, it was investigated that flag leaf fresh and dry weight and of bread wheat genotypes and relation with yield and yield component under rainfed environment conditions. There were significant differences among genotypes for flag leaf fresh and dry weight. Genotypes G17 and G16 had higher flag leaf fresh and dry weight. G17 has also been a prominent line based on yield components. Regression analysis also indicated that increasing in dry weight of flag leaf resulted in increased yield component of genotypes, and there was a positive association between yield components. There was a positive significant relation between spike length with flag leaf fresh and dry weight. Flag leaf fresh and dry weight was also significantly positively associated with spikelet number per spike. Kernel number per spike was slightly significant positively correlated with flag leaf fresh weight and significantly correlated with flag leaf dry weight. Flag leaf positively affected and increased spike dry weight in genotypes and it was found significant association among flag leaf fresh and dry weight with spike weight. Flag leaf fresh and dry weight was slightly positively correlated with days of heading. The results of this study suggest that flag leaf fresh and dry weight can be used as an indirect selection in bread wheat for yield components under rainfed conditions.

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