International Journal of Natural and Engineering Sciences
E-ISSN: 2146-0086 15(2): 13-21, 2021
Research Article

RELATIONS BETWEEN SPIKE YIELD and FLAG LEAF AREA in SIX and TWO ROWED BARLEY

Zekiye Budak Başçiftçi[1,a,*]

[1]*Eskişehir Osmangazi University, Faculty of Agriculture, Field Crop Department, Eskişehir, Turkey*

**Corresponding Author:*
E-mail: zbudak@ogu.edu.tr

(Received 27th May 2021; accepted 14th July 2021)

a: ORCID 0000-0002-4034-2537

ABSTRACT. This study was carried out in Eskişehir Osmangazi University Faculty of Agriculture research and trial field during the 2002-2004 production season. In this study, it was aimed to reveal the genotypic and environmental effects on leaf pattern in barley *(Hordeum vulgare L.)*. The study, in which 45 six-row and 7 two-row barley genotypes were used, was established according to a randomized block design. Flag leaf area index and spike characters were determined in barley populations. According to the findings obtained; It was determined that the flag leaf area was affected by environmental conditions and the difference between genotypes was not statistically significant. Larger leaf areas of two-row barley were associated with higher grain weight per ear, while smaller leaf areas of six-row barley were associated with more spike character. As a result of the study, it was determined that there were significant differences in flag leaf area and spike characters depending on barley row varieties.

Keywords: *two types barley, flag leaf area, years, regression, correlation*

INTRODUCTION

Barley (*Hordeum vulgare* L.), belonging the Poaceae family, is the most cultivated plant in the world after wheat. With wide range of uses both as animal feed and in the food industry, its wide adaptability in many regions of the world, barley is wide acreage and production in the world [1]. Due to its early development nature, barley is preferred especially in regions where rainfall is abundant or irrigation facilities are sufficient. In addition, it can be recommended for many areas where no severe drought and cold damage prevail. Due to its high salt tolerance, it can be easily grown in alkaline soil conditions. Having the beta-glucan content, barley is of great importance as a malting in animal feed, medicinal plant and food industry. As a result of many years of breeding programs, barley varieties with different characters for different areas of use; High-yielding, high-quality varieties resistant to biotic and abiotic stresses have been developed and put into use.

Dry matter accumulation in barley is shaped by photosynthetic activity, water and mineral utilization ability of the plant during the grain filling period. This ability takes place in barley stem and leaves with different efficiency and at different rates; many studies have been carried out on this subject. [2, 3, 4]. In the studies, it has been revealed that the effective parts in this regard are the flag leaves. Especially if it is considered that about half of the photosynthesis is the flag leaf, the importance of the flag leaf in photosynthesis is revealed by itself [3,7]. Again, there is a positive relationship between flag leaf area and flag leaf photosynthesis efficiency and grain weight per plant [5, 6, 7].

In similar studies, it was stated that the increase in leaf area and leaf area photosynthesis efficiency had a significant effect on grain yield [8]. Scientists working on this subject need to consider the effect of the flag leaf on photosynthesis and plant development. This is very important in terms of producing high yielding and quality varieties [9]. The relationships between morphological and physiological characteristics and grain yield, flag leaf and grain yield in barley have been revealed by many studies [2,10]. In this study, it was tried to determine between grain weight per spike, grain weight per spike and flag leaf area in six-row and two-row barley.

MATERIALS AND METHODS

This research was carried out in Eskişehir, one of the large barley growing provinces in the semi-arid Central Anatolian Region of Turkey. A field experiment was conducted at the research field of the Eskişehir Osmangazi University during 2002-03 and 2003-04 for two consecutive cropping seasons. According to analyses of soil samples taken from 0-30 cm depth, soil type was clay-loam, pH 7.1, $CaCO_3$ content 6.2 %, P_2O_5 content 4,2 kg/ha, organic matter 2,26 %. Precipitation during the growing period for 2002-2003 and 2003-2004 were 297, 1 and 273, 2 mm. respectively. Total water received by crops is summarized in Table 1. Mean differences in water input between 2003 and 2004 were 26,1 mm.

Table 1. *Total water received by crop in 2003-2004*

Month	**Total water received by the crop (mm)**	
	2003	**2004**
October	24,1	33,6
November	25,9	5,4
December	38,6	61,6
January	40,3	56,6
February	34,2	8,3
March	17,4	17,3
April	72,8	40,9
May	43,5	22,4
June	0	27,2
Total water received from March to June	133,7	107,8

The experimental layout was a Randomized Complete Block Design with three replications. The experimental plots consisted of six rows of 5 m long with 20 cm spaces and they were sown by hand. Forty-five six-rowed and seven two-rowed barley genotypes were used. Erginel 91 and Kıral 97 (six-rowed) and Tokak 157/37 and Karatay 94 (two-rowed) were used as the checks. Standard cultural practices were followed for raising the

crop. Data were collected from 10 plants from the center two rows of each plot and the mean of these 10 plants was computed for each plot. The characters studied were spike length, flag leaf area index (cm^2) (flag leaf lamina width x flag leaf lamina length x 0.67), number of spikelets per spike, number of kernels per spike, kernel weight per spike, thousand kernel weight. Analyses were conducted for each variable, and genotype, years, and interactions. Comparisons of means were made using the LSD test. Simple correlation of flag leaf area with kernel weight per spike (spike yield), number of kernel per spike, and thousand kernel weight were calculated for two- and six-rowed barleys. Relations between flag leaf area and three spike characters were described using regression analysis for all six- and two-rowed and selected genotypes.

RESULTS AND DISCUSSION

The general means, ranges, standard errors, LSD values, CV, and analysis of variance for seven characters were given in Table 1 and 2 for six- and two-rowed barley, respectively. A wide range of variability was observed for flag leaf area, number of spikelet per spike, kernel number per spike, kernel weight per spike, thousand kernel weight while spike length showed a narrow variability range in six-rowed barleys. Significant effects of years were obtained for all characters except for kernel weight per spike. There were significant differences in spike characters except for kernel number per spike and kernel weight per spike for forty-five six rowed barley genotypes understudy during both years. The genotype x year interaction was significant for all characters in six-rowed barley genotypes.

Table 2. *Mean values and analysis of variance of flag leaf area and spike characters of forty five six-rowed barleys grown in 2003 and 2004*

Year	**Flag leaf area (cm^2)**	**Spike length (cm)**	**Number of spikelet per spike**	**Number of kernel per spike**	**Kernel weight per spike (g)**	**Thousand kernel weight (g)**
2003	9,27	7,17	10,36	47,4	2,13	45,3
2004	12	6,87	10,51	52,4	2,23	43,1
combined	10,64	7,02	10,5	49,9	2,18	44,2
SE	0,2	0,18	0,71	0,81	0,08	1,67
LSD(0.05)	0,39	0,36	1,39	1,58	0,16	3,28
LSD(0.01)	0,52	0,47	1,82	2,09	0,21	4,3
CV	2,3	3,2	8,2	1,98	4,59	4,63
SOURCE df						
Replication 4	0,11	0,07	0,01	0,08	0,00	7,98
Genotypes (G) 44	6,02	2,33**	2,78*	92,1	0,17	67,67**
Years (Y) 1	505,9**	5,84**	6,44*	1654,4**	0,55	350,4**
G x Y 44	9,95**	0,78**	1,53**	73,3**	0,15**	41,3**
Error 176	0,06	0,05	0,75	0,98	0,01	4,19

Two-rowed barley exhibited a moderate range of variability for all characters. The genotypes of two-rowed barley differed significantly only in thousand kernel weight. The significant differences in thousand kernels' weight should be attributed to the differences in grain filling period and dry matter accumulation in grains [11, 12]. This variation might be affected by seasonal conditions. This character is highly stable in barley [13], which may be attributed to a high degree of remobilization of vegetative reserves during kernel growth, a phenomenon especially relevant to dry conditions [14]. Significant year effects were found for the number of kernel per spike and kernel weight per spike. The number of kernel per spike and kernel weight per spike showed significant differences. The genotype x year interaction was significant for spike characters except for thousand kernel weight and flag leaf area. Measuring genotype x environment interaction is also important to determine an optimum breeding strategy for releasing cultivars with adequate adaptation to target environments [15, 16, 17].

Table 3. *Mean values and analysis of variance of flag leaf area and spike characters of seven two-rowed barley grown in 2003 and 2004*

Year	**Flag leaf area (cm^2)**	**Spike length (cm)**	**Spikelet number per spike**	**Kernel number per spike**	**Kernel weight per spike (g)**	**Thousand kernel weight(g)**
2003	6,62	8,25	13,63	25,78	1,39	55,1
2004	8,87	8,60	14,31	28,59	1,59	55,4
combined	7,74	8,42	13,97	27,18	1,49	55,2
SE	0,32	0,28	0,18	1,23	0,08	1,50
LSD(0.05)	0,66	0,58	0,38	2,54	0,17	3,1
LSD(0.01)	0,9	0,78	0,50	3,44	0,22	4,2
CV	5,2	4,11	1,6	5,5	6,7	3,32
SOURCE df						
Replication 4	0,07	0,27	0,06	0,17	0,001	6,46
Genotypes (G) 6	17,66	2,96	2,33	16,2	0,11	176,03**
Years (Y) 1	53,3	1,28	4,76	83,01*	0,41*	0,91
G x Y 6	9,8**	1,17**	2,0**	9,40**	0,04*	7,21
Error 24	0,16	0,12	0,05	2,26	0,01	3,36

Variation accounted to flag leaf area were changed between 1.9- 9.9 %, 1-8.4 % respectively in 2003 and 2004. Statistically significant variations due to increased flag leaf area were estimated as 9.9 and 8.4 % respectively in 2003 and 2004. A significant and positive correlation was found between kernel weight per spike and flag leaf area for all six-rowed barley in 2003 while this correlation was significant and negative in 2004. For eachcm2 of increased flag leaf area, the kernel weight per spike was increased 0.05 g in 2003. In contrast, for each cm increased flag leaf area was caused 0.04g decrease in 2004 (Table 4).

Variation accounted to increased flag leaf area were changed from 2 to 30 cm^2, and from 7 to 60 cm^2 respectively in 2003 and 2004. There was a significant and positive correlation between flag leaf area and thousand kernel weight for all two-rowed barley. For each cm^2 flag leaf area, thousand kernel weight was increased 14.4 % in 2004 but decreased as 55% in 2003.

Table 4. *Relationship between flag leaf area(x) and spike characters of six and two rowed barley in two years*

Six-Rowed						
	2003			**2004**		
	Y=a + bx	**R**	**r**	**Y=a +bx**	**R**	**r**
Kernel number per spike	43,4 +0,44x	1,9	0,14	51,1+0,11x	0,1	-0,03
Spike weight (g)	1,71+0,05x	9,9	0,31*	2,7 -0,04x	8,4	-0,29*
Thousand kernel weight(g)	40,5+0,52x	4,4	0,21	51,3-0,69x	6,3	-0,25
Two-rowed						
	2003	2004				
	Y=a + bx	R	R	Y=a +bx	R	r
Kernel number per spike	20,5+0,80x	30	0,54	26,8+0,20x	7	0,27
Spike weight (g)	1,28+0,02x	5	0,22	1,14+0,05x	47	0,69
Thousand Kernel weight(g)	58,7-0,55x	2	-0,13	42,6+1,44x	60	0,77*

Among the six and two row barleys, genotypes 27 and 33 were selected with high spike characteristics and flag leaf area values. The fact that the genotype 27 with six rows had a large flag leaf area also resulted in high spike number, grain number per spike and thousand grain weight values (Table 5). Therefore, wide flag leaf area increases photosynthesis efficiency and positively affects grain yield [4]. Another study suggested that the broad flag leaf area creates more cell nuclei [6]. Barley no. 33 with two rows had larger flag leaf area and higher spike characteristics than other barley varieties. In addition, large flag leaf area accumulates more dry matter and provides a heavier single spike formation [18].

Table 5. *Mean values of flag leaf area and spike characters of selected two lines*

Genotype		Flag leaf area (cm^2)	Kernel number per spike	Kernel weight per spike (g)	Thousand kernel weight(g)
27 (six rowed)	**2003**	9,73	52,53	2,58	50,33
	2004	14,5	53,57	2,35	43,87
	Combined	12,11	53,05	2,46	47,10
33 (two rowed)	**2003**	8,35	28,70	1,57	59,67
	2004	10,60	30,67	1,83	59,82
	Combined	9,47	29,68	1,70	59,74

In both years, genotype had a larger leaf area, more kernel number per spike, kernel weight per spike, and thousand kernel weight directly affected the grain yield. Because of the fact that these three characters depended on growing season and location, grain yield depended fundamentally on the grain weight/spike and agro-ecological conditions during the growing period. As shown in Table 5, number 27 and number 33 were high spike yielders and well adapted to all years for seed yield.

In this study, a simple correlation analysis was conducted to determine the associations between flag leaf area and spike yield components of two genotypes by years.

Table 6. *Relationship between flag leaf area(x) and spike characters of two and six rowed barleys in combined years*

Six- rowed genotype 27			
	Combined		
	Y=a + bx	**R**	**r**
Kernel number per spike	63,03-1,31x	77	-0,88*
Kernel weight per spike (g)	3,02-0,05x	67	-0,82*
Thousand kernel weight(g)	5,03-2,09x	52	0,72
Two- rowed genotype 33			
	Y=a + bx	**R**	**r**
Kernel number per spike	56,1+0,38x	12	0,35
Kernel weight per spike (g)	0,53+0,12x	95	0,97**
Thousand Kernel weight(g)	19,3+1,10x	67	0,82*

The correlations for flag leaf area in genotype 33 were r = 0.82 and r = 0.97 for thousand kernel weight and kernel weight per spike, respectively. For each increased cm2 of flag leaf area 0, 12 grand 1, 10 gr increase of spike weight and thousand kernels weigh, respectively. Variation accounted to flag leaf area were changed from 12 % to 95 %. Leaf area of examined number 33 depended mainly on thousand kernel weight, kernel weight/spike, and agro-ecological conditions during the growing period. High correlations between grain yield and areas of green parts above the flag node have been reported [19, 20]. Results of the shading experiment by many workers have shown that carbohydrates contributed by assimilating green parts above the flag leaf node amount to more than 85 % of the total accumulation in the grain [21, 22, 23, 24, 25, 26].

CONCLUSION

Flag leaf area has been shown to be highly associated to yield [27, 28, 29, 30]. This study focused on the importance of variation between two and six-rowed barley flag leaf areas and their relationship on spike components. The study also demonstrates that six-rowed barley had a larger flag leaf area compared to two-rowed barley. This study showed that a larger flag leaf area in two-rowed barley positively associates with a higher grain yield per spike. Therefore based on observed correlations, improving single-plant grain yield through larger flag leaf area in two-rowed barley might be important for future barley breeding programs in the context of increasing spike grain yield. Thus two-rowed barleys may adapt better to stress conditions than six-rowed barleys whether the phenotypic differences between row types classes in flag leaf area and other traits that may be related to the action of the predominant row-type gene are not yet clear.

REFERENCES

[1] Kling, J.G., Hayes, P.M. and Ullrich, S.E. (2004): Barley Genetics and Breeding, In Encyclopedia of Grain Science, 27-37.

[2] Berdahl, J.D., Rasmusson, D.C., Moss, D.N.(1972): Effect of Leaf Area on Photosynthetic Rate, Light Penetration, and Grain Yield in Barley, Crop Sci.,12:177-180.

[3] Yap, T.C., Harvey, B.L. (1972): Relations between Grain Yield and Photosynthetic Parts above The Flag Leaf Node in Barley, Can. J. Plant Sci, 52: 241- 246.

[4] Alqudah, A.M., Schnurbusch, T. (2015): Barley Leaf Area and Leaf Growth Rates are Maximized During The Pre-Anthesis Phase, Agronomy, 5:107-129.

[5] Van Oosterom, E.J., Acevedo, E. (1993): Leaf Area and Crop Growth in Relation to Phenology of Barley in Mediterranean Environments, Plant Soil, 148:223-237.

[6] Rasmusson, D.C. (1987): An Evaluation of Ideotype Breeding. Crop Sci.27:1140-1146

[7] Bertholdsson, N.O. (2013): Screening for Barley Waterlogging Tolerance in Nordic Barley Cultivars (*Hordeum vulgare* L.) using Chlorophyll Fluorescence on Hydroponically- Grown Plants. Agronomy, 3: 376-390.

[8] Watson, D.J.(1956): Leaf Growth in relation to Crop Yield. In:The growth of leaves (Eds.: F.L. ,MILTHORPE)Proc. 3 rd Easter School Agr. Sci. Univ.Nottingham Butter- worth and Co. Ltd., London, 178-191.

[9] Spagnoletti, P.L., Qualset, C.O. (1990): Flag Leaf Variation and The Analysis of Diversity in Durum Wheat, Plant Breeding, 105:189-202.

[10] Thorne, G.N. (1966): Physiological Aspect of Grain Yield in Cereals. In The Growth of Cereals and Grasses. Butterworths, London, p. 88- 105.

[11] El-Banna, M.N., Nassar, M.A.A.E.G., Mohamed, M.N., Boseely, M.A.E. (2011): Evaluation 16 Barley Genotypes under Calcareous Soil Conditions in Egypt. Journal of Agricultural Science, 3(1):105-121.

[12] Olgun, M., Onarcan, A. O., Özkan, K., Işık, Ş., Sezer, O., Özgişi, K., Ayter, N. G., Budak Başçitçi, Z., Ardıç, M., Koyuncu, O. (2016): Wheat grain classification by using dense SIFT features with SVM classifier. Computers and Electronics in Agriculture, 122: 185-190.

[13] Gallagher, J.N., Biscoe, P.V., Scoot, R.K. (1975): Barley and Its Environment, V. Stability of Grain Weight, J. Appl. Ecol., 12:319-336.

[14] Austin, R.B., Morgan, C.L., Ford, M.A., Blackwell, R.D. (1980): Contributions to Grain Yield from Pre- Anthesis Asssimilation in Tall and Dwarf Barley Phenotypes in Two Contrasting Seasons, Ann. Bot.,45:309-319.

[15] Fox, P.N., Crossa, J., Romagosa, I. (1997): Multi-Environment Testing and Genotype x Environment Interaction, Statistical Methods for Plant Variety Evaluation, 117-138.

[16] Olgun, M., Karaduman, Y., Arpacıoğlu, N. G. A., Ardıç, M., Koyuncu, O., Sezer, O., Başçiftçi, Z. B., Tunca, Z. B., Belen, Ş., Aydın, D., Katar, D. (2018): Ekmeklik Buğday Çeşitlerindeki RGB, HSV ve Lab Renk Değerleri ile Nitrojen Dozları ve Kalite Parametreleri Arasındaki İlişki. Biyoloji Bilimleri Araştırma Dergisi, 11(2): 46-51.

[17] Olgun, M., Ardıç, M., Başçiftçi, Z. B., Katar, D., Arpacıoğlu, N. G. A., Aydın, D., Sezer, O., Belen, Ş., Koyuncu, O. (2018): Türkiye'de Hububat Üretiminin Uzun Yıllara Bağlı Değişiminin Analizi. Biyoloji Bilimleri Araştırma Dergisi, 11(1): 23-28.

[18] Yoshida, S. (1972): Physiological Aspects of Grain Yield. Annu. Rev. Plant Physiol., 23: 437-464.

[19] Simpson, G.M. (1968): Asssociation between Grain Yield per Plant and Photosynthetic Area above the Flag-Leaf Node in Wheat, Can.J. Plant. Sci., 48:253-260.

[20] Voldeng, H.D. and Simpson, G.M. (1967): The relationship between Photosynthetic Area and Grain Yield per Plant in Wheat, Can. J. Plant Sci., 47:359-365.

[21] Archbold, H.K. (1942): Physiological Studies in Plant Nutrition. 13. Experiments with Barley on Defoliation and Shading of the Ear in Relation to Sugar Metabolism, Ann. Bot., 6:487-531.

[22] Asana, R.D., Mani, V.S. (1950): Studies in the Physiological Analysis of Yield Varietal Differences in Photosynthesis in the Leaf, Stem and Ear of Wheat. Physiol. Plant, 3:22-39.

[23] Thorne, G.N. (1961): Effect of Age and Environment on Net Assimilation Rate of Barley, Ann. Bot., 25:29-38.

[24] Watson, D.J., Thorne, G.N., French, S.A.W. (1958): Physiological Causes of Differences in Grain Yield between Varieties of Barley, Ann. Bot.,22:321-352.

[25] Welbank, P.J., French, S.A.W., Witts, K.J. (1966): Dependence of Yields of Wheat Varieties on Their Leaf Area Durations, Ann. Bot., 30:291-299.

[26] Olgun, M., Sezer, O., Turan, M., Başçiftçi, Z. B., Arpacıoğlu, N. G. A., Ardıç, M., Koyuncu, O. (2018): Determination of the Effects of Mineral on Seed Yield by Different Statistic Methods in Bread Wheat (*Triticum aestivum* L.) under Drought Conditions. Sakarya Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 22(6): 1711-1719.

[27] Yap, T.C. (1970): Diallel Analyses of Some Developmental Morpho-Physiological and Agronomic Traits on Barley, *Hordeum vulgare* L. emend.Lam, Ph.Thesis. Crop Sci.Dep., Univ. of Saskatchewan, Saskatoon, Sask.

[28] Peng, S., Khush, G.S., Virk, P., Tang, Q., Zou, Y. (2008): Progress in Ideotype Breeding to Increase Rice Yield Potential. Field Crops Res. 108:32-38.

[29] Ardıç, M., Olgun, M., Sezer, O., Başçiftçi, Z. B., Ayter, N. G., Çiçek, A., Koyuncu, O. (2017): The effects of some heavy metal pollutants on faculty of agriculture of ESOGU planting wheat fields in Eskişehir-Turkey. Research Journal of Biology Sciences, 10(1): 21-25.

[30] Olgun, M., Dikmen, G., Başçiftçi, Z. B., Karaduman, Y., Ayter, N. G., Aydın, D., Belen, Ş., Ardıç, M., Koyuncu, O., Sezer, O. (2020): NMR Spektroskopisi ile Ekmeklik Buğdayda Kimyasal İçerik Analizi. Eskişehir Teknik Üniversitesi Bilim ve Teknoloji Dergisi-C Yaşam Bilimleri Ve Biyoteknoloji, 9(2): 190-197.