Pakistan J. Agric. Res. Vol 24 No. 1-4, 2011.

ASSESSMENT OF HETEROSIS AND HETEROBELTIOSIS FOR SPIKE CHARACTERS IN DURUM WHEAT

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ABSTRACT:- The present study was conducted to evaluate magnitude of heterotic effects in F_1 hybrids of seven durum wheat cultivars, and to investigate the performance and relationship of F_1 hybrids and parents for the spike characters and to select suitable parents and population for designing an effective wheat breeding programme. Highly significant genetic variability was present in parents and their genetic combinations for the characters. The degree and direction of heterosis varied for different characters and for different hybrids. The highest heterosis over mid and better parents (120.14-109.93%) was recorded in hybrid of Kýzýltan91xIDSN209 for grain weight/spike. Maximum limits of heterosis over mid and better parent for spike length, spikelets/spike, grains/spike, spike density, grains/spikelets and spike harvest index were 8.77-8.14 (Svevo//GedxYav), 8.37-7.37 (Svevo//GedxYav), 74.71-57.06 (Kýzýltan91xZenit), 19.41-10.55 (Kýzýltan91//GedxYav), 72.41-57.23 (Kýzýltan91xIDSN209) and 23.29-18.74% (Kýzýltan91xIDSN 209), respectively. Kýzýltan91, Svevo and IDSN209 should be utilized to improve spike characters in the hybridization scheme, and the hybrids Kýzýltan91xIDSN261, Kýzýltan91xSvevo, Kýzýltan91xIDSN209, SvevoxZenit and Kýzýltan91xSvevo must be considered for finding out transgressive segregants in late segregations to develop a potential durum wheat variety.

Key Words: Durum Wheat; Spike Characters; Heterosis; Mid Parents; Better Parents; F_1 Hybrids; Turkey.

INTRODUCTION

Durum wheat (*Triticum durum* Desf.) is an important crop for human diet (e.g., macaroni, pasta,couscous, semolina, etc.), particularly in the Mediterranean basin where 75% of the world's durum wheat grain is produced (Maccaferri et al., 2008) and the majority of the Mediterranean durum wheat is grown in Italy, Spain, Turkey, Syria, Tunisia, Algeria, Morocco, France and Greece (Nachit et al., 1988). In Turkey, although ecology offers an opportunity for the production of high-quality wheat, durum wheat has received less attention than the bread wheat. The yield levels of durums are low as compared to bread wheat. Therefore, it is necessary to improve new durum wheat with yielding capacity. This could be only realized via intensive and effective breeding programmes. Thus, careful selection of the parents is the first important step in the process for the development of superior high yielding cultivars.

Direct components of grain yield in durum wheat were reported to be harvest index , number of grains per square meter (Waddington et al., 1987), grain setting, spikelets/spike, fertile florets/ spike (Alvaro et al., 2008). Despite the theoretical upper limit of HI, estimated at 0.60 (Austin et al., 1980), there has been no quantum improvement in partitioning since it reached ca. 0.50 in the mid-1980's (Fischer and Quail, 1990). Therefore, the main way of the raising wheat yield seem to be improving souce and silk potential (Richards, 1998). The inflorescence in wheat is spike and would therefore have a direct bearing on grain yield in the crop. Spike is a one of the main photosynthetic parts of the plant which makes an important contribution to the final grain yield (Araus et al., 1993), especially arid and semi-arid conditions (Bort et al., 1994). In durum wheat varieties, spike sterility is a significant factor in yield potential variation (Fischer, 2001). The increase in the

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number of grains per spike has been found to explain up to 50% of genetic gains in the number of grains per unit area (Royo et al., 2007). Thus, any improvement of spike characteristics through selection and breeding would help improve the per plant productivity (Iqbal and Khan, 2006). For breaking the yield barrier level and make durum wheat cultivation more at tractive, it is now necessary to explore alternative approaches. Among the all possible alternatives, heterosis is an important approach for increasing wheat production. Exploitation of heterosis is considered to be one of the outstanding achievements of plant breeding (Jaiswal et al., 2010). The term of heterosis was defined as the better performance of hybrid plants over its parental inbreds in terms of viability, growth and productivity (Shull, 1952). The heterosis is a method which describes the improved vigour of F_1 hybrids in comparison to their parental homozygous lines and breeding programme (Shull, 1914; Sharma et al., 1986; Borghi et al., 1988). The present study was conducted to evaluate magnitude of heterotic effects in F_1 hybrids of seven durum wheat cultivars, and to investigate the performance and relationship of F_1 hybrids and parents for the spike characters and to select suitable parents and population for designing an effective wheat breeding programme.

MATERIALS AND METHODS

Plant Material

The experimental material for the study comprised distinct seven durum genotypes (Svevo and Zenit (Italy), Kýzýltan91(Turkey) and 4 advanced lines (GedxYav (Turkey), IDSN165 (CIMMYT), IDSN209 (CIMMYT) and IDSN261 (CIMMYT)) and their twelve hybrids [(i)SvevoxIDSN261,(ii) Svevox Kýzýltan91, (iii) SvevoxIDSN209, (iv) SvevoxZenit, (v) Svevo//GedxYav, (vi) SvevoxIDSN165, (vii) Kýzýltan91xIDSN261, (viii)Kýzýltan91xSvevo,(ix) Kýzýltan91xIDSN209, (x) Kýzýltan91xZenit, (xi)Kýzýltan91//GedxYav,(xii) Kýzýltan91xIDSN165].

Methods

The seven durum genotypes and 4 advance lines were used to attempt F_1 hybrids in 2005-06 crop season. Ten plants were pollinated for each combination. The seven parents along with their 12 hybrids were sown in a field using a randomized complete block design in four replication in November 2007 in Tekirdag, Turkey. Each entry considsted of a single 2 m long with plant to plant and spacing of 10 cm and 25 cm, respectively. All of the agronomic practices were done timely to achieve a good crop stand. At maturity, 10 guarded plants from each replication were selected at random and data were recorded for spike length (SL),spikelets/spike (SL/S), grains/spike (G/S), grains weight/spike (GW/S), spike density (SD), grains/spikelets (G/SL) and spike harvest index (SHI) in the main spike of the plant. The spike density, grains/spikelets and spike index were calculated as:

$$SD = \frac{\text{Spikelets / spike}}{\text{Spike length}}, \quad G/SL = \frac{\text{Grains / spike}}{\text{Spikelets / spike}} \quad \text{and}$$

$$SHI = \frac{\text{Grain weight / spike}}{\text{Spike weight}}$$

Statistical Procedures

Analyses of variance (ANOVA) were performed to determine the significance in differences among the experimental material (Steel and Torrie, 1960), and significant differences where indicated were further subjected to Least Significant Differences (LSD) Test for each character. Then, the heterosis calculations were performed in the characters showing significant differences. The percent increase (+) or decrease (-) of F_1 hybrids over mid as well as better parent was calculated to estimate possible heterotic effects for the characters by using the formula of Fonseca and Patterson (1968) as:

$$MPH(\%) = \frac{F_1 - MP}{MP} \times 100, \quad BPH(\%) = \frac{F_1 - BP}{BP} \times 100,$$

where, MPH=Mid-parent heterosis,
BPH=Better-parent heterosis,

MP=Mid parent and

BP=Better parent value.

The "t" test was computed to determine whether F_1 hybrid means were statistically significant from mid parent and better parent means as follows (Wynne et al., 1970).

$$t_{ij}= F_1ij - MPij \Big/ \sqrt{\frac{3}{8}EMS} \quad t_{ij}= F_1ij - BPij \Big/ \sqrt{\frac{1}{2}EMS}$$

where, F_1ij=mean of the ijth F_1 cross,

MPij=mid parent for ijth cross,

BPij=Better parent value for ijth cross

EMS=Error mean square.

RESULTS AND DISCUSSION

There were significant differences for the phenotypic characteristics of the parents and F_1 hybrids indicating that mean performance of hybrids was different with parents, in other words, heterosis can be attained for these characters in the studied genotypes (Table 1). The estimates heterosis of F_1,over mid and better parents for spike characters are given in Table 2.

Spike Length

The means of genotypes (Table 1) indicated that among parents Kýzýltan91 had maximum spike length (11.7 cm). The cultivar Zenit had minimum spike length (8.2 cm). Among the F_1 hybrids, Kýzýltan 91xIDSN261 had maximum spike length (10.0 cm) whereas minimum spike length (8.6 cm) was calculated in cross SvevoxZenit. The magnitude of estimated heterosis for spike length over mid and better parent varied from 8.77 to -18.18%, and 8.14 to -25.64%. Nearly all of the hybrids showed negative heterosis over mid and better parent were observed only for cross Svevo/GedxYav (8.77 and 8.14%). While negative heterosis over better parent was observed from 10 out of 12 hybrids, among them eight were significant (P<0.01), and the others were non-significant. The difference in response of genotypes towards heterosis is a studied phenomena e.g. Jaiswal et al. (2010) have reported positive mid parent heterosis, while Akhter et al. (2003) have recorded negative heterosis for spike length in wheat genotypes. This difference may be attributed to diversity in genetic material.

Spikelets per Spike

Spikelets/spike is an effective yield component and a greater number would result in more grains per spike, therefore, positive heterosis is desirable for this trait. Individual comparison of average number of spikelets/spike (Table 1) showed that Kiziltan91 gave maximum number of tillers per plant (26.0) among parents and from hybrids; Kiziltan91xZenit was at the top with an average of 26.3 spikelets per spike. Heterotic investigations revealed that 6 hybrids showed positive heterosis over mid-parent but small. All other hybrids exhibited negative heterosis either significant or non-significant that is why these are worthless for yield improvement. Among them only hybrid Svevo//GedxYav contributed highest value for mid-parent heterosis (8.37%) as well as for better parent heterosis (7.37%), and the others were non-significant for spikelets/spike. Similar findings had been reported by Abdullah et al. (2002) and Akbar et al. (2010).

Grains per Spike

It directly determines the yield potential of a genotype. There are marked differences for grains/spike among the parents and hybrids which varied from 55.5 (Kýzýltan91xIDSN209) to 26.8 (Zenit). Among parents GedxYav exhibited highest mean value (43.0) while among hybrid Kýzýltan91xIDSN209 exhibited maximum mean value (55.5) for grains/spike (Table 1). Analysis of the data revealed that all of 12 hybrids were positive mid parent heterotic and 10 out of 12 hybrids were positive better parent heterotic in interaction. Çiftçi and Yaðdý (2007) calculated very high positive heterotic effects over mid and better-parent as 82.54% and 48.12% for grain weight, respectively. Impressive positive significant mid-parent heterosis i.e. 74.71% was observed in hybrid of Kýzýltan91xZenit, followed by SvevoxZenit (58.15%) and Kýzýltan91xIDSN209 (57.22%)

whereas maximum positive better-parent heterosis was revealed by the hybrid Kýzýltan91-xZenit (57.06%) followed by Kýzýltan91-xIDSN165 (38.87%). These results could be verified from the findings of Inamullah et al. (2006) and Farahani and Arzani (2007) who reported highly significant mid and better parent heterosis for grains per spike in wheat.

Grain Weight per Spike

Grain weight is an essential componentcontributing for yield production, so positive heterosis is desirable for this trait. The maximum grain weight/spike (3.17 g) was recorded from the cross Kýzýltan91xIDSN209, while the minimum value (1.37 g) was obtained from parent Kýzýltan91. The relative mid and better parent heterosis for grain weight/spike ranged from -14.20 to 120.14 and -25.27 to 109.93% (Table 1). Fida et al. (2004) and Solomon et al. (2007) measured very high positive heterotic effects over mid-parent as 51.89% and 97.00% for grain weight, respectively. Likewise, Yaðdý and Karan (2000) estimated heterosis over mid-parent and better-parent ranging from 80.0% to -20.0% and from 73.9% to -29.1%, respectively. Out of 12, six hybrids showed positive and significant mid-parent heterosis ranging from 120.14 (Kýzýltan91xIDSN209) to 29.88 (SvevoxIDSN165). Hybrids of Kýzýltan 91xIDSN209, Kýzýltan91xIDSN261 and Kýzýltan91xSvevo depicted significant better parent heterosis in positive direction ranging from 109.93 to 32.80%. These results are also in agreement with Daðüstü (2005) and Çiftçi and Yaðdý (2007) who reported the highly significant heterosis values over mid-parent (47.1% and 69.88%) forgrainweight/spike.

Grains per Spikelets

This trait is the most important yield determinant of wheat (Sinclair and Jamieson, 2006) and it products of plants m-^{2}, ears/plant and grains/spike. The individual comparison of means of all genotypes (Table 1) indicated that among the genotypes hybrids SvevoxZenit (2.52) and Kýzýltan91xIDSN209 (2.50) had maximum

Table 1. Average values for spike traits of parents and F1 hybrids of durum wheat

Hybrids and parents	Spike length (cm)	Spikelets/ spike (No.)	Grains/ spike (No.)	Grain weight/ spike (g)	Grains/ spikelets (No.)	Spike density (%)	Spike harvest index (%)
SvevoxIDSN261	9.1 d-g	21.5 fg	41.5 efg	1.52 de	1.93 a-d	2.37 de	68.3 c
SvevoxKyzypltan91	9.8 bcd	24.3 a-e	50.0 a-d	1.39 e	2.07 abc	2.49 b-e	54.2 gh
SvevoxIDSN209	8.9 d-g	22.3 d-g	42.8 c-g	1.59 de	1.93 a-d	2.48 b-e	69.6 bc
SvevoxZenit	8.6 fg	21.8 fg	54.8 a	2.32 bc	2.52 a	2.53 b-e	60.8 d-g
Svevo//GedxYav	9.3 c-f	23.3 c-g	44.5 b-f	1.75 cde	1.91 a-d	2.52 b-e	53.7 hi
SvevoxIDSN165	8.8 efg	22.8 d-g	50.5 abc	2.13 bcd	2.23 abc	2.58 bcd	47.1 i
Kýzýltan91xIDSN261	10.0 bc	23.8 b-f	51.5 ab	2.37 bc	2.17 abc	2.37 de	64.0 c-f
Kýzýltan91xSvevo	9.8 bcd	22.8 d-g	53.3 a	2.47 b	2.35 ab	2.34 de	76.0 ab
Kýzýltan91xIDSN209	9.0 d-g	22.2 d-g	55.5 a	3.17 a	2.50 a	2.47 cde	77.3 a
Kýzýltan91xZenit	9.6 b-e	26.3 a	52.5 a	1.66 de	2.02 abc	2.75 abc	66.7 cd
Kýzýltan91//GedxYav	8.7 efg	24.5 a-d	43.0 c-g	1.88 b-e	1.76 bcd	2.83 ab	75.9 ab
Kýzýltan91xIDSN165	9.7 bcd	25.3 abc	49.3 a-e	1.68 de	1.96 abc	2.60 bcd	56.2 gh
Svevo	8.6 fg	21.3 g	42.5 d-g	1.86 b-e	2.01 abc	2.55 bcd	64.4 c-f
IDSN261	9.4 c-f	22.0 efg	38.8 fgh	1.56 de	1.76 bcd	2.35 de	70.5 bc
Kýzýltan91	11.7 a	26.0 ab	33.3 hi	1.37 e	1.31 de	2.18 e	65.1 cde
IDSN209	10.3 b	23.3 c-g	37.3 fgh	1.51 de	1.59 cde	2.25 de	60.3 d-h
Zenit	8.2 g	24.5 a-d	26.8 i	1.65 de	1.10 e	2.98 a	57.6 fgh
GedxYav	8.5 fg	21.7 fg	43.0 c-g	1.47 e	1.99 abc	2.56 bcd	58.4 e-h
IDSN165	9.2 c-f	23.0 c-g	35.5 gh	1.42 e	1.79 bcd	2.52 b-e	54.8 gh
Mean	9.3	22.3	44.6	1.83	1.94	2.51	63.2
LSD 0.01	0.881	2.470	7.891	0.618	0.628	0.352	6.822

Means followed by same letter (s) do not differ significantly at 0.5 % probability level.

grains/spikelet while parent Zenit had minimum grains/spikelets. (1.10). The heterotic effects (Table 2) indicated out of 12 F_1 hybrids, 11 hybrids showed positive mid-parent heterosis ranging from 2.12 (SvevoxIDSN261)to72.41% (Kýzýltan91-xIDSN209) among the 7 hybrids were significant and the others were non-significant. As far as the heterosis over better parent is concerned that 8 F_1 hybrids exhibited the positive values ranged from 2.99% (SvevoxKýzýltan91) to 57.23% (Kýzýltan91xIDSN209). Presence of hybrid vigour in grains/spikelets had already been reported by Ulukan (2007).

Spike Density

A perusal of data indicated the highly significant differences among the genotypes for this character (Table 1). For parents the average spike density ranged from 2.98 (Zenit) to 2.18 (Kýzýltan91). Out of 12 hybrids, 8 hybrids showed positive mid-parent heterosis for spike density that ranged from 1.58% to 19.41%. Of 8 hybrids, Kýzýltan91//GedxYav, Kýzýltan91xIDSN-209 and Kýzýltan91x IDSN165 displayed significant mid-parent heterosis values of 19.41, 11.26 and 10.64%, respectively (Table 2). In better parent heterosis, positive effects were observed in 5 hybrids and only better parent heterosis of hybrid of Kýzýltan91//GedxYav was significant (10.55%) for this character. These results are in general agreement with Iqbal (2004) who reported the highly significant heterosis values for spike density over mid and better parents.

Spike Harvest Index

Spike harvest index (SHI) is the spike dry weight (at anthesis) to total dry weight ratio at physiological maturity. It shows the proportion of mobilized dry matter to spike in a genotype (Donalson, 1996). A marked variation is evident (Table 1) for average spike harvest index among the parents and hybrids which varied from 47.1

Table 2. Heterosis (%) (MPH and BPH) for spike traits of F_1 hybrids during 2006-07

Hybrids and parents		Spike length (cm)	Spikelets/ spike (No.)	Grains/ spike (No.)	Grain weight/ spike (g)	Grains/ spikelets (No.)	Spike density (%)	Spike harvest index (%)
SvevoxIDSN261	MPH	1.11	-0.69	2.09	-11.11	2.12	-3.27	1.26
	BPH	-3.19	-2.27	-2.35	-18.28	-3.98	-7.06	-3.12
SvevoxKýzý	MPH	-3.45	2.75	31.93**	-14.20	24.70*	5.06	-16.29**
ltan91	BPH	-16.24**	-6.54	17.65*	-25.27*	2.99	-2.35	-16.74**
SvevoxIDSN209	MPH	-5.82	0	7.27	-5.92	7.22	3.33	11.63**
	BPH	-13.59**	-4.29	0.71	-14.52	-3.98	-2.75	8.08*
SvevoxZenit	MPH	2.38	-4.80	58.15**	31.82**	61.54**	-8.66*	-3.28
	BPH	0	-11.02**	28.94**	24.73	25.37*	-15.10**	-5.59
Svevo//GedxYav	MPH	8.77*	8.37*	4.09	4.79	-4.50	-1.56	-12.54**
	BPH	8.14*	7.37	3.49	-5.91	-4.98	-1.56	-16.62**
SvevoxIDSN165	MPH	-1.12	2.93	29.49**	29.88*	17.37	1.58	-20.97**
	BPH	-4.35	-0.87	18.82**	14.52	10.95	1.18	-26.86**
Kýzýltan91	MPH	-5.21	-0.83	42.86**	61.22**	40.91**	4.41	-5.61
xIDSN261	BPH	-14.53**	-8.46*	32.73**	51.92**	23.30	0.85	-9.22*
Kýzýltan91x	MPH	-3.45	-3.59	40.63**	52.47**	41.57**	-1.27	17.38**
Svevo	BPH	-16.24**	-12.31**	25.41**	32.80*	16.92	-8.24	16.74**
Kýzýltan	MPH	-18.18**	-9.94**	57.22**	120.14**	72.41**	11.26*	23.29**
91xIDSN209	BPH	-23.08**	-14.62**	30.59**	109.93**	57.23**	9.78	18.74**
Kýzýltan91	MPH	-3.52	4.16	74.71**	9.93	66.94**	6.59	8.72*
Zenit	BPH	-17.95**	1.15	57.06**	-0.60	54.20**	-7.72	2.46
Kýzýltan	MPH	-13.86	2.73	12.71	32.39*	6.67	19.41**	22.92**
91//GedxYav	BPH	-25.64**	-5.77	0	27.89	-11.56	10.55*	16.59**
Kýzýltan	MPH	-7.18	3.27	43.31**	20.00	26.45*	10.64*	-6.26
91xIDSN165	BPH	-17.09**	-2.69	38.87**	18.31	9.50	3.18	-13.67**

** and **significant at 0.05 and 0.01 probability level, respectively*

(SvevoxIDSN165) to 77.3% (Kýzýltan91-xIDSN209). Out of 12 hybrids, 6 were positive and among them 5 hybrids exhibited significant mid-parent heterosis. Simultaneous evaluation of mid and better parent heterosis values indicate that Kýzýltan91xIDSN209, Kýzýltan91//GedxYav, Kýzýltan91xSvevo and SvevoxIDSN209 hybrids gave the most desirable heterosis over mid and better parent values of 23.29-18.74%, 22.92-1659%, 17.38-16.74% and 11.63-8.08%, respectively.

It is therefore, concluded that most of the hybrids exhibited remarkable heterosis over mid and better parents for the spike length, spikelets/spike, spike density and spike harvest index, but they were not as high as for grains/spike, grain weights/spike, grains/spikelets. It is concluded that parents Kýzýltan91 and line IDSN209 should be utilized to improve spike characters in the hybridization programme. The hybrids Kýzýltan91xIDSN209 which showed the highest mid and better parent heterosis values for grain weight/spike (120.14-109.93%), grains/spikelet (72.41-57.23%), spike harvest index (23.29-18.74%), spike density (11.26-9.78%) was the best combination which can be considered for selection as hybrid or pure line wheat varieties. Crosses Kýzýtan91x Svevo, Kýzýltan91x IDSN261 and Kýzýltan91xIDSN165 should be evaluated and followed in next generations as promising progenies in terms of spike traits for yield improvement after achieving desired homozygosity.

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