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HETEROSIS FOR YIELD AND ITS COMPONENTS IN BREAD WHEAT CROSSES AMONG POWDERY MILDEW RESISTANT AND SUSCEPTIBLE GENOTYPES

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Abstract

The objective of this research was to investigate heterotic effects between five powdery mildew resistant wheat lines derived from CIMMYT and three susceptible commercial wheat varieties growing in Turkey and to determine mode of gene actions of the parents for yield characters in F_1 generation. All 15 F_1 crosses and their parents were planted in randomized complete block design in three replications. Measurements were done for plant height, spike length, spikelet and kernel number per spike, grain weight per spike and 1000-kernel weight. Promising findings of the crosses 72 x Golia, 70 x Golia, 70 x Basribey, 48 x Basribey, 48 x Atilla-12 and 72 x Atilla12 were obtained to breed new varieties or pure lines having shorter plant height and taller spike length, more number of spikelet and kernel per spike, besides higher grain yield than their mid or better parents to improve powdery mildew resistant varieties.

Introduction

Selection of parents is the most important stage from the standpoint of breeding programs in order to develop new genotypes having desirable characters. One of the methods for this purpose is heterosis in other words hybrid vigor. Previously, exploitation of heterotic effects for grain yield was largely attributed to cross-pollinated crops. It was reported in wheat for the first time by Freeman (1919) who informed the superiorities of F_1 crosses over mid parent (Özgen, 1989). Briggle (1963) reported presence of heterosis in considerable quantity for grain yield components in various F_1 wheat crosses. Success of hybrid vigour in wheat besides other plants is directly proportional with effectively selection of parents. However results of different researchers on heterosis do not show parallelism in such a way. Busch *et al*., (1974), Bailey & Comstock (1976), Cox & Murphy (1990) and Picard *et al*., (1992) claimed that in some cases, possibility of developing predominant genotype is greater if both parents have similar performance instead of one parent being inferior or superior in terms of one or more traits. However genetic distance between parents is necessary to develop superior hybrid (Martin *et al*., 1995; Güler & Özgen, 1994; Fonseca & Patterson, 1968; Baric *et al*., 2004; Morgan, 1998; Fabrizius *et al*., 1998). For this purpose, parents having different characteristics or differing genetically were used by Fonseca & Patterson (1968) such as combination of hard red and soft white wheat, winter and spring wheat varieties (Kronstad, 1996; Baric *et al*., 2004), old and modern wheat varieties (Morgan, 1998), short and tall (Bailey *et al*., 1980). According to Morgan *et al*., (1989), if parents show high yielding potential, heterosis for grain yield would be less because parents have already many beneficial genes in homozygous state. In addition, Fabrizius *et al*., (1998) reported that the more genetic differences among parents are, the more heterosis can be possible positively for grain yield in a hybrid. Also, Singh *et al*., (2004), suggested that especially heterosis over better parent (heterobeltiosis) can be useful for determining true heterotic cross combinations. In fact, heterosis shows combining ability of parents so their usefulness in hybridization programs. On the other hand, Perenzin *et al*., (1998) informed that respecting the genetic distance of parental lines do not seem helpful to predict F_1 performance. Regarding the RFLP and RAPD markers which were used to predict the performance of hybrids, they suggested that it has been required to develop specific strategies in order to determine most promising parental wheat lines or varieties.

In the present research considering this dilemma, determination of heterotic effects among genetically diverse genotypes which were in between five powdery mildew resistant wheat lines derived from CIMMYT (International Maize and Wheat Improvement Center) and three commercial wheat varieties known as susceptible to powdery mildew and growing in Turkey, and investigation of mode of gene actions of the parents for yield characters in F_1 generation were aimed.

Materials and Methods

Three registered bread wheat varieties susceptible to powdery mildew (*Erysiphe graminis tritici*) were crossed with five resistant bread wheat lines (Table 1) derived from CIMMYT. The crosses were made by hand and all parents using in this research originated from different pedigrees. Eight parents and their resulting 15 F_1's were grown in randomized complete block design with three replications during 2005-2006 growing season under rain fed conditions at the experimental area of Ege University, Faculty of Agriculture, Department of Field Crops in İzmir. Each plot consisted of four rows of 200 cm in length with 30 cm apart. At maturity, 20 plants of F_1's and their parents were selected randomly from every plots and measurements were done for plant height, spike length, number of spikelet per spike, number of grain per spike, main spike yield and 1000-grain weight.

In order to determine significant differences among hybrids and parents, the mean of plot for each character was subjected to analysis of variance (ANOVA) as suggested by Steel & Torrie (1980). Increase or decrease of heterosis of F_1 over mid parent and better parent (heterobeltiosis) for all characters were estimated as formulated by Matzinger *et al*., (1962) and Fonseca & Patterson (1968).

Heterosis over mid parent (Ht%) = $[(F_1\text{-MP})/\text{MP}]*100$, where MP is mid parent and; Heterosis over better parent (heterobeltiosis: Hbt%) = $[(F_1\text{-BP})/\text{BP}]*100$, where BP is better (higher) parent.

Significance of heterosis and heterobeltiosis were tested with t-test as suggested by Cochran & Cox (1950) and Wynne *et al*., (1970).

Results and Discussion

Analysis of variance (Table 2) revealed highly significant differences among parents and 15 F_1 cross combinations for all characters. Significant differences suggested the presence of genetic diversity in this material. The mean performance of parents and hybrids for all characters measured were presented in Table 3.

Heterosis values over mid parent and better parent were presented in Table 4. Also contribution percentages of each parent to the heterosis and heterobeltiosis over all crosses were given in Tables 5 and 6.

Table 1. Bread wheat genotypes used in the experiment.

Genotypes	Origine/Pedigree
Susceptible varieties	
Atilla-12	Hungary
Basribey	Aegean Agricultural Research Institute-Turkey
Golia	Italy
Resistant lines	
27	MV MARTINA
35	RALEIGH
48	YM11/GEN
70	SAVLESKU#43/3/GEN*2//BUC/FLK
72	TJB916.46/CB306//2*MHB/3/BUC/41TOOY

Table 2. Mean squares for yield and yield components in F_1 generation.

Sources	d.f.	Plant height (cm)	Spike length (cm)	Spikelet number/ spike	Kernel number/ spike	Grain weight/ spike (g)	1000-kernel weight (g)
Replic.	2	10,491	0,064	0,232	11,659	0,027	2,041
Genotypes	22	279,30**	8,016**	12,330**	204,447**	0,176**	76,032**
Error	44	6,896	0,115	0,467	18,260	0,031	8,157
CV (%)		3,62	3,16	3,24	7,88	12,74	10,88

* p<0.05; ** p<0.01

Table 3. Mean performance of the parents and their crosses for measured characters in the F_1 generation.

Crosses and parents	Plant height (cm)	Spike length (cm)	Spikelet number per spike	Kernel number per spike	Grain weight per spike (g)	1000-kernel weight (g)
72xGolia	64.57	10.32	21.93	58.13	1.50	27.55
72xBasribey	77.43	12.09	23.10	65.50	1.40	21.43
72xAtilla-12	78.47	12.30	21.87	51.37	1.54	28.70
70xGolia	64.97	9.81	20.90	57.17	1.64	28.03
70xBasribey	72.40	11.09	22.10	67.50	1.81	27.72
70xAtilla-12	80.77	11.71	20.67	59.13	1.56	27.27
48xGolia	72.43	11.42	23.63	65.63	1.54	24.52
48xBasribey	72.97	12.38	22.50	63.63	1.67	25.77
48xAtilla-12	77.17	13.17	22.57	59.03	1.50	24.82
35xGolia	60.40	10.29	22.17	56.80	1.26	22.30
35xBasribey	67.10	11.36	22.13	57.07	1.226	24.12
35xAtilla-12	68.17	12.28	22.20	59.97	1.23	20.63
27xGolia	53.17	9.57	22.23	51.23	1.21	24.38
27xBasribey	65.47	10.56	22.37	49.20	1.01	20.17
27xAtilla-12	73.14	12.36	21.33	42.00	0.79	19.25
72	81.37	10.87	21.70	57.90	1.12	20.23
70	82.00	9.42	18.50	52.50	1.40	27.22
48	81.57	12.94	23.07	46.20	1.02	22.267
35	74.97	9.68	19.67	50.10	1.46	29.47
27	73.53	7.14	17.73	36.27	1.35	38.33
Golia	52.50	7.19	16.60	44.23	1.35	31.08
Basribey	77.83	9.50	18.80	54.17	1.68	31.23
Atilla-12	94.20	9.70	16.97	40.77	1.48	37.03
LSD (0.05)	4.32	0.56	1.12	7.03	0.29	4.70

Table 4. Heterotic and heterobeltiotic effects on grain yield and various components.

Crosses	Plant height (cm)		Spike length (cm)		Spikelet number per spike		Kernel number per spike		Grain weight per spike (g)		1000-kernel weight (g)	
	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
72 x Golia	-3,54**	22,98**	14,34**	-5,03	14,53**	1,08	13,84**	0,40	20,99**	10,92	7,37	-11,37
72 x Basribey	-2,72**	-0,51	18,72**	11,25**	14,07**	6,45*	16,89**	13,13*	-0,34	-16,90	-16,71**	-31,38**
72 x Atilla-12	-10,61**	-3,56	19,59**	13,16**	13,10**	0,77	4,12	-11,28	18,67**	4,51	0,23	-22,50**
70 x Golia	-3,40**	23,75**	18,21**	4,21	19,09**	12,97**	18,19**	8,89	19,46**	17,31	-3,83	-9,81
70 x Basribey	-9,41**	-6,98*	17,20**	16,66**	18,50**	17,55**	26,56**	24,62**	17,08**	7,18	-5,16	-11,26
70 x Atilla-12	-8,32**	-1,50	22,55**	20,76**	16,54**	11,71**	26,80**	12,63	8,41	5,57	-15,12**	-26,37**
48 x Golia	8,06**	37,97**	13,48**	-11,75**	19,16**	2,46	45,15**	42,06**	30,01**	14,25	-8,09*	-21,13**
48 x Basribey	-8,45**	-6,25*	10,29**	-4,35*	7,48**	-2,46	26,80**	17,48*	23,15**	-1,05	-3,68	-17,50*
48 x Atilla-12	-12,19**	-5,39*	16,34**	1,78	12,74**	-2,17	35,76**	27,78**	19,66**	1,24	-16,30**	-32,99**
35 x Golia	-5,23**	15,05**	22,03**	6,30*	22,24**	12,71**	20,42**	13,37	-10,57*	-13,99	-26,34**	-28,26**
35 x Basribey	-12,17**	-10,49**	18,45**	17,35**	15,08**	12,54**	9,46**	5,35	-22,02**	-27,19**	-20,54**	-22,79**
35 x Atilla-12	-19,41**	-9,07**	26,74**	26,63**	21,20**	12,88**	31,99**	19,69**	-16,04**	-16,50	-37,94**	-44,28**
27 x Golia	-15,63**	1,27	33,64**	33,21**	29,51**	25,38**	27,29**	15,83	-10,56*	-10,62	-29,75**	-36,39**
27 x Basribey	-13,50**	-10,97**	26,94**	11,15**	22,45**	18,97**	8,81*	-9,17	-33,55**	-40,19**	-42,02**	-47,39**
27 x Atilla-12	-11,47**	0,97	48,44**	28,85**	23,33**	20,66**	12,98**	6,74	-41,77**	-44,32**	-48,92**	-49,78**
Mean	-8,53	3,15	21,80	11,35	17,94	10,10	21,67	12,50	1,51	-7,32	-17,79	-27,55

Ht = Heterosis, Hbt = Heterobeltiosis *$p < 0.05$, **$p < 0.01$

Table 5. Contribution percentages of parents to heterosis.

Parents	Plant height (cm)	Spike length (cm)	Spikelet number per spike	Kernel number per spike	Grain weight per spike (g)	1000-kernel weight (g)
72	-5,62	17,55	13,90	11,62	13,11	-3,03
70	-7,04	19,32	18,04	23,85	14,98	-8,04
48	-4,20	13,37	13,13	35,91	24,27	-9,36
35	-12,27	22,41	19,51	20,63	-16,21	-28,27
27	-13,53	36,34	25,10	16,36	-28,62	-40,23
Golia	-3,95	20,34	20,91	24,98	9,87	-12,13
Basribey	-9,25	18,32	15,52	17,71	-3,14	-17,62
Atilla-12	-12,40	26,73	17,38	22,33	-2,21	-23,61
Mean	-8,53	21,80	17,94	21,67	1,51	-17,79

Table 6. Contribution percentages of parents to heterobeltiosis.

Parents	Plant height (cm)	Spike length (cm)	Spikelet number per spike	Kernel number per spike	Grain weight per spike (g)	1000-kernel weight (g)
72	6,30	6,46	2,76	0,75	-0,49	-21,75
70	5,09	13,88	14,08	15,38	10,02	-15,81
48	8,77	-4,77	-0,72	29,11	4,82	-23,87
35	-1,51	16,76	12,71	12,81	-19,23	-31,78
27	-2,91	24,41	21,67	4,47	-31,71	-44,52
Golia	20,20	5,39	10,92	16,11	3,58	-21,39
Basribey	-7,04	10,41	10,61	10,28	-15,63	-26,06
Atilla-12	-3,71	18,23	8,77	11,11	-9,90	-35,19
Mean	3,15	11,35	10,10	12,50	-7,32	-27,55

Plant height: Significant and useful negative heterosis was observed for all 15 combinations over mid parent. Although nine combinations exhibited negative heterosis over better parent, considerable heterobeltiosis values of six combinations were observed significantly (Table 4). In the mean of all crosses, -8.53% decrease was observed in plant height regarding the mid parent but increase of 3.15 % was obtained over better parent. Heterosis values for plant height changed from -19.41% to 8.06% for mid parent and -10.97% to 37.97% for better parent. These results are in agreement with Soylu & Akgün (2003) who found heterosis values between -24.97% and 48.87 % for plant height among 42 crosses obtained with line x tester method in Konya.

In this study, dominant inheritance was determined in nine cross combinations and other six combinations showed over dominant gene action to develop genotypes having short plant height. McNeal *et al*., (1965) and Fonseca & Patterson (1968) observed intermedier inheritance for plant height for all F_1 hybrids in their studies while Budak & Yıldırım (1996) and Abdullah *et al*., (2002) reported superdominance gene actions for plant height in some cross combinations. Fedin (1976) also pointed out that there should be different dominant alleles at least one or two dominant genes among two parents to achieve negative heterosis for plant height.

Considering the contribution rates of parents to heterosis and heterobeltiosis (Tables 5 and 6), relatively the most contribution to short plant height was obtained from powdery mildew resistant lines 35 and 27 (Tables 5 and 6). It was concluded that these lines may be useful to improve varieties having short plant height and resistance to powdery mildew.

Spike length: Percentages of positive heterosis for spike length over mid parent in all cross combinations and over 10 crosses for better parent were found to be highly significant. The mean heterosis value of the combinations with regard to mid parent was 21.80% and the highest proportional increase in the all measured traits was obtained from spike length also 11.35% increase was obtained in the mean value of all crosses over better parent. Hybrid vigour ranged from 48.44% to 10.29% with respect to heterosis and from 28.85 % to -11.75% for heterobeltiosis. These results positive significant heterosis values on spike length are agreement with the findings of Özgen (1989), Altınbaş & Tosun (1994) and Ulukan (1997), however relatively higher than the results of Jan *et al*., (2005) and Dağüstü (2005). This difference may be attributed to diversity in materials or other environmental factors.

Although line 27 among the resistant genotypes to powdery mildew had the shortest spike length, this line made the biggest contribution with 36.34% value to develop this character (Tables 5 and 6). Inheritance of spike length was observed as over dominance in 10 cross combinations and dominance in five combinations. Mackey (1976) described over dominance as favourable interaction between two alleles at the same locus i.e. intra locus or inter allelic interactions and Singh *et al*., (2004) also reported that heterosis resulting from inter allelic interactions of dominant types is not possible to fix in homozygous condition in subsequent generations.

It is known that there is a strong linkage between plant height and spike length (Özgen, 1989). Even though highly significant and useful negative heterobeltiosis percent values were obtained for plant height in 4 combinations (70 x Basribey, 35 x Basribey, 27 x Basribey and 35 x Atila-12), significant heterobeltiosis values were observed for spike length of the same combinations. This result implied that the strong linkage between plant height and spike length might be broken in these combinations. Özgen (1989) reported similar findings and proposed to take benefit from F_1 vigor in order to develop wheat varieties with shorter plant height besides longer spike length.

Spikelet number per spike: Highly significant and positive heterosis values for spikelet number per spike were found in all cross combinations (Table 4) and 11 out of 15 combinations exhibited significantly positive heterobeltiosis. Hybrid vigour values for spikelet number per spike ranged from 29.51% to 7.48% over mid parent and 25.38% to -2.46% over better parent. Yağdı & Karan (1998) reported 2.2% mean heterosis and -0.9% mean heterobeltiosis for spikelet number per spike in the crosses obtained from 13 wheat lines originating from Anatolia. Their results and our findings are highly different in terms of spikelet number per spike. It can be stated that this difference arises from genetic diversity among the parents used in the present research. In fact, Morgan (1998) noted that heterosis was more likely to occur and to be greatest where the parents came from different genetic backgrounds.

When contribution percentage of parents to heterosis for spikelet number of spike is examined, the parent 27 came into prominence with 25.10% mean heterosis and 21.67% mean heterobeltiosis also same parent indicated superdominance inheritance in its three combinations (Tables 5 and 6). The other powdery mildew resistant line 48 displayed dominant type of inheritance in its all combinations for this trait. Meanwhile, dominant inheritance was observed in 72 x Golia and 72 x Atilla-12, over dominance was observed in all other combinations. Abdullah *et al*., (2002) found negative heterosis in most of the crosses in the F_1 level for spikelet number per spike and they informed that the heterosis could have resulted from gene effects of over dominance and additive.

Kernel number per spike: Kernel number increased in all crosses over mid parent and in 13 crosses over better parent. Significant heterosis values of 14 crosses and heterobeltiosis values of 6 crosses were estimated (Table 4). Mean value of this trait over all crosses increased 21.67% and 12.50% in comparison with mid and better parent respectively. Heterosis values changed from 4.12% to 45.15% and heterobeltiosis values varied between -11.28% to 42.06%. Although these results in are agreement with the studies of some researchers who investigated hybrid vigor in kernel number per spike (Özgen, 1989; Çifci & Yağdı, 2007), they are less than findings of Fonseca & Patterson (1968) who found 100 % heterobeltiosis value in combinations obtained from genetically different parents. On the other hand, Baric *et al*., (2004) found negative heterosis values in terms of kernel number per spike in bread wheat crosses.

Mode of gene effect for kernel number per spike in F_1 generation was dominant in six combinations, over dominant in other six combinations and intermedier in three combinations. If the contribution percentages of parents to the mean heterosis is considered, powdery mildew resistant line 27 showed the highest heterotic effects for this character as was in spikelet number per spike (Tables 5 and 6).

Grain weight per spike: Of the main yield components, grain weight per spike showed significantly positive heterosis in 7 cross combinations over mid parent. Although some crosses showed positive heterosis above that of the better parent, it was observed that none of these differences were significant (Table 4). For grain weight, negative heterosis and heterobeltiosis were observed in 7 combinations and in 8 combinations, respectively. Among all crosses, heterosis values ranged from 30.01 % to -41.77%, and the mean heterosis over all crosses was positive with 1.51% low value. Heterobeltiosis values changed from 17.31% to -44.77%, and the mean heterobeltiosis over all crosses was negative with -7.32 % value. Those negative or lack of significant positive heterosis and heterobeltiosis values for grain yield in some crosses was in agreement with the results of some researchers (Randhawa & Minhas, 1977; Rathore & Chauhan, 1986; Özgen, 1989; Singh *et al*., 2004). In addition, Morgan (1998) who obtained same results for some crosses, pointed out that the parents showing negative heterosis for grain yield either did not contain useful alleles or they were not expressed. Furthermore, these parents may have deleterious alleles at different loci. Increases for grain yield resulted from dominance effects in 7 cross combinations and partially dominance effects in 2 cross combinations. In other 6 combinations, effects of some genes reduced grain yield. Our results are in accordance with Lumpton (1961) who observed dominance for high yield but not with Singh *et al*., (1969) who reported that grain yield was controlled by additive gene effects in F_1 generation.

According to contribution percentages of parents to heterosis and heterobeltiosis (Tables 5 and 6), powdery mildew resistant parent line 48 showed 24.27% mean heterosis over its three combinations for grain yield and other resistant line 70 contributed average 10.02% heterobeltiosis value for this trait. Both of these resistant lines may be used to improve wheat varieties for high yield and resistance to powdery mildew.

1000-Kernel weight: Positive heterosis values for 1000-kernel weight were obtained from only two of the 15 cross combinations but the values were insignificant. However other 10 cross combinations showed significantly negative heterosis over mid parent (Table 4). Heterosis values ranged from 7.37% to -44.32% and heterobeltiosis values changed from -9.81% to -49.78%. Although the mean heterosis over all crosses was positive for spike length (21.80 %), spikelet number per spike (17.94%), kernel number per spike (21.67%) and grain weight per spike (1.51%), the mean heterosis over all crosses was observed to be highly negative for 1000-kernel weight. This result indicated that in some crosses while spikelet number, kernel number and grain yield per spike increase, 1000-kernel weight may decrease significantly. Özgen (1989) reported that kernel number per spike in F_1 crosses of bread wheat was negatively correlated with 1000-kernel weight (r = -0.22) but it positively correlated with grain weight (r = 0.45). As Adams (1967) mentioned a compensate mechanism for crop plants, the reason for low 1000-kernel weight values could have been resulted from negative correlations among grain yield components. In addition, of the two studies conducted in Bornova-İzmir, Korkut & Açıkgöz (1986) reported that none of 10 bread wheat crosses for 1000-kernel weight did not perform over better parent for 1000-kernel weight and Altınbaş & Tosun (1994) stated -31.4% mean heterosis value of 28 durum wheat F_1 crosses for the same trait. The results of these studies, which were carried out under rainfall conditions in Bornova-İzmir, are in agreement with the present results about 1000-kernel weight. Negative heterosis values for 1000-kernel weight except two combinations show that desirable combinations for 1000-kernel weight were not able to obtain, however it may be probable that these results can change in different environments and irrigated environments.

It is concluded that heterobeltiosis values are insufficient to exploit hybrid vigor for commercial production but significant heterosis values of the crosses 72 x Golia, 70 x Golia, 70 x Basribey, 48 x Basribey, 48 x Atilla-12, and 72 x Atilla-12 for all characters except 1000-kernel weight indicates that it can be utilized to improve high yielding and powdery mildew resistant varieties or pure lines among the progenies.

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