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Comparison of Grain Yield and Some Characteristics of Hulled, Durum and Bread Wheat Genotypes Varieties

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A R T I C L E I N F O

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A B S T R A C T

In spite of the low grain yield they produce, the hulled wheat have become even more important in recent years because of their resistance to negative environmental conditions and healthy nutritional content. The research was carry out in order to comparison the yield and yield characteristics of durum (Kiziltan-91 and C-1252), hulled (Einkorn and Emmer) and bread wheat (Tir) varieties in Isparta ecological conditions in 2013-14 and 2014-15 vegetation periods. In both years, the highest grain yield was obtained in Kiziltan-91 variety (3992 and 3758 kg ha^{-}1 respectively). The grain yield of hulled wheats in the first year (Einkorn 1269 kg ha^{-1}, Emmer 2125 kg ha^{-1}) was around Turkey averages. However, grain yield decreased of commercial wheat varieties due to the negative effect of high amount of rainfall in June in the second year, but considerably increased in (Einkorn 2150 kg ha^{-1}, Emmer 2533 kg ha^{-1}). N uptake was found to be lower in the than durum wheats. In terms of grain protein content, the highest values were obtained in Emmer variety (16.4%-15.3%).

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Ö Z E T

Kavuzlu buğdaylar düşük tane verimlerine rağmen olumsuz çevre koşullarına dayanım ve sağlığa faydalı besin içerikleri ile son yıllarda önem kazanmışlardır. Araştırma makarnalık (Kızıltan-91 ve C-1252), kavuzlu (Kavılca ve Siyez) ve ekmeklik (Tir) buğdayların verim, verim özellikleri bakımından karşılaştırmak amacıyla Isparta ekolojik koşullarında 2013-14 ve 2014-15 vejetasyon döneminde yürütülmüştür. Her iki yılda da en yüksek verim Kızıltan 91 çeşidinde (3992 ve 3758 kg ha^{-1}) elde edilmiştir. Kavuzlu buğdaylar ilk yıl Türkiye ortalamaları dolayında verim (Siyez 1269, Kavılca 2125 kg ha^{-1}) verirken, ikinci yıl yüksek haziran yağışlarının olumsuz etkisi nedeniyle ticari buğday çeşitlerindeki düşüşe rağmen belirgin verim artışı (Siyez 2150, Kavılca 2533 kg ha^{-1}) olmuştur. Kavuzlu buğdaylarda azot alımı makarnalık buğdaylara göre daha düşük bulunmuştur. Tane protein oranı bakımından en yüksek değerler her iki yılda Kavılca çeşidinde (sırasıyla %16,4-15,3) belirlenmiştir.

Introduction

Ninety-five percent of the world's total wheat production is bread wheat varieties and the remaining 5% is durum and other varieties (Shewry, 2009). Commercial wheat varieties, which play a significant role in the nutrition of the increasing world population and form an enormous part of production today, are expected to become even more important in the near future. Unfortunately, both the size of cultivation areas and the amount of production have greatly decreased in hulled wheats by reason of the efforts to boost production and commercial concerns (Karagoz, 1995).

Cultivation of hulled wheats (Einkor and Emmer) began approximately 10,000 years ago in the region called 'Fertile Crescent', which also includes the Southeastern Anatolia Region of Turkey (Zohary et et al., 1993; Smith, 1995; Nesbitt, 1998). Then, it spread from the Fertile Crescent to Asia and Europe, contributing remarkably to the development of civilizations (Diamond, 1999). Hulled wheats have made a great contribution to the development of modern wheat varieties (Quisenberry and Reitz, 1974).

Hulled wheats are generally used as bulgur and animal feed. As bulgur, they are considered to be a healthy alternative to rice and pasta. Being resistant to diseases and environmental conditions (Hammer and Perrino, 1984; Castagna et al., 1995), hulled wheats (Einkorn, Emmer, etc.) also have the potential of being an alternative to rye and triticale in marginal areas. They are used as natural antioxidants in human nutrition because of higher total antioxidant activity, total phenolics, ferulic acid and flavonoids (Serpen et al., 2008). In recent studies, it is recommended to use hulled wheats in the production of special nutrition products for their high and high-quality protein and nutritional content (Vallega, 1979; Brandolini et al., 2008).

This research was carried out for the purpose of determining the opportunities of cultivation for hulled wheats, the production of which has decreased in recent years, by comparing them to other varieties.

Materials and Methods

The experiment was carried out on experimental fields of Suleyman Demirel University in Isparta in Turkey during 2013-14 and 2014-15 growing seasons in without irrigation conditions. The experimental layout was a randomized complete block design with 3 replications. Durum cultivars Kiziltan-91 (*Triticum durum* L.), C-1252 (*Triticum durum* L.), hulled varieties Einkorn (*Trirticum monococcum* L.), Emmer (*Triticum dicoccum* L.) and bread variety Tir (*Triticum aestivum* var. *leucospermum*) were used in the study. Hulled wheats and Tir were collected as populations from different province of Turkey.

Climatic data of crop growing seasons was shown at Table 1 (Anonymous 2016). In the growing periods 2013-14 and 2014-15, total rainfall from October to July was 559.7 mm and 692.7 mm respectively, mean of long term was 512.1 mm. Mean temperature from October to July was 10.7°C for 2013-14 growing season and it was 10.2°C for 2014-15, being higher than the long term (average 10.4°C) (Table 1). The soil of experiment (depth of 60 cm) was clay-loam content (Akgül and Başayiğit 2005), 1.8% of organic matter, 3.1 NO_3 kg ha^{-1} of nitrogen, 7.9 of pH, 1.3% of calcium carbonate, 20.4 kg ha^{-1} P_2O_5 and 12.7 kg da^{-1} K_2O contents.

The plot size 1.2x6 m. Seeds were sown with the dibbler maintaining row to row distance 15 cm and plant to plant distance of 5 cm. Seeds were sown in the first week of October in both years on plots. Prior to sowing, half of the nitrogen fertilizer (40 kg N ha^{-1}) was broadcasted as ammonium sulphate. The other half (40 kg N ha^{-1}) was applied during stalk development (stem formation) as ammonium sulphate. All of the phosphors fertilizer (60 kg P_2O_5 ha^{-1}) was given as triple super phosphate before sowing.

In the study, spike number in per m^2, spike length, number of kernels per spike, kernels weight per spike, 1000-kernel weigh, biological yield (total aboveground plant), N uptake, protein content, and grain yield (gross yield for hulled wheats) were measured. Seed nitrogen content was analyzed using a semi-micro Kjeldahl method. Nitrogen uptake was calculated for each variety as formula by Delogu et al. (1998).

Nitrogen uptake = [t.a.p. N at N_x (kg ha^{-1}) – t.a.p. N at N_0 ($kgha^{-1}$)] / applied N (kg ha^{-1}).

Where; t.a.p. is total aboveground plant.

Means were compared according to the LSD test by using SAS (1998) statistics package program (Steel and Torrie, 1985).

Results and Discussions

The effect of cultivation years was found to be significant on spike length, kernels per spike, and kernel weight per spike; whereas the spikes per m^2 and thousand kernel weight were non-significant. Abovementioned plant traits were also significantly different among the varieties. Besides the kernel weight per spike, year x cultivar interaction was non-significant for the investigated traits (Table 2). In both years, Einkorn variety had the highest number of spikes per square meter but the lowest values in terms of spike height, number of grains per spike, grain weight per spike, and 1000-grain weight, followed by Emmer variety (Table 2). The number of grains per spikelet was found to be one, two, and three in Einkorn variety, Emmer variety, and other varieties, respectively, resulting from the genetic characteristics of Einkorn and Emmer. The average spike length and the average number of kernels per spike were lower in the first year. The average weight of kernels per spike, however, was lower in the second year. In other characteristics, no difference was encountered between the years. Wheat-landraces exist in populations, which increase their adaptability and cause large variation in yield and yield characteristics (Castagna et al., 1995; Sonmez et al., 1999; Marino et al., 2009).

Despite biological yield was significant in both years, the combined effect of the years was somehow not significant. Year x cultivar interaction resulted in different biological yield since the response of each variety to the rainfall in the growth years was likely to be different

(Table 2). In the first year, biological yield was found to be significantly low in Einkorn (7315 kg ha^{-1}) and Emmer (7546 kg ha^{-1}) varieties (Table 2). In the second growth year, however, decreased biological yield for C-1252 (9500 kg ha^{-1}) and Tir (8900 kg ha^{-1}) varieties observed but the rest of the varieties showed significant increase. Because of this significant increase, second year's averages were found to be higher. Compared to previous studies (Togay et al., 2009), the biological yield of hulled wheat was considerably higher than the Turkey average. The amount of precipitation during blooming and grain filling, which was much higher than the average in the second year, caused extra development in vegetative parts especially in hulled wheats.

Table 1 The climate data of experimental years

CF	Y/M	Octo.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	M/T
MT	2013-14	10.7	8.7	1.0	3.7	5.2	7.3	11.7	15.1	20.0	24.5	10.7
	2014-15	12.9	6.8	6.0	1.9	3.3	6.7	9.0	13.2	18.3	24.2	10.2
	Long term	12.9	7.4	3.5	1.9	2.9	6.2	10.7	15.6	20.2	23.6	10.4
TP	2013-14	104.0	67.6	29.4	61.3	23.4	78.6	44.8	107.0	42.8	0.8	559.7
	2014-15	57.1	37.0	108.6	125.9	57.7	117.6	26.1	67.5	92.2	3.0	692.7
	Long term	38.0	46.3	84.9	72.2	64.7	54.2	56.0	51.4	29.8	14.6	512.1

CF: Climatic factors, MT: Mean temperature (°C), TP: Total precipitation (mm), Y/M: Years/Months, , M/T: Means/Total,

Table 2 Yield components of wheat varieties

C/L		Spikes per m^2 (number)			Spike length (cm)			Kernels per spike (number)		
		2013-14	2014-	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Kiziltan-91		356.0 b	400.0 b	378.0 c	5.5 bc	8.0 abc	6.8 b	27.5 ab	43.7 ab	35.6 b
C-1252		442.6 b	441.3 b	442.0 b	7.5 ab	9.3 ab	8.4 a	37.3 a	47.8 a	42.6 a
Einkorn		806.0 a	738.7 a	772.3 a	3.8 c	6.9 c	5.3 c	9.3 c	23.2 c	16.3 d
Emmer		430.6 b	449.3 b	440.0	6.6 b	7.7 bc	7.1 b	23.7 b	24.3 c	24.0 c
Tir		377.3 b	426.7 b	402.0	8.7 a	9.7 a	9.2 a	28.7 ab	33.3 bc	31.0 b
Mean		482.5	491.2	486.9	6.4 B	8.3 A	7.4	25.3 B	34.5 A	29.9
$LSD_{cultivar}$		102.4	173.9	40.3	2.1	1.9	0.6	13.2	12.4	3.6
F value	Year	-	-	0.21^{ns}	-	-	53.5**	-	-	29.4*
	Cultivar	73.0 **	14.5**	57.9 **	17.9**	8.8**	25.5**	13.6**	18.1**	28.6*
	Y x C	-	-	1.23^{ns}	-	-	2.3^{ns}	-	-	2.9^{ns}
CV (%)		7.7	12.9	10.7	12.0	8.2	9.8	19.0	13.1	15.6
C/L		Kernels weight per spike (g)			1000 kernel weigh (g)			Biological yield (kg ha^{-1})		
		2013-14	2014-	Mean	2013-14	2014-15	Mean	2013-14	2014-15	Mean
Kiziltan-91		1.6 b	1.6 a	1.6 b	48.5 a	38.0 a	43.3 a	10063 ab	12807 ab	11435
C-1252		2.4 a	1.5 ab	2.0 a	45.0 ab	35.3 ab	40.2 a	10241 ab	9500 b	9871
Einkorn		0.4 c	0.7 d	0.5 d	22.0 c	29.3 b	25.7 c	7315 b	10710 b	9013
Emmer		0.9 c	0.8 cd	0.9 c	23.8 c	33.8 ab	28.8 bc	7546 b	13600 a	10573
Tir		1.7 b	1.1 bc	1.4 b	33.2 bc	28.3 b	30.8 b	11973 a	8900 b	10437
Mean		1.4 A	1.1 B	1.3	34.5	32.9	33.7	9428 B	11103 A	10266
$LSD_{cultivar}$		0.6	0.4	0.1	13.0	8.4	3.1	3309.9	2247.7	1185
F value	Year	-	-	14.4**	-	-	1.1^{ns}	-	-	9.0**
	Cultivar	34.3**	22.6**	53.7**	19.3**	5.4*	21.8**	7.99**	4.1*	2.1^{ns}
	Y x C	-	-	7.9**	-	-	8.7**	-	-	8.3**
CV (%)		16.4	13.3	15.3	13.7	9.3	11.8	12.8	12.2	14.9

C/L: Cultivars/Landraces, Means in the same columns followed by the same letters are not significantly different as statistically, *P>0.05, **P>0.01, ns; non-significant

Table 3 Nitrogen uptake, protein content and grain yield of wheat varieties

C/L		N uptake (kg ha^{-1})			Protein content (%)			Grain yield (kg ha^{-1})		
		2013-14	2014-	Mean	2013-	2014-15	Mean	2013-14	2014-15	Mean
Kiziltan-91		110 ab	136	123 a	10.6 b	10.9 b	10.8c	3992 a	3758 a	3875a
C-1252		132 a	113	122 a	15.1 a	14.0 a	14.5 b	3862 a	2644 b	3253b
Einkorn		73 c	98	86 c	15.1 a	13.7 a	14.4b	1269 d	2150 bc	1710d
Emmer		99 b	104	102 bc	16.4 a	15.3 a	15.9a	2125 c	2533 b	2329c
Tir		127 a	99	113 ab	15.4 a	14.0 a	14.7b	2922 b	1347 c	2135c
Mean		104.6	109.8	109.1	14.6 A	13.6 B	14.1	2834 A	2486.5 B	2660
$LSD_{cultivar}$		24.4	48.7	10.9	2.60	2.3	0.7	680.4	1064.9	252.5
F value	Year	-	-	0.1^{ns}	-	-	9.1**	-	-	8.5*
	Cultivar	21.2**	2.3^{ns}	7.5**	16.9**	11.2**	27.9**	65.1**	15.2**	43.9**
	Y x C	-	-	4.7*	-	-	1.0^{ns}	-	-	15.4**
CV (%)		8.2	16.2	12.9	6.5	6.1	6.4	8.8	15.6	12.2

C/L: Cultivars/Landraces, Means in the same columns followed by the same letters are not significantly different as statistically, *P>0.05, **P>0.01, ns; non-significant.

In the first year of the experiment, N uptake per hectare was higher in C-1252 and Tir varieties than the other varieties. Cultivars took up different amounts of N kg ha^{-1} in the first growth season and this effect made the combined-year-effect significant (Table 3). However, the lowest values were obtained in Einkorn variety (73-98 kg ha^{-1} N) in two years. Even though biological yield and grain yield were higher in Einkorn and Emmer varieties in the second year, the nitrogen they took up did not increase much because these varieties are less dependent on nitrogen (Castagna et al., 1995). In the second year, the amount of nitrogen taken up by Tir and C-1252 varieties decreased depending on decreasing grain yield. It was stated that plant nutrient increased depending on increasing number of genomes and nutrient uptake efficiency increased depending on fertilization (Huang et al., 2007). In the second year, there was a decrease in the annual average of grain yield but an increase in biological yield values, resulting in a difference between years in terms of N uptake.

In terms of protein contents of grains, varieties differently responded to growth years but somehow the combined effect of growth seasons and varieties did not change it. In Kiziltan 91 variety, protein content was found to be low in both years (10.6% and 10.9%). Although there was no significant difference between other varieties, the highest values were obtained in Emmer variety. Compared to the first year of the experiment, the second year produced lower protein contents. The grain protein content of Tir wheat was around 12%-14% in other studies conducted with nitrogen treatment (Togay et al., 2009) but higher in our study (14%-15%). In Emmer populations, however, protein content varied between 6.7% and 18% (Blanco et al., 1990; Kaplan et al., 2014). The results given above demonstrate once again that variation is higher in the varieties comprising of populations. Compared to Einkorn, higher protein content was found in Emmer variety, which is similar to the results obtained by Unal (2009).

The grain yield was statically significant in terms of the years, cultivars and year x cultivar interaction (Table 3). The yield of diploid varieties is lower due to genetic characteristics such as lower spike height and lower number of grains per spikelet. This expected result was clearly seen in the first year of the experiment. The highest yields were obtained from Kiziltan 91 (3992 kg ha^{-1}) and C-1252 (3862 kg ha^{-1}) varieties, while the lowest yields (gross yield) were found in Einkorn (1269 kg ha^{-1}) and Emmer (2125 kg ha^{-1}) varieties. In the second year of the experiment, the highest yield was again produced by Kiziltan 91 (3758 kg ha^{-1}). However, in Tir (1347 kg ha^{-1}) and C-1252 (2644 kg ha^{-1}) varieties, there was a decrease in yield. In contrast, a notable increase of yield was encountered in Einkorn (2150 kg ha^{-1}) and Emmer (2533 kg ha^{-1}) varieties. In Turkey, yield is quite lower than the country average in the hulled wheats (810-1400kg ha^{-1}) and Tir wheat (959 kg ha^{-1}) (Karagöz, 1995; TUIK, 2014). Marino et al., (2009) obtained 2400kg ha^{-1}yield from Emmer variety. However, the yield obtained in the second year of our study was higher (2533 kg ha^{-1}). Although it was reported in previous studies that the grain yield of Tir wheat varied between 650kg $ha^{-1}$and 1570kg ha^{-1} (Togay et al., 2009), the first year of our study produced much higher yield (2922 kg ha^{-1}).

Mean annual temperature, humidity and precipitation values in the years of experiment were higher than the long-term average. During blooming and grain filling (May, June), which is a critical period for yield, temperature values were similar to averages in the first year but decreased in the second year (Table 1). In both years, the amount of precipitation in this period was considerably higher than the average precipitation. But in the second year of the experiment, the amount of precipitation in June was three times higher than the annual average and approximately two times higher than the previous year, giving rise to rust and decrease in yield. It is known that some Tir varieties are sensitive to yellow rust, while others have moderate resistance to it (Sönmez et al., 2002). Compared to other varieties, Einkorn and Emmer had less black rust and septoria (unpublished data). This adverse situation led to a decrease in the yield of other varieties in the second year but caused an apparent yield increase in hulled wheats.

Conclusions

Wheat genotypes highly varied by yield and yield characteristics because they generally exist in populations. It was seen that the hulled wheats, which gave much higher yield values than general averages in the second year, had the potential of being a strong alternate under marginal climate conditions. Of all commercial varieties, Kiziltan 91 was more stable in terms of yield. On the other hand, C-1252 was found to be better in quality but more sensitive to climate conditions. The hulled wheats, which are undoubtedly good for health, need to be registered and put into commercial production. Besides, further studies intended for increasing the yield of the hulled wheats are necessary.

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