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Estimation the extent of heterosis in elite wheat cultivars of Pakistan

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Abstract: Heterosis has been a popular technique for boosting crop production, and breeders are always interested to find parental lines with improved cross performance among the many hybrid combinations available.**Materials and Methods:**The present study was conducted at Botanical Garden, Sindh Agriculture University, Tandojam during the Rabi season of 2019-20. A set of six female lines (TD-1, TJ-83, Kiran-95, Khirman, NIA-Amber and NIA-Sundar) were crossed with three male testers (Benazir, Pakistan-2013 and NIA-Sarang) into line × tester fashion; consequently, 18 F_1 hybrids were produced. Eleven agronomical characters were studied for heterosis extent in intraspecific crosses of wheat.**Results:**The desirable negative heterosis was recorded for maturity and plant height traits, however, positive mid and better parent heterosis was recorded for all other agronomical traits. Considering the heterotic effects for grain yield plant^{-1}, the best parent heterosis was ranged from 41.18% (Kiran-95 × NIA-Sarang) to65.34% (TJ-83 × Benazir). **Conclusions:**The crosses TD-1 × Benazir, TJ-83 × NIA-Sarang, TD-1 × NIA-Sarang and Khirman × Pakistan-2013 showed the highest heterosis against better parent for grain yield and its related parameters, displaying the genetic resources these crosses possess for heterosis breeding.

Keywords: Bread wheat, F_1 hybrids, agronomical traits, heterosis

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most widely grown food crop in Pakistan, and its products are widely used. Because it is the main food of the majority of people, it outnumbers all other crops in terms of area and production. Wheat has an agricultural value added of 8.7%, whereas GDP has a value of 1.7%. In order to ensure that future generations' consumption demands are met, one of the most significant aims for contemporary agricultural policy is to increase wheat yields over the following decades. Wheat breeders are mainly responsible for developing superior wheat varieties, and their role in increasing crop yield is becoming increasingly important over time (Reynolds *et al.*, 2012). In comparison with other cereals, wheat supplies more energy and is also the primary food source. Genetic progress of wheat occurs both by slow processes and through rapid selection after the first time the wheat has been grown (Soshma, *et al.*, 2015).

Analyzing heterosis is essential factor to consider in developing usefulhybrids from inbred lines. One of the most essential steps in plant breeding is progeny selection, however obtaining great offspring is dependent on the parents chosen (Liu *et al.*, 2021). Heterosis, a frequent natural occurrence, is the biological process of crossbreeding; it is based on genetic differences between the parents, is most intense in F_1, and gradually decreases in F_2. It has been widely employed in field crops (e.g., rice and maize) as well as vegetable crops (e.g., Cruciferae and Solanaceae species) as a great approach of genetic improvement (Liu *et al.*, 2019).In Europe, for example, the hybrids of sugar beet (100%), the hybrids of rapeseed (more than 90%), the hybrids of rye (more than 70%) and more than 80% of cotton hybrids are being grown in India. In agricultural production, heterosis can greatly enhance production, quality, and resistance. Crop heterosis is regarded as a landmark breakthrough in advance agriculture, with significant economic benefits (Hochholdinger and Baldauf, 2018). Although heterosis is common, it does not always occur in every hybridization between two parents or materials, and excellent crosses do not always result from good parents. The degrees of heterosis in various crossings or different characteristics within the same cross vary because of this variation. As a result, choosing parents based on prior performance does not necessarily result in the desired output (Golabadi, *et al.*, 2015) parents should be assessed on their potential to generate great hybrids rather than on their own mean performance (Riedelsheimer, *et al.*, 2012).Assessing the strength of heterosis necessitates determining the portion of heterosis' genetic effects that are usable but difficult to fix between different crosses or traits, as well as evaluating their practical value in heterosis breeding,

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and this assessment serves as a foundation for parental choice (Li, 2011).

2. MATERIALS AND METHODS

Experimental materials, design, and cultural practices: The present study was conducted at Botanical Garden, SAU, Tandojam during the Rabi season of 2019-20. In the current study, a set of six female lines (TD-1, TJ-83, Kiran-95, Khirman, NIA-Amber and NIA-Sundar) were crossed with three male testers (Benazir, Pakistan-2013 and NIA-Sarang) into line x tester fashion; consequently, 18 F_1 hybrids were produced. Randomized Block Design was used for experimentation having three repeats. The fertilizer dose with 134N: 67 P_2O_5 kg ha^{-1} was used in the investigation. The Nitrogen was applied three times, while Phosphorus was used before sowing the crop (Baloch *et al.*, 2014). The research trail was irrigated at each growth stage. The weedicide Loughran (160g $acre^{-1}$) was applied for weeds removal.

Phenotypic characterization: When 75% of the spikes emerged from the flag leaf, the days to heading were recorded. When the peduncles became yellow and the crop phenotypically reached 90% maturity, the days to 90% maturity were recorded. At maturity, the height of 10 randomly selected wheat plants was measured in centimeters from base to top, omitting awns. For the selected/tagged plants, the tillers $plant^{-1}$ were counted. Using measuring tape, the length of the spike (cm) was measured, omitting the awns.Spikelets $spike^{-1}$ were manually counted. After manual threshing, the number of grains $spike^{-1}$ was counted; straw was separated, and grains in completely developed spikes were totaled. The grain weight of the primary spike was calculated in grams.Each spike was threshed individually, and grains were weighed on an electronic scale and yield $plant^{-1}$ was weighed in grams.Individual plants were picked at maturity and weighed together with grains and straw to determine the biological yield $plant^{-1}$ (g). For seed index, 1000 grains were randomly counted and measured in grams on an electronic balance for each genotype.

Soil analysis of experimental area: Soil analysis was done before cultivation of experimental materials. In a total, three samples of soil were done at the depth of 12 inches, where silty clay loam was categorized as soil texture. The electric conductivity (0.58, 0.69 and 0.60 dSm^{-1}), pH (7.5, 7.7 and 7.8) and organic matter (0.51, 0.67 and 0.49) were observed suitable in all three samples hence soil was referred as well fertile for wheat experimentation.

Statistical analysis: Mean squares of treatments were obtained after Gomez and Gomez (1984). Effects of heterosis were carried out by Fehr (1987).

3. RESULTS

The results of heterosis are given in **(Tables 1, 2,3 and 4).**For the character days to 75% flowering, the highest heterosis over mid parent (15.77%) was noted in TD-1 × NIA-Sarang, while the greatest positive heterosis over better parent (11.44%) was shown by NIA-Amber × NIA-Sarang.However, the minimum positive mid parent (1.65%) heterosis recorded in TJ-83 × Pakistan-2013 and minimum positive better parent (1.42%) heterosis was shown by Khirman × Pakistan-2013. The maximum negative better parent (-3.49%) heterosis was estimated in TD-1 × Benazir.Considering maturity, the highest positive mid (7.02%) and better parent (4.24%) heterosis was noticed in F_1 combinations TD-1 × NIA-Sarang and Khirman × Pakistan-2013, respectively.Nevertheless, the minimum but positive mid parent (0.17%) and better parent heterosis (0.75%) was observed in NIA-Sundar × Benazir and TJ-83 × Benazir, while the maximum negative mid and better parent (-6.84% and -12.39%) heterosis was revealed by NIA-Sundar × Pakistan-2013 and TD-1 × Benazir, respectively. Regarding plant height, the maximum positive mid and better parent (34.69% and 22.48%) heterosis was noted in same F_1 hybrid NIA-Sundar × Pakistan-2013. However, the minimum positive mid parent (0.11%) heterosis shown by Khirman × NIA-Sarang and minimum positive better parent (2.99%) heterosis was noted by Kiran-95 × Benazir. The maximum negative mid parent (-19.62%) heterosis was noted in TD-1 × Benazir, while the maximum negative better parent (-34.27%) heterosis was noticed in TD-1 × NIA-Sarang.

With respect to tillers $plant^{-1}$, the highest mid (116.34%) and better (110.78%)parent heterosis with positive rank was found in Kiran-95 × Benazir and TJ-83 × NIA-Sarang, respectively. While the next highest positive better parent heterosis of 107.89% and 106.41% were observed in Kiran-95 × NIA-Sarang and Kiran-95 × Pakistan-2013, respectively. For spike length, positive mid parent heterosis was ranged from 36.23% (Kiran-95 × Pakistan-2013) to 61.17% (TJ-83 × Pakistan-2013). Positive better parent heterosis was ranged from 35.25% (Kiran-95 × Pakistan-2013) to 60.58% (TJ-83 × Pakistan-2013). The minimum mid and better parent heterotic effects were observed in TD-1 × Pakistan-2013 with heterosis of 41.89% and 38.68%, respectively. For spikelets $spike^{-1}$, the maximum positive mid parent heterotic effects27.56% and26.74% were exhibited by Kiran-95 × NIA-Sarang and Kiran-95 × Pakistan-2013, respectively. However, Kiran-95 × Pakistan-2013 and Kiran-95 × NIA-Sarang showed maximum positive better parent heterosis of 26.28% and 26.28%, respectively. Nonetheless, the minimum positive mid and better parent heterosis were demonstrated by TD-1 × Benazir (18.49% and18.38%)

and NIA-Sundar×Pakistan-2013 (20.66% and 20.22%).For the character of grainsspike^{-1}, the maximum positive mid parent (55.79%) and (53.45%) heterosis was noted in Kiran-95 × Benazir and Khirman × NIA-Sarang, respectively, while the maximum positive better parent (53.51%) and (52.11%) heterosis was shown by Kiran-95 × Benazir and Khirman × NIA-Sarang, respectively. However, the minimum positive mid parent (53.61%) and (36.52%) heterosis noted in NIA-Amber × Benazir and Khirman × Pakistan-2013, respectively. While minimum positive better parent (33.63%) and (35.08%) heterosis was recorded in NIA-Amber × Benazir and NIA-Amber × NIA-Sarang, respectively.Considering the grain weight spike^{-1}, the maximum positive mid and better parent heterosis were 26.69% and 26.56%as observed in F_1 combination TJ-83 × Pakistan-2013. Nevertheless, the minimum but positive mid (16.79%) and better (16.18%) parent heterosis was noted in TD-1 × Benazir. For grain yield plant^{-1}, the top two positive mid (67.72% and 65.34%) and better parent (66.87% and 64.88%) heterosis was noted in TJ-83 × Benazir and TD-1 × NIA-Sarang, respectively. The next higher mid parent heterosis of 62.94%, 62.68%, 62.64% and 61.00% were calculated in TD-1 × Benazir, TD-1 × Pakistan-2013, Khirman × NIA-Sarang and Khirman ×Pakistan-2013, respectively. All crosses showed positive heterotic effects for seed index. However, the range was 24.33% (TD-1 × Benazir) to 37.35 (Kiran-95 × Pakistan-2013) for mid parent, while better parent heterosis was varied from 23.30% (TD-1 ×Benazir) to 37.35 (Kiran-95 × Pakistan-2013).In regard to biological yield plant^{-1}, The maximum positive mid parent heterosis of 48.81%, 47.62% and 47.07%was recorded by NIA-Amber × Pakistan-2013, Kiran-95 × NIA-Sarang and Khirman× Pakistan-2013, respectively, while the maximum positive better parent heterosis of 48.48% and 47.62% heterosis was shown by NIA-Amber × Pakistan-2013 and Kiran-95 × NIA-Sarang, respectively. However, the minimum positive mid parent *i.e.*, 37.34% and 37.37% heterosis was shown by TD-1× Benazir and NIA-Amber × Benazir, respectively. While minimum positive better parent *i.e.*, 36.75% and 37.07% heterosis was noted in TD-1 × Benazir and NIA-Amber × Benazir, respectively.

Table 1. Heterotic effects for maturity and plant height

F_1 hybrids	Days to 75% flowering		Days to 90% maturity		Plant height	
	HMP (%)	HBP (%)	HMP (%)	HBP (%)	HMP (%)	HBP (%)
TD-1 × Benazir	5.99	-3.49	-2.22	-12.39	-6.53	-21.59
TD-1 × Pakistan-2013	10.90	-2.08	1.64	-9.17	-11.16	-25.17
TD-1 × NIA-Sarang	15.77	2.97	7.02	-3.72	-19.62	-34.27
TJ-83 × Benazir	9.00	2.11	0.89	0.75	3.70	-2.19
TJ-83 × Pakistan-2013	1.65	-1.56	3.19	3.04	10.06	4.30
TJ-83 × NIA-Sarang	2.97	-1.09	2.57	1.95	1.46	-7.10
Kiran-95 × Benazir	7.45	7.31	2.39	2.24	11.23	2.99
Kiran-95 × Pakistan-2013	3.36	0.00	1.12	0.97	3.10	-4.09
Kiran-95 × NIA-Sarang	4.95	2.37	2.46	1.84	3.98	-6.48
Khirman × Benazir	8.83	8.64	1.88	1.67	-3.21	-12.96
Khirman × Pakistan-2013	4.78	1.42	4.75	4.24	-4.98	-14.16
Khirman × NIA-Sarang	4.99	2.46	2.99	2.72	0.11	-12.46
NIA-Amber × Benazir	7.41	6.60	3.00	2.15	32.30	22.19
NIA-Amber× Pakistan-2013	7.96	5.08	0.37	-0.17	27.88	18.66
NIA-Amber × NIA-Sarang	13.56	11.44	2.50	1.19	17.36	5.30
NIA-Sundar × Benazir	9.27	8.98	0.17	-0.68	32.11	19.60
NIA-Sundar × Pakistan-2013	1.94	-1.25	-6.84	-7.37	34.69	22.48
NIA-Sundar × NIA-Sarang	8.11	5.59	-1.55	-2.83	26.02	10.90

HMP = Heterosis for mid-parent; HBP = Heterosis for better parent

Table 2. Heterotic effects for agro-morphological characters

F_1 hybrids	Tillers plant^1		Spike length		Spikelets spike^{-1}	
	HMP (%)	HBP (%)	HMP (%)	HBP (%)	HMP (%)	HBP (%)
TD-1 × Benazir	89.17	73.82	47.96	45.64	18.49	18.38
TD-1 × Pakistan-2013	85.59	68.59	41.89	38.68	24.01	23.90
TD-1 × NIA-Sarang	80.65	61.26	45.65	42.86	22.22	21.55
TJ-83 × Benazir	93.02	80.43	55.64	53.96	24.23	23.10
TJ-83 × Pakistan-2013	96.47	81.52	61.17	60.58	23.86	22.74
TJ-83 × NIA-Sarang	110.78	91.30	50.00	48.91	25.39	23.47
Kiran-95 × Benazir	116.34	96.92	57.55	57.55	23.26	22.81
Kiran-95 × Pakistan-2013	109.09	106.41	36.23	35.25	26.74	26.28
Kiran-95 × NIA-Sarang	109.27	107.89	57.40	56.83	27.56	26.28
Khirman × Benazir	102.44	97.62	59.57	58.99	23.97	22.97
Khirman × Pakistan-2013	101.23	94.05	52.00	51.45	22.15	21.16
Khirman × NIA-Sarang	93.71	83.33	55.07	55.07	25.87	24.05
NIA-Amber × Benazir	92.50	92.50	52.35	51.80	20.96	20.96
NIA-Amber× Pakistan-2013	97.47	95.00	53.45	52.90	22.06	22.06
NIA-Amber × NIA-Sarang	108.64	94.25	53.62	53.62	22.85	22.06
NIA-Sundar × Benazir	101.26	100.00	53.07	52.52	21.77	21.32
NIA-Sundar × Pakistan-2013	105.10	103.80	54.18	53.62	20.66	20.22
NIA-Sundar × NIA-Sarang	107.79	102.53	54.35	54.35	22.56	22.22

Table 3. Heterotic effects for yield and its related characters

F_1 hybrids	Grains spike^{-1}		Grain weight spike^{-1}		Grain yield plant^{-1}	
	HMP (%)	HBP (%)	HMP (%)	HBP (%)	HMP (%)	HBP (%)
TD-1 × Benazir	48.84	45.91	16.79	16.18	62.94	57.39
TD-1 × Pakistan-2013	47.16	44.36	18.04	17.43	62.68	55.87
TD-1 × NIA-Sarang	41.22	38.14	22.47	22.08	66.87	64.88
TJ-83 × Benazir	42.15	39.04	25.23	25.10	67.72	65.34
TJ-83 × Pakistan-2013	51.23	48.02	26.69	26.56	57.71	54.19
TJ-83 × NIA-Sarang	53.32	49.64	24.66	24.53	65.19	63.74
Kiran-95 × Benazir	55.79	53.51	20.74	20.12	53.72	49.20
Kiran-95 × Pakistan-2013	47.74	45.68	25.49	24.85	55.74	52.41
Kiran-95 × NIA-Sarang	47.15	44.69	21.20	20.33	48.73	41.18
Khirman × Benazir	43.49	42.54	25.16	24.90	53.37	51.67
Khirman × Pakistan-2013	36.52	35.72	22.87	22.61	61.00	60.56
Khirman × NIA-Sarang	53.45	52.11	22.92	22.92	62.64	57.22
NIA-Amber × Benazir	35.61	33.63	18.23	17.38	47.80	43.09
NIA-Amber× Pakistan-2013	40.01	38.07	22.97	22.09	52.59	48.94
NIA-Amber × NIA-Sarang	37.38	35.08	22.60	21.47	52.25	44.15
NIA-Sundar × Benazir	39.61	37.57	22.79	22.41	54.93	53.63
NIA-Sundar × Pakistan-2013	46.99	44.95	24.66	24.27	54.19	54.19
NIA-Sundar × NIA-Sarang	44.93	42.50	21.58	21.46	55.04	50.28

Table 4. Heterotic effects for yield and biomass characters

F_1 hybrids	Seed index		Biological yield plant^{-1}	
	HMP (%)	HBP (%)	HMP (%)	HBP (%)
TD-1 × Benazir	24.33	23.30	37.34	36.75
TD-1 × Pakistan-2013	29.25	28.66	43.53	42.31
TD-1 × NIA-Sarang	26.16	25.11	40.65	39.74
TJ-83 × Benazir	29.59	28.34	42.37	42.06
TJ-83 × Pakistan-2013	33.23	31.45	43.41	42.49
TJ-83 × NIA-Sarang	33.63	32.34	45.26	44.64
Kiran-95 × Benazir	35.31	34.80	43.84	43.53
Kiran-95 × Pakistan-2013	37.35	37.35	43.60	43.29
Kiran-95 × NIA-Sarang	33.94	33.43	47.62	47.62
Khirman × Benazir	34.95	34.64	42.12	41.81
Khirman × Pakistan-2013	37.14	36.93	47.07	46.75
Khirman × NIA-Sarang	33.59	33.28	42.42	42.42
NIA-Amber × Benazir	28.42	27.84	37.37	37.07
NIA-Amber× Pakistan-2013	35.32	35.21	48.81	48.48
NIA-Amber × NIA-Sarang	31.31	30.71	41.13	41.13
NIA-Sundar × Benazir	30.14	29.35	39.74	37.93
NIA-Sundar × Pakistan-2013	34.00	33.69	39.47	38.26
NIA-Sundar × NIA-Sarang	33.79	32.98	45.30	43.72

4. DISCUSSION

The current study reported that among wheat genotypes, there is extremely high heterosis for economically significant characteristics such as seed yield. Several breeders have extensively utilized the parental genetic potential of numerous field crops in recent years, revealing a wide range of heterotic effects, such as in rice by Ghaleb, *et al.* (2020); in cotton by Li *et al.* (2018) in sugarcane by Anbanandan and Eswaran (2018); in maize by Elmyhun, *et al.* (2020); in millet by Warrier, *et al.* (2020) in Kebede and Hua (2020); in sunflower by Tyagi *et al.* (2020); in mustard by Singh *et al.* (2020) and in rapeseed by Wolko (2019). Generally, positive heterosis is preferred for most of the traits; however, in the wheat crop, earliness and plant height are the only characters where negative heterosis is beneficial, revealing that hybrids mature sooner and are semi-dwarf in stature than their parents are useful for vastcultivation.For days to 75% heading, five wheat combinations (TD-1 × Benazir, TD-1 × Pakistan-2013, TJ-83 × Pakistan-2013, TJ-83 × NIA-Sarang and NIA-Sundar×Pakistan-2013) showed negative better parent heterosis, while seven F_1 hybrids (TD-1×Benazir, TD-1×Pakistan-2013, TD-1×NIA-Sarang, NIA-Amber× Pakistan-2013, NIA-Sundar × Benazir, NIA-Sundar × Pakistan-2013 and NIA-Sundar × NIA-Sarang) displayed negative heterotic effects over better parent for days to 90% maturity. As a result, these cross combinations might be valuable genetic resources for hybrid development in terms of earliness. Semi-tall plants are considered desirable in wheat, therefore, F_1 hybrids having negative heterotic effects shall be an asset for future wheat breeding programs. A total of ten wheat cross combinations were noted for negative heterotic effects for plant height, the combinations were TD-1 × Benazir, TD-1 × Pakistan-2013, TD-1 × NIA-Sarang, TJ-83 × NIA-Sarang, Kiran-95 × Pakistan-2013, Kiran-95 × NIA-Sarang, Khirman × Benazir, Khirman × Pakistan-2013 and Khirman × NIA-Sarang.In wheat crop, different agronomical traits directly contribute to grain yield. Thus, improvement of wheat hybrids through positive heterotic effects is very important (Baloch *et al.*, 2014). Remarkably, negative heterosis was not recorded in any cross combinations for yield contributing traits.Nevertheless, the maximum positive heterosis over better parent were displayed by TJ-83 × NIA-Sarang, Kiran-95 × Benazir, Kiran-95 × Pakistan-2013, Kiran-95 × NIA-Sarang, Khirman × Benazir, Khirman × Pakistan-2013, NIA-Sundar × Benazir, NIA-Sundar × Pakistan-2013 and NIA-Sundar × NIA-Sarang for tillers plant^{-1}, spike length and spikelets spike^{-1}. Hence, these experimental hybrids may prove an excellent source for wheat hybrid development program. The extent of heterosis in this study over better parent was quite higher than those reported by Mahpara, *et al.* (2015)and Kajla, *et al.* (2020). The top five rank heterotic effects over better parent for grains spike^{-1}and grain weight spike^{-1}were noted in TJ-83 × Pakistan-2013, TJ-83 × NIA-Sarang, Kiran-95 × Benazir, Kiran-95 × Pakistan-2013 and Khirman × NIA-Sarang. The superiority of hybrids over better parents (heterobeltiosis) is more essential and beneficial in assessing theviability of heterosis and also identifying the parental combinations capable of producing the maximum amount of transgressive segregants (Kajla, *et al.*, 2020).

In terms of grain yield plant^{-1}, a significant level of heterosis over better parent was noticed in TJ-83 × Benazir, TD-1 × NIA-Sarang, TJ-83 × NIA-Sarang, Khirman × Pakistan-2013, TD-1 × Benazir and Khirman × NIA-Sarang. As a result, these crosses might be regarded a potential type for improving bread wheat yields.Those parents, which revealed desirable heterosis for grain yield plant^{-1}, also exhibited desirable heterosis for one or more yield attributing traits. Such as, heterosis for grain yield plant^{-1} was mainly contributed by number of grains spike^{-1} and number of tillers plant^{-1}. The findings of this study are supported byGrafius' (1959) research work that there could be no distinct gene system for yield per se since yield is the result of multiplicative interactions among its numerous contributing characteristics. It is not necessary that high heterosis for all yield components lead to high heterosis for yield; rather, an increase in just one or two yield component characteristics might lead to a high degree of heterosis for yield (Sharma and Kamaluddin, 2020). The results of this study clearly showed that there was significant heterosis for all characteristics investigated. As a result, a rise in the values of other yield-contributing characteristics obviously leads to an increase in F_1 hybrid yield.The yield of wheat plants rises significantly as the seed index increases, indicating that there is a positive relationship between seed index and grain yield. All F_1 hybrids had positive better parent heterosis, according to the heterosis for seed index.Hybrids, TD-1 × Benazir, Khirman × NIA-Sarang, Kiran-95 × Benazir, Kiran-95 × Pakistan-2013, Kiran-95 × NIA-Sarang, Khirman × Benazir, Khirman × Pakistan-2013 and NIA-Amber× Pakistan-2013. These crosses demonstrated potential heterosis for seed index for future heterosis breeding. Desirable heterosis for seed index were also observed by various breeders in wheat (Ilker,*et al.*, 2010; Bache,*et al.*, 2013; Mahpara,*et al.*, 2015 and Khokhar,*et al.*, 2019).The heterosis for biological yield plant^{-1} revealed that all F_1 hybrids recorded positive relative heterosis and heterobeltiosis. Hybrids, TJ-83 × NIA-Sarang, Kiran-95 × NIA-Sarang,Khirman × Pakistan-2013 and NIA-Amber× Pakistan-2013 showed greater amount of heterotic effects over better parents. The superiority of these crosses in heterosis for biological yield plant^{-1} was recorded. Other researchers such as Chowdhry*et al.* (2005) and Baloch *et al.* (2016) showed substantial and a reasonable amount of mid parent as well as improved parent heterosis for biological yield plant^{-1}, which may be further utilized in wheat breeding.

5. CONCLUSIONS

It is concluded that the crosses TD-1 × Benazir, TJ-83 × NIA-Sarang, TD-1 × NIA-Sarang and Khirman × Pakistan-2013 showed the highest heterosis against better parent for grain yield and its related parameters, displaying the genetic resources these crosses possess for heterosis breeding.

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