A Research on Heterosis in Cultivated (*Triticum* spp.) × Semi-Wild Wheat Hybridization

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Direction and magnitude of mid-parent (MP) and high-parent (HP) heterosis were detected and estimated in 18 combinations, 180 F_1s and 150 F_2s for plant height (PH); spike length (SL); number of spike per plant (NS), number of spikelet per spike (NSP) and number of grain per spikelet (NG). For this, 9 females (7 commons *Triticum aestivum* (L.) Em. (Thell), P_5 = Aköz 867, P_7 = Köse 220/39, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11} = Sürak 1593/51, P_{12} = Sertak 52 and P_{13} = Yektay 406 and 2 durums (*Triticum durum* Desf., P_1 = Kunduru 414/44 and P_4 = Kunduru 1149) and 4 semi wild males (P_2 = *T. dicoccum*., 2n = 28; P_3 = *T. carthlicum*; P_6 = *T. vavilovi* and P_8 = *T. spelta*., 2n = 42) were hybridized. The MP was varied between –33.1% (P_{13}×P_8) at the F_1 for the NG and 152.6% P_7 x P_8 at the F_2 for the NS; the HP was ranged between –71.2% (P_7×P_8) at the F2 for the NG and 135.3% (P_7×P_8) at the F_1 for the NS. Heterosis effect was appeared mostly on the SL and PH; but fixed the highest on the NS and NSP in the each generation. The semi wilds were ordered as to be P_8>P_6>P_3>P_2. Statistically significant correlations were fixed between (MP-F_1) and traits; SL and PH traits were found have been impressed as to be more adventageous and stable.

Keywords: mid-parent heterosis, high-parent heterosis, genotypic diversity, parental selection

Kültür Buğdayı (*Triticum* spp.) × Yarı Yabani Buğday Melezlemesinde Heterosis Üzerine Bir Araştırma

Bitki boyu (PH), başak uzunluğu (SL), bitkide başak sayısı (NS), başakta başakçık sayısı (NSP) ve başakçıkta tane sayısı (NG) bakımından anaç ortalaması (MP) ile üstün anaç (HP) heterosisinin şiddeti ve yönü 18 kombinasyon, 180 F_1 ve 150 F_2 bitkisinde saptanmıştır. Bunun için, 9 ana (7 ekmeklik *Triticum aestivum* (L.) Em. (Thell), P_5 = Aköz 867, P_7 = Köse 220/39, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11} = Sürak 1593/51, P_{12} = Sertak 52 and P_{13} = Yektay 406 ve 2 makarnalık *Triticum durum* Desf., P_1 = Kunduru 414/44, P_4 = Kunduru 1149) ile 4 yarı yabani baba (P_2 = *T. dicoccum*., 2n = 28; P_3 = *T. carthlicum*; P_6 = *T. vavilovi* and P_8 = *T. spelta*., 2n = 42) anaç melezlenmiştir. MP; % –94.1 [F_2 de NS için P_5×P_3] ile % 87.3 [F_1'de NG için (P_{13}×P_6]; HP ise % –85.6 [F_2 'de NG için P_{10}×P_8] ile % 185.6 [F_1'de NS için P_7×P_8] arasında; çoğunlukla SL ve PH'de ortaya çıkmış; ancak, en yüksek değerler NS ile NSP'nin F_1 ve F_2'nde saptanmış; yarı yabaniler ise P_8>P_6>P_3>P_2 şeklinde sıralanmışlardır. NG dışındaki diğer özelliklerle (MP-F_1) arasında istatistiksel olarak önemli korelasyonlar saptanmış; SL ve PH'nın daha avantajlı ve kararlı olduğu izlenimi edinilmiştir.

Anahtar kelimeler: anaç ortalaması heterosis, üstün anaç heteosisi, genotipik farklılık, anaç seçimi.

Introduction

"Wheat heterosis" has long been recognized and it was first time used by Briggle, (1963). The utilization of heterosis depends mainly upon the direction and magnitude of heterosis (Agnus, 1977). Estimation of the MP and HP may be useful in identifying true heterotic crosses (Singh et al. 2004). These parameters may be a useful indicator in predicting the breeding value in any wheat breeding program. It also provides information about combining ability of the parents and their usefulness in breeding programs (Sharma et al. 1986). The use of MP as a predictor mean F_1 was suggested earlier owing to its simple assessment and because of reliable information about the line breeding programs. Thus, estimates of MP and HP as well as mean of the F_1 relative to the control can be considered encouraging for large-scale development and global acceptance of hybrid wheats. The choice of parental combinations yielding superior hybrids is the most important aspect in hybrid wheat breeding. So, analysis of the relative importance of general combination ability

(GCA) and special combination ability (SCA) provides knowledge of the type of gene action involved in the expression of traits and it allows inferences about optimum allocation of resources in hybrid breeding. Combining abilities (GCA and SCA) need to be tested to select the best parents for the process of hybrid wheat seed production. They are connected both with extension of breeding programmes and high costs. Commercially exploitable yield advantages of hybrids will also depend on the HP and on advances in line development, where considerable progress can be expected in the future. To select potential parents for hybrid production, testcrosses in various environments are required because SCA variance is one of the main component (Oettler et al. 2003). Additionaly, the tight correlations of GCA suggest that the probability of obtaining superior hybrids is greater when crossing the highest yielding parents. Thus, hybrid wheat breeding should be respectively efficient based only on selection for parental performance and a respectively small number of testcrosses involving outstanding parental lines. However, despite useful predictions of the combinations abilities, it is not possible to find out when used the semi wilds or/and wild wheats as parents (Walton, 1971) due to their responses of unstabilities and changabilities. In spite of numerous and different heterosis findings were reported for heading date, plant height and weight, 1000-kernel weight, number of spike and spikelet and grain yield (Briggle, 1963; Knott, 1965; Fonseca and Patterson, 1968; Shamsuddin, 1985; Sharma and Gill, 1986; Cox and Murphy, 1990; Cregan and Bush, 1992; Picket, 1993; Larik et al. 1995; Khan and Khan, 1996; Picket and Galway, 1997; Morgan, 1998; Prasad et al. 1998; Rajaram, 2000; Bashir, 2002; Singh et al. 2004; Dreisigacker et al. 2005). There are no scientific information or literature findings on the cultivated × semi wild wheats. On the other hand, hybridization among the parents at the different ploidy level always gave interesting results in plant breeding. Especially, using or applicate these results can be bring new possibilites to the plant production, especially in wheat breeding. Aims of this paper are *i*) to provide and observe of the heterotic information in the combinations and progenies, *ii*) to detect and estimate of its direction and magnitude, *iii*) to assessment of the heterotic effect in terms of the male parents.

Material and Methods

9 females (7 common *Triticum aestivum* (L.) Em. Thell), 2n = 42; P_5 = Aköz 867; P_7 = Köse 220/39; P_9 = Penjamo 62; P_{10} = Sivas 111/33; P_{11} = Sürak 1593/51; P_{12} = Sertak 52; and P_{13} = Yektay 406 and 2 durum *Triticum durum* Desf., 2n = 28; P_1 = Kunduru 414/44 and P_4 = Kunduru 1149) and 4 semi wild males (P_2 = *T. dicoccum*, 2n = 28; P_3 = *T. carthlicum*; P_6 = *T.* v*avilovii* and P_8 = *T. spelta*, 2n = 42) were hybridized in all possible combinations without reciprocals and derived 18 combinations, 180 F_1s and (due to the non-seed setting) 150 F_2s. They were grown in a randomized completely block design (RCBD) with four replications under field conditions at the University of Ankara, Faculty of Agriculture, Department of Field Crops, Experimental field during 1992/1995 in Ankara, Turkey. Males were chosen according to their differences in origin, adaptability and some dominance agro-morphological characteristics such as long spike, spikelet number (Zencirci and Kün, 1996). All parents were provided from the Prof. Dr. Osman Tosun Germplasm Maintaining Bank, University of Ankara, Faculty of Agriculture, Department of Field Crops, Ankara, Turkey. Soil characteristics of the experimental site are clay structure, dark brown, pH = 5.7, lime 23.7%, organic matter 1.33% and changeable potassium level is 0.028% (Anonymous, 1999). Average temperature, rainfall and relative humidity parameters during the growing seasons are presented in Table 1. The experimental plots were designed as to be five rows of 2 m in length with the distance between rows was 20 cm and on rows was 1-2 cm. Sowing procedure was done at the density of 250 seeds/m^2 in the beginning of October 10 competetive plants from the parents, F_1s and F_2s randomly selected for the observations on five agronomic characters on the basis of mean each plots as follows: PH-in cm: (measuring between the soil surface and tip of the terminal spikelet, excluding awns, on the main culm); SL-in cm (from the base of ear to the tip of terminal spikelet, excluding awns, on the main culm); NS-no (counting of the total spike number for

each plant); NSP-no (fixed by the manually counting of the total spikelet number on five randomly chosen spikes-no) and NG (mechanically harvested and balanced). The mean of the each plot was subjected to the statistical analysis, analysis of variance (ANOVA) with the MSTAT-C Statistical Software (1998) and new multiple range tests which were performed among the means as described by (Duncan, 1955). In addition, increasing (+) and decreasing (–) percentages of the MP and HP percentages were calculated as the deviation of F_1's value according to given formulae (Matzinger et al. 1962; Fonseca and Patterson, 1968):

[1] $MP (\%) = 100 \times (F_1 – MP) / MP$

[2] $HP (\%) = 100 \times (F_1 – HP) / HP$

Where, F_1 = mean value of the trait in the hybrid, MP = mean of the two parents = $(P_1+P_2) / 2$; and HP = mean value of the trait in the better or high parent and calculated the heterosis values from this formulae were presented in Table 4 and 5. In addition, all obtained data were summarized as heterotic effect (+: significant or –: non significant) according to the female and male parents, and the combinations in terms of the examined traits as the MP and HP in the F_1 and F_2 in Table 6.

Results

A perusal of analysis of variance indicated significant heterotic differences among the parents, combinations and the progenies for all the investigated and obtained results were presented at the Table 2 to 6.

Heterosis for the parents: P_7 was showed the significant and negative MP for the PH at the F_1 and the significant and positive for the NSP at the F_2. Similarly, P_{11} for the SL at the F_2, P_4 for the NSP at the F_1, and P_{13} for the NG at the F_1 were also expressed the significant and positive MP; however, P_7 was displayed the significant HP for the NS at the F_1 and F_2, and the NSP at the F_2 (Table 2, 3 and 6). P_{13} and P_4 were also showed the statistically significant HP for the NG at the F_1 and for the NS, respectively (Table 6). Out of nine female parents, P_{13}, P_{11}, P_7, P_4 were showed the statistifically significant and positive MP; and, P_{13}, P_7, P_4, were exhibited HP. From them, P_{11} and P_7 were effective on the PH and NS at the F_1 and F_2, P_{13}, P_9 and P_4 have also been maximized of the SL, NG and NSP (Table 6). These results are agreement with Shamsuddin, (1990) and Sharma et al.(1984). Common wheats much more affected and contributed the heterosis and dry matter yield within the parents in this research.

Heterosis for the semi wilds: P_8 was exhibited the significant and negative MP heterosis for the PH at the F_1 (Table 6). In spite of P_3 and P_6 (for the NSP at the F_1 and F_2), they were also expressed the significant and positive MP (Table 6). But, P_8 was displayed the significant and positive HP for the NS and NG at the F_1 and the F_2, respectively (Table 6). Similarly, P_6 has shown the significant and positive HP for the NSP at the F_2 and for the NG at F_1 (Table 6). P_3 had also a significant HP for the NSP at the F_1 (Table 6). Semi wilds were showed three distinc groups for the contribution in terms of heterotic effect according to examined agro-morphological traits in this research such as *i*) P_6 for the NG at the F_1 and F_2, *ii*) P_3 for the PH and NSP at the F_1 and *iii*) P_8 for the SL at the F_1 and for the NS at the F_1 and F_2 (Table 6). In addition, it was seen that P_6 and P_8 are common participatory female parents for the all traits (Table 6).

Heterosis for the combinations: In the research, seven combinations; namely, $P_{10}\times P_6$ for the PH; $P_9\times P_6$, $P_{11}\times P_3$ and $P_{11}\times P_6$ for the SL; $P_{10}\times P_6$, $P_7\times P_6$ for the NSP and $P_1\times P_3$ for the NG were showed the statistically significant and positive MP; two combinations $P_7\times P_8$ for the NS and $P_7\times P_6$ for the NSP were displayed the statistically significant and positive HP (Table 2, 3 and 6). All examined traits were exhibited the significant and positive MP but two combinations ($P_7\times P_8$ and $P_7\times P_6$) were showed the significant and negative HP for the NS and NSP (Table 2, 3 and 6). Only, $P_4\times P_3$ showed both significant and positive MP and HP at the F_1 and F_2 for the SL (Table 6).

Heterosis for the examined traits: Mean values were found significantly for the all traits except for NS, SL and NG (Table 2, 3 and 6). The MP and HP mean values were varied for the PH, –26.6 to 16.3% for F_1 and 28.0 to -11.8% for F_2; 28.1 to -13.4% for F_1 and 12.8 to -19.3% for F_2, respectively (Table 2 and 3). For the SL, 51.8 to 29.4% and 65.5 to -66.7% for F_1; 32.3 to -49.7% and 42.3 to -62.0% for F_1, relatively (Table 2 and 3). For the NS, 152.6 to -21.4% for F_1 and 148.4 and -47.6% for F_2, respectively (Table 2 and 3). For the NSP, 20.0 to -9.2% for F_1 91.6 to -8.4% for F_2, respectively; 18.3 to -23.0% for F_1 and 54.3 to -73.6% for F_2, respectively (Table 2 and 3) . For the NG, 69.0 to -33.1% for F_1 and 86.3 to -45.9% for F_2, respectively; 44.0 to -50.3% for F_1 and 2.4 to -58.3% for F_2, respectively (Table 2 and 3) . Prasad et al. (1998) were found the maximum positively HP heterosis for the NS and NG between –25.1 to 16.9 %; for the SL between -33.0 to 26.7%, respectively. Individually, all observed heterosis the MP and HP evolution can be summarized as follows according to examined agro-morphological traits and combinations (Table 2,3 and 6):

Plant height (PH): Maximum and minimum values with standardized deviations are 90.40±0.42 cm $P_7 \times P_8$ and 120.10±0.28 cm $P_{11} \times P_3$ at the F_1; 92.80±0.26 cm $P_{12} \times P_8$ and 137.84±0.78 cm $P_{11} \times P_6$ at the F_2 (Table 2 and 3). The MP was varied between -26.6 $P_{12} \times P_8$ at the F_1 to 20.8% $P_4 \times P_2$ at the F_2 (Table 2 and 3). For the HP it was realized between -28.2 $P_{12} \times P_8$ at the F_1 to 11.9% $P_9 \times P_6$ at the F_1 (Table 2 and 3). Totally the 33 MP (15 positive, 3 negative at the F_1 and 11 positive, 4 negative at the F_2) and the 33 HP (13 positive, 5 negative at the F_1 and 5 positive, 10 negative at the F_2) were recorded (Table 4). Brown et al. (1966) were informed 105.0% MP and 101.0% HP at the F_1; Amaya et al. (1972) were determined the MP and HP between 6.3 to 3.5% at the F_1 and 5.1 to 0.7% at the F_2, respectively; Güler and Özgen, (1994) were obtained the MP and HP between –7.0 to 6.0% and –12.0 to –2.0% at the F_1, respectively; Sun et al. (1999) were reported the MP is 11.0% and the HP is 0.3% at the F_1; Luo et al. (2000) were recorded them (13.0 to 1.3%) for the MP at the F_1 and (3.3 to 0.3%) for HP at the F_2. Halloran, (1975) recorded variable heterosis of 10 to 82.0% over the MP and the HP. He was added that heterosis rarely exceed 1.0% of the MP in the PH. Larik et al. (1995) were reported that heterosis values for this trait were ranged from 0.9 to -9.2% to the MP and -1.3 to -14.6% for the HP. Bashir (2002) was estimated as 15.11% over the MP and 0.21% over the HP.

Spike length (SL): Minimum and maximum mean values with the standardized deviations are observed as 7.20±0.65 cm $P_1 \times P_3$ and 13.1±1.82 cm $P_{13} \times P_8$ at the F_1 while 5.08±0.87 cm $P_5 \times P_3$ and 15.78±1.47 cm $P_{11} \times P_6$ at the F_2 (Table 2 and 3). The MP ranged between -49.5 $P_{12} \times P_8$ at the F_2 to 51.8% $P_7 \times P_6$ at the F_1 and HP varied between -62.0 $P_{12} \times P_8$ to 150.0% $P_7 \times P_8$ at the F_2 (Table 2 and 3). Totally the 33 MP (14 positive, 4 negative in the F_1 and 5 positive, 10 negative at the F_2) and the 33 HP (8 positive, 10 negative at the F_1 and 7 positive, 8 negative at the F_2) were fixed (Table 4). Gyawali et al. (1968) obtained heterosis ratios for the MP and HP that lied between –1.0 to 18.0% at the F_1 and between –3.0 to 17.0% at F_1, respectively. In general, obtained results are in accordance with those obtained by Singh, (1978) who reported 10% increase over the MP for the SL. It is possible to develop new wheat cultivars or hybrid combinations having long spike but dwarf PH (Li et al. 1997).

Number of spike per plant (NS): For this trait, mean values with the standardized deviations were found as 3.3±1.17 $P_4 \times P_3$ and 12.0±3.19 $P_7 \times P_8$ at the F_1; 2.2±0.86 $P_5 \times P_3$ and 11.8±0.11 $P_7 \times P_8$ at the F_2 (Table 2 and 3). The MP and the HP were varied between –96.6 $P_5 \times P_6$ at the F_2 to 84.0% $P_1 \times P_3$ at the F_1 and 67.3 $P_5 \times P_6$ to 185.6% $P_7 \times P_8$ at the F_2 (Table 2 and 3). Totally, the 33 MP (16 positive, 2 negative in the F_1 and 7 positive, 8 negative at the F_2) and the 33 HP (7 positive, 11 negative at the F_1 and 5 positive, 10 negative at the F_2) were fixed (Table 4). Fonseca and Patterson (1968) were reported for MP between 93.0 to 119.0% and 90.0 to 110.0% at the F_1. Winzeler et al. (1994) were determined the HP between –2.37 to 2.22% at the F_1; Gyawali et al. (1968) were obtained the MP and HP estimates between –40.0 to –21.0% and –48.0 to –23.0% at the F_1, respectively. Similar results have been reported and confirmed by Chakraborty and Tiwari, (1995) and Larik et al. (1987) and Larik et al. (1995) for the NS.

Number of spikelets per spike (NSP): Minimum and maximum values with the standardized deviations for the number of spikelets are 17.9±0.59 $P_{10} \times P_8$ and 22.2±0.93 $P_7 \times P_6$ at the F_1 while 18.6±0.17 $P_{13} \times P_8$ and 36.6±2.09 $P_7 \times P_6$ at the F_2 (Table 2 and 3). The MP was ranged between -57.4 $P_5 \times P_3$ at the F_1 to 93.7% $P_5 \times P_6$ at the F_2; and the HP was varied between -57.5 $P_5 \times P_3$ at F_1 and 71.0% $P_7 \times P_6$ at the F_2 (Table 2 and 3). Totally, the 33 MP (15 positive, 3 negative at the F_1 and 13 positive, 2 negative at the F_2) and the 33 HP (11 positive, 7 negative and 12 positive, 3 negative at the F_2) were obtained (Table 4). Fonseca and Patterson, (1968) determined the MP and HP values between 1.1 at the F_1 to

0.8% at the F_2 and 3.7 at the F_1 and 4.3% at F_2 for this trait, respectively. Obtained findings were supported and confirmed by Singh et al. (2004); but not Prasad et al. (1972) who did not find any significant amount of the HP in the combinations. The NSP proved to be an important trait and may explain the superiority of the hybrids over the traditional varieties.

Number of grain per spikelet (NG): This trait is the most important yield determinant of wheat (Sinclair and Jamieson, 2006) and it products of plants per m^2, ears per plant and grains per spike. The overall means with the standardized deviations of the crosses were varied between 27.4±0.28 $P_{12}\times P_8$ to 50.8±0.66 $P_9\times P_6$ at the F_1 and 14.4±0.20 $P_{11}\times P_8$ to 59.6±0.79 $P_{11}\times P_6$ at the F_2 (Table 2 and 3). The MP was varied between -25.0 $P_{13}\times P_8$ to 87.3% $P_{13}\times P_6$ only at the F_1; and the HP was ranged between -85.6 $P_{10}\times P_6$ at the F_2 and 50.3% $P_{12}\times P_6$ at the F_1 (Table 2 and 3). Totally, the 33 MP (15 positive, 3 negative at the F_1 and 13 positive, 8 negative at the F_2) and the 34 HP (8 positive, 10 negative at the F_1 and 4 positive, 12 negative at the F_2) were fixed (Table 4). These results were in accordance with Garcia et al. (1991) who reported MP is 4.0% in the F_1 and 4.3% in the F_2 and HP is 4.3% in the F_1 and 7.3% in the F_2.

Correlation coefficients: The highest positive significant correlation coefficient was found between (MP-F_2) and NS, (r=0.570) and the lowest positive significant correlation coefficient was found between (P_2-F_1) and NS, (r=0.380). Four negative but non significant coefficients were found among (P_1-F_1) and NG, (r=-0.126); (P_1-F_2) and NG, (r=-0.050); (P_2-F_2) and NS, (r=-0.250) and (HP-F_1) and NG, (r=-0.160). Among (P_1-F_1) and SL, (r=0.495, p>0.01); (P_1-F_1) and NSP, (r=0.500, p>0.01); (P_2-F_2) and NSP, (r=0.200, p>0.01); (MP-F_1) and PH, (r=0.450, p>0.01); (MP-F_1) and SL, (r=0.570, p>0.01); (MP-F_1) and NS, (r=0.550, p>0.01); (MP-F_1) and NSP, (r=0.540, p>0.01); (MP-F_2) and NS, (r=0.625, p>0.01); (MP-F_2) and NG, (r=0.125, p>0.05) and (HP-F_1) and NS, (r=0.450, p>0.01); (HP-F_2) and NSP, (r=0,380, p>0.01); (HP-F_2) and NG, (r=0.150, p>0.05) (Table 5). These correlations verified and supported to our research results. In the light of these findings, it can be suggested that always the MP must be preferred and for the NS and NG (for both F_1 and F_2). Bai et al. (1992) and Zhang et al. (1985) are being supported this judgment with their research findings. Similarly, Shamsuddin, (1985) was done the identical studies and he was reported the similar significant and positive associations among the investigated various morphological, genetical and agronomic characters in his study with 20 winter and spring wheat hybrids (r=0.460 and r=0.450, respectively; Kaltsikes and Larter, (1970) were also found a significant and positive correlation between the PH and yield in wheat.

Discussion

Female and male parents can be ordered according to their heterotic effect (heterosis) from the maximum to minumum as $P_4>P_7>P_{10}>P_5>P_9>P_{13}>P_{11}>P_{12}>P_1$ and $P_3>P_6>P_8>P_2$, respectivey in this research (Table 6). P_6 and P_8 are the common participitory female parents for the traits. Highest significant and positive MP was taken from the $P_7\times P_8$ for the NS at the F_1 with 152.6% and for HP was also taken from the same combintion with 135.3% for the NS at the F_1 (Table 4). It may have been the result of interaction between the parental cytoplasm (genotypic diversity) and applied agronomic practices or environmental effects. It was seen that the more genetic diversity the more and violently MP. This testimony was observed and verified by Shamsuddin, (1985). Semi wilds showed less heterosis than the cultivars; but much more affected from the PH for the MP and SL for the HP; however, not at the F_1 and F_2. According to data, it can be suggested that only MP values must be used without paying the attention for the F_1 or F_2 to be able to get a higher hybrid wheat yield. This case also been reported by Briggle, 1967; Singh and Singh, 1971; Krishna and Ahmad, 1992; Picket, 1993; Sinclair and Jamieson, 2006). On the other hand, it showed that the gene pool of spelt wheat (P_8) could be potentially useful for the selection of parents for the hybrid wheat production. This result verified by Winzeler et al. 1993). But, there are several problems that to be solved and needs to be more improved so despite the very high heterosis effect no short statued varieties exist at the present, close and hard, tightness of the glumes pollination or pollination easly could be hamperring if used as a pollinator. However, a breeding effort to select for improved parents within the gene pool of spelt appears useful for future F_1 hybrids between spelt and wheat. These findings can be applied to the hybrid wheat breeding as a cultivars x semi wild wheats. First of all, plant height traits can be shortened with the heterotic effect of this type hybridization. Obtained reslts research showed that to be able to get maximum level of heterosis is possible only for MP at the level of F_1. If this process continue to the out of this limits (esp. for HP at the F_1 or F_2) yield level is being celarly decreased ! On the other hand, with their genetical backgrounds or by genepools semi-wild wheats can be use against to stress conditions such as disease and pest resistance. Similarly, with the addition of the modern biotechnological approaches apomixis might be hope to facilitate seed production; llinkage maps and DNA based molecular markers can be considered a promising tool to predict hybrid performance, at the same time it could be a powerful tool for the identification of genetically diversified sources such as wild or semi wild wheats in the long run.

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Table 1. Meteorological data for 1992-1995 growing seasons (monthly average).

	Average Temperature (°C)					**Rainfall (mm)**					**Relative Humidity (%)**				
	Years					**Years**					**Years**				
Months	**1992**	**1993**	**1994**	**1995**	**LTA§ 1926-92**	**1992**	**1993**	**1994**	**1995**	**LTA§ 1926-92**	**1992**	**1993**	**1994**	**1995**	**LTA§ 1926-92**
January	-4.0	-4.0	3.8	3.3	-0.1	4.9	28.8	30.2	33.6	40.9	76.5	79.5	75.5	33.6	78.0
February	-3.0	-0.7	1.8	5.2	1.3	5.7	33.4	33.6	10.8	34.9	69.5	72.8	74.2	10.8	74.0
March	3.9	5.7	6.8	6.7	5.4	50.3	22.4	18.4	92.6	35.6	70.1	61.3	60.1	92.6	65.0
April	11.4	10.4	14.0	9.9	11.2	40.2	28.1	30.7	61.6	40.3	59.0	56.5	55.0	61.6	59.0
May	16.2	15.3	17.0	17.6	15.9	1.6	88.1	39.0	30.8	51.3	45.4	65.1	56.5	30.8	57.0
June	19.0	19.7	20.6	21.8	19.8	54.9	13.1	6.6	60.8	32.6	57.6	52.5	47.2	60.8	51.0
July	20.5	22.9	24.2	23.1	23.1	29.9	3.5	5.0	10.7	13.5	55.4	45.3	44.4	10.7	44.0
August	23.4	23.1	23.5	23.4	23.0	19.9	11.1	1.1	3.7	10.3	46.0	49.7	46.7	3.7	42.0
September	16.7	19.3	22.8	19.0	18.4	2.6	11.1	6.3	12.7	17.4	52.0	49.7	44.0	12.7	47.0
October	15.1	15.0	16.0	11.6	12.8	35.1	1.8	30.0	27.8	24.4	60.1	45.8	60.9	27.8	58.0
November	5.4	4.1	5.6	3.4	7.3	47.0	33.6	67.5	61.6	36.4	68.4	65.7	75.0	61.6	70.0
December	-0.6	4.0	0.5	2.4	2.3	37.9	33.0	20.6	52.3	45.6	77.4	76.6	78.8	52.3	78.0

§ Long term averages.;
Source: Republic of the Environment and Forest Ministry, General Directorate of Meteorology

Table 2. Means with the standardized errors in the combinations and parents in F_1 and F_2.

Combinations and Parents	PH (cm)		SL (cm)		NS (no)		NSP (no)		NG (no)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
$P_1 \times P_2$	104.21±0.06 A	-	8.1±0.28 B	-	5.8±1.56 B	-	20.7±0.85 A	-	39.0±4.01 B	-
P_1	93.3±0.13 CD		7.4±0.43 C		3.4±0.11 C		21.3±0.63 A		40.3±0.15 B	
P_2	85.9±0.45 E		5.6±0.25 E		5.9±0.24 B		20.1±0.51 A		22.3±0.12 E	
$P_1 \times P_3$	109.57±0.25 A	119.24±0.30 A	7.2±0.65 C	7.38±0.64 B	4.6±1.01 B	5.6±0.08 B	19.8±0.50 A	30.4±3.61A	39.6±0.88 B	30.4±0.21 D
P_1	100.64±0.82 CD		6.5±0.30 D		2.0±0.37 D		19.5±0.24 A		30.1±0.63 D	
P_3	105.63±0.25 CD		6.9±0.82 D		3.0±0.88 C		19.7±0.36 A		33.5±0.47C	
$P_4 \times P_3$	118.87±0.40 AD	108.60±0.61C	7.9±0.93 C	7.36±0.26 B	3.3±1.17 C	5.2±0.24 B	22.2±0.93 A	21.4±2.06 C	37.7±0.38 B	21.8±0.69 DE
P_4	111.87±0.11 D		6.2±0.10 D		3.7±0.46 C		19.7±0.18 A		32.4±0.26 C	
P_3	110.78±0.36 D		7.0±0.65 C		4.7±0.52 C		19.8±0.20 A		32.4±0.55 C	
P_4 × P_2	113.75±0.92 A	105.16±0.85 C	9.6±0.57 B	6.90±0.50 C	4.6±0.58 C	4.8±0.80 B	21.0±0.67 A	19.4±1.81 C	33.0±0.25 C	30.4±0.63 D
P_4	109.30±0.15 D		8.9±0.97 B		2.8±0.19 D		20.0±0.25 A		33.7±0.37 C	
P_2	94.90±0.39 CD		6.5±0.33 D		5.3±0.26 B		19.6±0.30 A		33.4±0.28 C	
$P_5 \times P_3$	117.12±0.04 A	104.48±0.23 C	8.1±0.74 B	5.08±0.87 C	4.3±1.24 C	2.2±0.86 D	18.8±0.14 B	21.6±1.40 C	43.4±0.74 A	26.0±0.19 DE
P_5	112.70±0.58 B		8.6±0.50 B		4.1±0.13 C		20.3±0.19 A		35.2±0.66 BC	
P_3	109.58±0.81 C		7.5±0.29 C		4.3±0.36 C		21.1±0.17 A		38.0±0.90 B	
$P_5 \times P_6$	114.36±0.67 A	109.46±0.56 C	11.0±1.21 A	11.52±1.49 A	4.1±1.40 B	3.4±0.51 C	20.4±0.55 A	33.2±2.92 A	41.0±0.59 A	43.0±0.60 C
P_5	111.32±0.64 B		8.1±0.13 B		2.0±0.18 D		20.1±0.50 A		42.0±0.13 A	
P_6	116.50±0.25 A		10.5±0.24 A		5.0±0.40 B		16.6±0.65 B		34.0±0.66 BC	
$P_7 \times P_6$	116.19±0.29 A	120.06±0.15 A	12.9±1.72 A	12.90±1.40 A	7.1±3.66 A	5.6±0.40 B	22.0±0.10 A	36.6±2.09 A	38.0±0.56 B	31.6±0.57 D
P_7	99.47±0.51 D		5.0±0.45 E		8.8±0.66 A		18.4±0.80 B		27.0±0.41D	
P_6	114.41±0.14 A		12.0±0.78 A		4.7±0.20 C		20.0±0.54 A		39.3±0.29 B	
$P_7 \times P_8$	90.40±0.42 C	99.24±0.62 D	12.1±1.14 A	7.24±1.00 B	12.0±3.19 A	11.8±0.11 A	20.4±0.72 A	29.2±1.66 A	33.3±0.13 C	28.8±0.16 DE
P_7	97.55±0.26 D		10.5±0.66 A		5.1±0.75 B		16.0±0.34 B		17.1±0.36 F	
P_8	95.35±0.40 D		12.3±0.19 A		4.4±0.50 C		21.0±0.10 A		23.2±0.88 E	
$P_9 \times P_8$	119.55±0.51 A	-	11.7±1.33 A	-	4.1±1.34 C	-	21.0±0.23 A	-	33.2±0.40 C	-
P_9	111.15±0.36 B		9.5±0.57 B		3.3±0.39 C		18.8±0.61 B		31.1±0.41CD	
P_8	110.30±0.47 B		13.7±0.81 A		5.7±0.15 B		21.2±0.50 A		31.4±0.17 CD	
$P_9 \times P_6$	115.70±0.21 A	116.50±0.11 A	12.6±1.26 A	14.38±2.02 A	6.0±2.40 A	10.0±0.97 A	19.5±0.18 A	28.4±4.43 A	50.8±0.66 A	48.8±0.11 B
P_9	103.27±0.78 BC		9.9±0.76 B		5.2±0.04 B		18.8±0.36 B		28.8±0.53 D	
P_6	103.43±0.53 BC		12.8±0.94 A		5.7±0.16 B		20.0±0.40 A		43.6±0.25 A	
$P_{10} \times P_6$	107.95±0.89 AB	115.38±0.61 A	8.3±1.03 B	9.12±0.40 B	6.8±1.25 A	6.0±0.10 B	18.7±0.14 B	26.4±4.48 B	30.2±0.51 D	48.4±0.39 B
P_{10}	102.90±0.18 BC		5.1±0.65 E		9.2±0.63 A		18.3±0.24 B		28.4±0.64 D	
P_6	113.00±0.77 A		11.4±0.71 A		4.4±0.70 C		19.0±0.68 A		32.0±0.34 CD	
$P_{10} \times P_8$	92.70±0.33 BD	109.22±0.51C	7.8±0.55 C	10.80±1.07 B	8.5±1.86 A	4.6±0.51 B	17.9±0.59 B	29.2±1.66 A	42.3±0.88 A	14.4±0.20 F
P_{10}	107.00±0.41 AB		6.6±0.25 D		6.1±0.52 A		17.9±0.53 B		28.8±0.95 D	
P_8	103.40±0.99 BC		15.5±0.37 A		6.1±0.80 A		23.2±0.32 A		34.5±0.31BC	

P_1= First parent, P_2 = Second parent, PH = Plant height, SL = Spike length, NS = Number of spike per plant; NSP = Number of spikelet per spike; NG = Number of grain per spikelet; means within each column followed by the same letter are not significantly different; $P< 0.05$; P_1 = Kunduru 414/44, P_2 = *T. dicoccum*, P_3 = *T. carthlicum*, P_4 = Kunduru 1149, P_5 = Aköz 86, P_6 = *T. vavilovii*, P_7 = Köse 220/39, P_8 = *T. spelta*, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11}= Sürak 1593/51, P_{12}= Sertak 52, P_{13} = Yektay 406

Table 3. Means with the standardized errors in the combinations and parents in F_1 and F_2 (cont.).

Combinations and Parents	PH (cm)		SL (cm)		NS (no)		NSP (no)		NG (no)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
P_{11} × P_3	120.10±0.28 A	117.98±0.19 A	12.5±1.48 A	12.2±0.62 A	8.4±1.30 A	5.8±0.74 B	20.0±0.90 A	26.8±2.22 B	30.0±0.70 D	17.6±0.83 E
P_{11}	115.41±0.42 A		13.0±0.48 A		6.3±0.96 A		22.0±0.45 A		32.0±0.46 CD	
P_3	104.92±0.86 BC		9.6±0.52 B		7.6±0.62 A		19.0±0.96 B		33.0±0.51 C	
P_{11} × P_6	111.36±0.45 A	137.84±0.78 A	11.0±1.23 A	15.8±1.47 A	8.7±2.13 A	6.6±0.98 B	21.0±0.36 A	23.0±2.53 C	32.0±0.31 CD	59.6±0.79 A
P_{11}	106.20±0.88 AB		11.1±0.55 A		8.0±0.46 A		18.8±0.55 B		31.0±0.42 CD	
P_6	109.10±0.54 AB		8.0±0.80 B		4.8±0.17 C		20.0±0.91 A		33.0±0.40 C	
P_{12} × P_6	113.60±0.29 A	-	9.0±0.45 B	-	5.3±0.29 B	-	21.3±0.15 A	-	45.1±0.46 A	-
P_{12}	98.43±0.26 C		8.7±0.14 B		6.0±0.59 A		17.5±0.21 B		23.4±0.23 E	
P_6	115.76±0.13 B		10.5±0.65 A		4.4±0.66 C		18.0±0.13 B		30.0±0.37 D	
P_{12} × P_8	105.20±0.06 B	92.80±0.26 E	10.6±0.36 A	6.1±0.26 C	6.5±0.84 B	9.2±0.92 A	20.3±0.50 A	35.4±0.51A	27.4±0.28 D	31.2±0.28D
P_{12}	102.95±0.83 BC		6.5±0.38 D		7.5±0.78 A		17.3±0.96 B		22.0±0.54 E	
P_8	107.45±0.52 AB		14.8±0.47 A		5.5±0.61 B		23.3±0.05 A		32.8±0.60 CD	
P_{13} × P_8	115.55±0.74 A	113.76±0.29 B	13.1±0.82 A	8.5±0.76 B	5.6±0.15 B	5.4±0.03 B	21.4±0.89 A	18.6±0.17 D	29.3±0.19 D	31.6±0.61D
P_{13}	111.70±0.73 B		11.5±0.52 A		6.2±0.60 B		19.5±0.42 B		45.3±0.80 A	
P_8	108.50±0.45 AB		22.2±0.38 A		6.2±0.47 B		21.3±0.87 A		32.7±0.19 CD	
P_{13} × P_6	110.53±0.38 A	112.24±0.91 B	12.3±0..55 A	12.3±0.57A	5.4±0.06 B	5.0±0.63 B	22.0±0.76 A	34.2±0.08 A	47.7±0.28 A	32.6±0.76 D
P_{13}	88.63±0.65 D		8.1±0.44 B		5.6±0.74 B		19.7±0.56 B		20.0±0.75 F	
P_6	121.42±0.89 A		12.3±0.19 A		4.1±0.24 C		17.7±0.32 B		41.1±0.56 A	
Mean	110.92±0.35	112.13±0.13	10.32±0.02	10.18±0.89	6.2±0.02	6.1±0.73	20.5±2.26	27.5±0.45	37.4±0.54	32.8±0.82

P_1 = First parent; P_2 = Second parent; PH = Plant height; SL = Spike length; NS = Number of spike perplant; NSP = Number of spikelet per spike; NG = Number of grain per spikelet; MP = Mid-parent heterosis; HP = High-parent heterosis, Means within each column followed by the same letter are not significantly different, n = 4, P_1 = Kunduru 414/44, P_2 = *T. dicoccum*, P_3 = *T. carthlicum*, P_4 = Kunduru 1149, P_5 = Aköz 86, P_6 = *T. vavilovii* P_7 = Köse 220/39, P_8 = *T. spelta*, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11}= Sürak 1593/51, P_{12}= Sertak 52, P_{13} = Yektay 406.

Table 4. Heterosis percentages (%) in the F_1 and F_2 for the MP and HP according to the examined traits in the combinations.

Combinations	PH (cm)				SL (cm)				NS (no)				NSP (no)				NG (no)			
	MP		HP		MP		HP		MP		HP		MP		HP		MP		HP	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
$P_1 \times P_2$	16.3**	-	11.7**	-	24.6**	-	9.5**	-	24.7**	-	-1.7	-	0	-	-3.0	-	24.6**	-	18.2**	-9.3*
$P_1 \times P_3$	6.2	6.1	3.7	4.6	7.5	10.2**	9.2**	7.0	84.0**	124.0**	53.3**	86.7**	1.0	55.1**	0.5	54.3**	24.5**	-4.4	16.4**	32.7**
$P_4 \times P_3$	6.7	-2.5	6.3	-0.5	19.7**	-44.2**	12.9**	5.1	-21.4**	24.0**	-29.8**	10.6*	12.4**	8.4	12.1**	8.1	20.1**	-30.6**	14.2**	-31.6**
$P_4 \times P_2$	11.4**	3.0	4.1	-1.1	24.5**	-0.1	32.3**	-22.5**	13.6**	18.5**	-13.2**	-9.4*	6.1	-2.0	5.0	-3.0	1.6	-9.0*	-2.1	-9.8*
$P_5 \times P_3$	5.4	3.0	4.0	-7.5	0.6	-37.0**	-5.8	-5.0	2.4	-47.6**	0	-48.8**	-9.2*	4.3	11.0**	2.4	18.6**	-29.0**	-2.4	2.4
$P_5 \times P_6$	0.4	-6.0	-1.6	-13.0**	18.3**	4.8	23.9**	9.7*	17.1**	-2.9	-18.0**	-32.0**	11.2**	81.0**	1.5	65.2**	7.9	13.2**	-3.3	2.4
$P_7 \times P_6$	8.7	12.3**	1.6	-19.3**	51.8**	52.0**	7.5	7.5	5.2	-17.0**	-19.3**	-36.4**	14.6**	91.6**	10.0**	83.0**	-3.3	-19.6**	44.0**	24.1**
$P_7 \times P_8$	-6.3	2.9	-7.3	-7.3	6.1**	-36.5**	-1.6	-41.1**	152.6**	148.4**	135.3**	131.4**	10.3*	0.6	-2.9	0.4	65.3**	43.0**	5.8	-71.2**
$P_9 \times P_8$	7.8	-	7.6	-	0.9	-	-14.6**	-	-8.9*	-	-28.1**	-	5.0	-	-1.0	-	6.2	-	17.0**	-
$P_9 \times P_6$	12.0**	12.7**	11.9**	2.2	11.0**	26.7**	-1.6	12.3**	10.1*	83.5**	5.3	75.4**	0.5	46.4**	-25.0**	42.0**	40.3**	35.0**	-5.6	-12.0**
$P_{10} \times P_6$	1.2	6.9	-3.3	-8.2	0.6	-10.6**	-27.2**	-20.0**	0	-11.8**	-26.1**	-34.8**	0.3	41.6**	-1.6	39.0**	0	60.3**	23.0**	-51.3**
$P_{10} \times P_8$	-11.9**	3.8	-13.4**	-0.4	-29.4**	-2.3	-49.7**	-30.3**	41.0**	-24.0**	39.3**	-24.6**	-12.9**	42.1**	-23.0**	25.7**	33.7**	-54.5**	- 9.1**	-58.3**
$P_{11} \times P_3$	9.0*	7.1	4.1	12.8**	10.6**	-3.8	8.0	8.0	21.0**	-16.6**	11.0**	-23.7**	-2.4	31.0**	-9.1*	22.0**	-7.7	-45.9**	- 3.0	-46.7**
$P_{11} \times P_6$	3.5	28.0**	2.1	8.2	15.2**	65.5**	-1.0	42.3**	36.0**	-3.1	8.8	-17.5**	8.3	18.6**	5.0	15.0**	0	86.3**	- 50.3**	-26.6**
$P_{12} \times P_6$	6.1	-	-1.9	-	-6.3	-	-14.3**	-	2.0	-	-11.7**	-	20.0**	-	18.3**	-	69.0**	-	- 16.5**	-
$P_{12} \times P_8$	-26.6**	-11.8**	28.1**	-14.9**	-0.5	-43.0**	-28.4**	-59.0**	0	42.0**	- 13.3**	22.7**	0	74.4**	12.9**	52.0**	0	13.9**	- 35.3**	-4.9
$P_{13} \times P_8$	5.0	3.3	3.5	4.3	-22.3**	-50.0**	-41.0**	-62.0**	0	-12.9**	-9.7*	-13.0**	5.4	-8.4	0.5	-12.7**	-33.1**	-19.0**	16.1**	-30.2**
$P_{13} \times P_6$	5.2	-9.0*	6.9	-12.0**	20.6**	-66.7**	0	-38.2**	11.3*	3.1	-3.6	-10.7**	17.6**	82.9**	11.7**	-73.6**	56.4**	6.4	-2.1	-20.7**
Mean	3.3	4.0	3.8	3.0	8.5	1.3	-4.6	-7.3	22.0	21.0	4.4	5.1	4.9	38.0	-1.4	-31.1	1.0	3.1	8.0	-4.5

PH=Plant height, SL=Spike length, NS=Number of spike per plant; NSP=Number of spikelet per spike; NG=Number of grain per spikelet; MP=Mid-parent heterosis; HP=High-parent heterosis,
P_1 = Kunduru 414/44, P_2 = *T. dicoccum*, P_3 = *T. carthlicum*, P_4 = Kunduru 1149, P_5 = Aköz 86, P_6 = *T. vavilovii*, P_7 = Köse 220/39, P_8 = *T. spelta*, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11}= Sürak 1593/51, P_{12} = Sertak 52,
ay 406

*P< 0.05, ** P = 0.01

Table 5. Minumum and maximum mean values, heterosis percentages as MP and HP according to the combinations and generations, and phenotypic correlation coefficients.

Traits	**Combinations**	**Generations**	**Means**	**MP**	**HP**	**(P1-F1)**	**(P1-F2)**	**(P2-F1)**	**(P2-F2)**	**(MP-F1)**	**(MP-F2)**	**(HP-F1)**	**(HP-F2)**
PH (cm)	[1] $(P_{11} \times P_3)$	F_1	(120.10±0.28)	9.0	4.1	0.473**	0.331**	0.315**	0.220**	0.450**	0.386**	0.217*	0.160*
	[2] $(P_7 \times P_8)$		(90.40±0.42)	-6.3**	-7.3								
	$(P_{11} \times P_6)$	F_2	(137.84±0.78)	3.5	2.1								
	$(P_{12} \times P_8)$		(92.80±0.26)	-26.6	-28.1								
SL (cm)	$(P_{13} \times P_8)$	F_1	(13.1±0.82)	-22.3	-41.0	0.495**	0.129*	0.456**	0.041ns	0.570**	0.633**	0.120*	0.080 ns
	$(P_1 \times P_3)$		(7.2±0.65)	7.5	9.2								
	$(P_{11} \times P_6)$	F_2	(15.8±1.47)	15.2	-1.0								
	$(P_5 \times P_3)$		(5.1±0.87)	0.6	5.8								
NS (no)	$(P_7 \times P_8)$	F_1	(12.0±3.19)	152.6	135.3	0.400**	0.050 ns	0.074 ns	-0.250 ns	0.550**	0.625**	0.450**	0.001 ns
	$(P_4 \times P_3)$		(3.3±1.17)	-21.4	29.8								
	$(P_7 \times P_8)$	F_2	(11.8±0.11)	152.6	135.3								
	$(P_5 \times P_3)$		(2.2±0.86)	-94	1.7								
NSP (no)	$(P_4 \times P_3)$	F_1	(22.2±0.93)	12.4	12.1	0.500**	0.330**	0.391**	0.200**	0.540**	0.113**	0.320 ns	0.380**
	$(P_{10} \times P_8)$		(17.9±0.59)	12.9	-23.0								
	$(P_7 \times P_6)$	F_2	(36.6±2.09)	14.6	10.0								
	$(P_{13} \times P_8)$		(18.6±0.17)	54.0	0.5								
NG (no)	$(P_{13} \times P_6)$	F_1	(47.7±0.28)	56.4	-2.1	-0.126 ns	-0.050 ns	0.390	0.110 ns	0.155	0.125	-0.160 ns	0.150
	$(P_{13} \times P_8)$		(29.3±0.19)	33.1	-30.2								
	$(P_{11} \times P_6)$	F_2	(59.6±0.79)	0	-35.3								
	$(P_{10} \times P_8)$		(14.4±0.20)	-33.7	-58.3								

PH = Plant height, SL = Spike length, NS = Number of spike per plant; NSP = Number of spikelet per spike; NG = Number of grain per spikelet; MP = Mid-parent heterosis; HP = High-parent heterosis, [1)] Maximum, [2)] Minimum,

P_1= Kunduru 414/44, P_3=*T. carthlicum*, P_4 = Kunduru 1149, P_5 = Aköz 86, P_6 = *T. vavilovii*, P_7 = Köse 220/39, P_8 = *T. spelta*, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11} = Sürak 1593/51, P_{12} = Sertak 52, P_{13} = Yektay 406

F_1= First generation, F_2= Second generation; P1: Mean values of the female parents, P2: Mean values of the male parents, * $P < 0.05$. **$P < 0.01$, ns = non significant.

MP-Fn = n generation's mean values of the mid-parent heterosis values of the females, HP-Fn = n generation's mean values of the mid-parent heterosis values of the semi wilds.

Table 6. The parental and the combinational participations at the F_1 and F_2 for the MP and HP. (+ yes; - or blank no; s= significant; ns= non significant)

Genotypes	PH (cm)				SL (cm)				NS (no)				NSP (no)				NG (no)			
	MP		HP		MP		HP		MP		HP		MP		HP		MP		HP	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
(♀)																				
P_1																				
P_4												(-) s	(+) s						(-) s	
P_5																				
P_7											(+) s	(+) s		(+) s		(+) s				
P_9																				
P_{10}																				
P_{11}						(+) s														
P_{12}																				
P_{13}												(-) s					(+) s		(-) s	
(♂)																				
P_2													(-) s							
P_3													(+) s	(+) s	(+) s					
P_6													(+) s	(+) s						
P_8																(+) s			(+) s	
mbinations																				
$P_1 \times P_2$	(+) ns	No seed	(+) ns	No seed	(+) ns	No seed	(+) ns	No seed	(+) ns	No seed	(-) ns	No seed	(+) ns	No seed	(-) ns	No seed	(+) ns	No seed	(+) ns	(-) ns
$P_1 \times P_3$	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) s	(-) ns	(+) ns	(+) ns
$P_4 \times P_3$	(+) ns	(-) ns	(+) ns	(-) ns	(+) s	(-) ns	(+) s	(+) s	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns
$P_4 \times P_2$	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns
$P_5 \times P_3$	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(-) ns	(+) ns
$P_5 \times P_6$	(+) ns	(-) ns	(-) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(-) ns	(-) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns
$P_7 \times P_6$	(+) ns	(+) ns	(+) s	(-) ns	(+) ns	(+) ns	(+) ns	(+) s	(+) ns	(-) ns	(-) ns	(-) ns	(+) ns	(+) ns	(+) s	(+) ns	(+) ns	(-) ns	(+) s	(+) ns
$P_7 \times P_8$	(-) ns	(+) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) s	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) s	(-) ns
$P_9 \times P_8$	(+) ns	No seed	(+) ns	No seed	(+) ns	No seed	(-) ns	No seed	(-) ns	No seed	(-) ns	No seed	(+) ns	No seed	(-) ns	No seed	(+) ns	No seed	(+) ns	No seed
$P_9 \times P_6$	(+) ns	(+) ns	(+) ns	(+) ns	(+) s	(+) ns	(-) ns	(+)ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) ns	(-) ns	(-) ns
$P_{10} \times P_6$	(+) ns	(+) ns	(-) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns
$P_{10} \times P_8$	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(-) ns	(-) ns
$P_{11} \times P_3$	(+) ns	(+) ns	(+) ns	(+) ns	(+) s	(-) ns	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns
$P_{11} \times P_6$	(+) ns	(+) ns	(+) ns	(+) ns	(+) s	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(-) ns
$P_{12} \times P_6$	(+) ns	No seed	(-) ns	No seed	(+) ns	No seed	(-) ns	No seed	(+) ns	No seed	(-) ns	No seed	(+) ns	No seed	(+) ns	No seed	(+) ns	No seed	(-) ns	No seed
$P_{12} \times P_8$	(-) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(-) ns	(-) ns	(+) ns	(+) ns	(-) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(-) ns
$P_{13} \times P_8$	(+) ns	(+) ns	(+) ns	(+) ns	(-) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(-) ns	(-) ns	(+) ns	(-) ns
$P_{13} \times P_6$	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(-) ns	(+) ns	(+) ns	(+) ns	(-) ns	(+) ns	(+) ns	(-) ns	(-) ns

PH=Plant height, SL=Spike length, NS=Number of spike per plant; NSP=Number of spikelet per spike; NG=Number of grain per spikelet; MP=Mid-parent heterosis; HP=High-parent heterosis

P_1 =Kunduru 414/44, P_2 = *T. dicoccum*, P_3 = *T. carthlicum*, P_4 = Kunduru 1149, P_5 = Aköz 86, P_6 = *T. vavilovii*, P_7 = Köse 220/39, P_8 = *T. spelta*, P_9 = Penjamo 62, P_{10} = Sivas 111/33, P_{11}= Sürak 1593/51, P_{12} = Sertak 52, P_{13} = Yektay 406