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The Outbreeding Enhancement and Correlation Studies in F_1 Hybrids of Hexaploid Wheat (*Triticum aestivum* L.) Cultivars

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Abstract

The current study was conducted in the experimental field of the Department of Biotechnology and Genetic Engineering, Faculty of Life Science, University of Development Alternative, Dhaka, Bangladesh during the winter season 2017-2018. The study was performed to reduce the heterotic effect and phenotypic correlation among numerous yield characters for F_1 hybrids of hexaploid wheat (*Triticum aestivum* L.). The experimental design has consisted of six parental variants (Sonalika, Balaka, Prodip, Kanchan, Agrahani and Protiva), which were crossed and nine possible cross combinations (F_1 hybrids) (Prodip × Agrahani, Balaka × Agrahani, Prodip × Protiva, Protiva × Agrahani, Agrahani × Kanchan, Kanchan × Sonalika, Protiva × Prodip, Sonalika × Agrahani, and Prodip × Kanchan) were obtained. The experimental fields were selected and arranged in a randomized complete block design with four replicates, where eight characters were studied. The mean square of the analysis of variance showed that the hybrids differed significantly ($p \leq 0.01$) for all studied characters except for maturity to 75% of days and height of the plant, while the parents only had no differences in grain yield. The mean square of the parent and the F_1 hybrid indicated that considerable heterosis existed in the F_1 hybrids. In general, correlation coefficients indicated that the maturity to 75% of days was significant but negatively correlated with most of the yield traits, suggesting that the genotypes which became mature early may have lower yields. Plant height was also negatively correlated with grain spike^{-1}, seed index, and harvest index. The grain yield plant^{-1} was significant and positively correlated with all yield traits. Correlation indicates that single or multiple production-related ingredients can be used as selection time to select plants with higher yield traits with larger grains.

Keywords

Wheat, Heterosis, Correlation, Genotypes, Yield

1. Introduction

Wheat (*Triticum aestivum* L.) is an important species of grass family grown throughout the world for human consumption [1]. The numbers of wheat species together are known as *Triticum*, the major widely grown wheat is known as bread wheat (*Triticum aestivum*). *T. aestivum* L. is a haxaploid (2n = 6x = 42) and the most grown wheat in the world [2]. Wheat is the most valuable grain crop and a staple food for increasing the human population around the world. The genotypically and environmental elements play a positive and negative role in grain yield [3] [4]. Wheat is considered a 3rd main source of calories in cereal crops [5]. The agriculture industry since the last 50 years has been growing up so fast and 50% of global food production depends on cereal crops [6]. Three main factors have been documented for rapid improvements in wheat yield: 1) genetically modified varieties using new breeding methods, especially the hybrid varieties are more important for yield; 2) Extension of the area under irrigation; 3) Prevailing use of fertilizers, especially phosphorus (P) and Nitrogen (N) [4]. Generally, access to the increasing area under irrigation and enhancing the use of fertilizers are getting limited. Therefore, the use of new breeding techniques is necessary for improving wheat yield [7] [8]. Improvement in wheat yield is very important for ensuring global food security as predicted by (FAO's) United Nations. There is increasing interest in new methods that extend yield production, especially for low-yielding conditions where wheat is broadly grown [9]. One of the most encouraging alternatives is to improve the yield production by heterosis (hybrid vigor) in a hybrid wheat variety. The heterosis is considered an important factor for improvement in wheat yield from 3.5% to 15% [10]. In the past, it was difficult to explore the heterosis in wheat varieties due to the complex nature of wheat inbreeding [11].

For the last 10 years, the hybrid wheat program is becoming more prominent for a modification if the total area under hybrid cultivation around the world. In the 1960s, the discovery of restoration processes and the sterility system in males for hybrid wheat increased the interest of public and private sectors for the development of hybrid varieties [12]. However, the exploration of the hybrid system was impractical and consequently difficult to adopt [13]. Nowadays, genetic engineering is being utilized to develop a range of new hybrids breeding innovation systems with many expects under the improvement of wheat varieties reviewed by [14]. There are some important objectives that breeders keep in mind to achieve wheat cultivars with high yielding ability, develop resistance varieties against plant pathogens as well as insects and against environmental factors [15]. Yield is one of the most complex quantitative traits of most cultivars, and it is also hard for estimating which factors are responsible for low yielding [16]. Character-based selection helps wheat breeders to improve yield and its associated traits [17] [18].

Hybrid varieties frequently show more yield, increasing the stability of yield, and enhance resistance against abiotic and biotic factors due to hybrid vigor [19]. Thus, heterotic studies can be very useful for obtaining information about the increase/decrease percentage of hybrids (F_1) over their mid parents and superior parents. Breeding efforts have resulted in various varieties of hexaploid wheat, having improved yield and grain characters. Varieties and advanced lines with different morphological and economic characteristics are now available as breeding stock. For further progress, knowledge of breeding behavior, particularly of combining ability and type of gene action for the various traits, is necessary [20]. Heterobeltiosis is mainly associated with specific character combining the ability of the hybrids. Generally, positive heterosis is desired for yield improvement and selection of its components, whereas early maturity and short plant height are considered in negative heterosis [21]. The prevailing genetic theories related to the manifestation of hybrid vigor include actions of dominant, over-dominant and epistasis genes [22]. However, heterosis utilization is measured as the most important plant breeding attainment. Hybrid breeding in wheat through the utilization of heterosis is more informative than local techniques of plant breeding. Heterosis also provides informative knowledge relating the capability in breeding plans of parents as well as their practices [8] [23]. Assessment of heterosis over the improved parents (heterobeltiosis) could be helpful in classifying true heterotic cross groups. Heterosis is a quicker, cheaper and easier method of increasing crop production. With a sufficient level of heterosis, commercial production of hybrid varieties will be justified, and heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in breeding programs. Hybrid wheat technology can play an effective role in enhancing grain production [24]. Genetic diversity is one of the key factors for the improvement of many crop plants, including wheat. Evaluation of hybrids for heterosis ability in the field is both expensive and time consuming. For this reason, other parameters such as pedigree information, qualitative and quantitative traits and biochemical data were adapted to study heterosis [25] [26].

The correlation coefficient is an important breeding parameter, which determines how close two traits are associated with each other? It is assumed that, if the relationship between two traits is strong and well established for improving low heritable trait-like yield, the indirect selection average as a high heritable character should be used [27]. The positive associations of the length of spike with spike-lets spike^{-1}, tillers/plant with grain yield/plant and spike-lets spike^{-1} with tillers/plant were reported [28]. Thus, the present study was planned to determine the heterosis and correlation in hexaploid wheat varieties. The current research was aimed to analyze the ability of wheat varieties in hybrid combination to find out the heterosis (%) over-improved parent and mid parent and the correlation among various yield traits in the F_1 generation.

2. Materials and Methods

The six parents of seeds along with their nine F_1 hybrids were obtained from the Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh. The study was laid out in a randomized complete block design with four replications. The study was carried out in the Agro ecological region of "Madhupur Tract" (AEZ No.28) at field of the Department of Biotechnology and Genetic Engineering, Faculty of Life Science during November 2017 to February 2018. The land was clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH range is 5.47 - 5.63 and organic carbon content is 0.82%. The experimental plots have consisted of four rows, individually 10 feet long. The plant to plant and row to row distances were kept at 20.0 and 5.0 cm, respectively. The agronomic applications, selection of soil conditions, weed control, proper irrigation, and utilization of fertilizer were applied and allowed to standard procedures. Parents and their possible combinations *i.e.* F_1 are given in (**Table 1**).

The data of 10 plants and each genotype were collected from each replication selected at ten randomly selected plants at random was labeled for data recording in the laboratory and field.

Table 1. Parents and cross combinations.

Sl. No.	Parents	Pedigree	Year of release	Sl. No.	Cross combinations of F_1 hybrids
1	Sonalika	1154-88/AN/3/YT54/N1OB/LR64 II 18427-4R-1M	1973	1	Prodip × Agrahani
2	Balaka	PI`S'/HD 845 HD 1981-100JA-0I	1979	2	Balaka × Agrahani
3	Prodip	G. 162/BL 1316//NL 297	2005	3	Prodip × Protiva
4	Kanchan	UP301/C306 1187-1-1P-5P-5JO-0JO	1983	4	Protiva × Agrahani
5	Agrahani	INIA/3/SON64/P416OE//SON 64 PK 6841-2A-1A-OA	1987	5	Agrahani × Kanchan
6	Protiva	KU Head Selection	1993	6	Kanchan × Sonalika
				7	Protiva × Prodip
				8	Sonalika × Agrahani
				9	Prodip × Kanchan

Days to 75% maturity: This character was observed when the plants showed a 75% maturity yellow peduncle, thus reached to 75% physiological development.

Plant height (cm): The height of plants was measured from the root of the plant to the top of the ear (not including awns at maturity).

Length of spike: The length of the spike is divided in centimeters from the neck node to the highest spikelet (excluding the canopy) in centimeters.

Spikelets spike^{-1}: The Spikelets of the main spikes were counted at harvest time and the average was worked out.

Grains spike^{-1}: The total amount of main spike seeds was calculated and results were observed as grains spike^{-1}.

Seed index (1000 grains weight g): With the help of a laboratory digital balance, 1000 seeds were randomly calculated and weighed in grams.

Grain yield plant^{-1} (g):

The harvested plants were threshed by hand, the grains were weighed on a digital electronic balance, and the production of plants was expressed in grams.

Total dry matter (g): After plant harvesting, individual plants were weighed on electronic weight balance.

Harvest index (%): Harvest index (%) was calculated according to the following formula:

$$\text{H.I}(\%) = \frac{\text{Grain yield per plant}(\text{g})}{\text{Biological yield per plant}(\text{g})} \times 100 \quad (1)$$

Heterosis estimation: It is expressed as a percentage and calculated as under:

$$\text{Mid parent heterosis } \% = \frac{F_1 - \text{MP}}{\text{MP}} \times 100 \quad (2)$$

$$\text{Better parent heterosis } \% = \frac{F_1 - \text{BP}}{\text{BP}} \times 100 \quad (3)$$

where F_1 = hybrid performance; MP = Mid-parent value (the mean of two parents) and BP = Better-parent value (the mean of better parents).

Statistical analysis

The results were compiled in excel software to form a database for analysis. All the studied traits were analyzed statistically by (ANOVA) applied using Statistics 8.1. To differentiate the mean performance of genotypes, the statistical method of [29] was used. Whereas, the heterosis was calculated with the formula developed by [30] and correlated by [31].

3. Results and Discussion

The current study was laid-out to determine the heterotic effects and correlation studies in F_1 crosses of wheat. The experimental material has consisted of six parental varieties and their nine F_1 crosses. The field trial research was conducted in a randomized complete block design with four repetitions. The results achieved for several characters are shown hereunder:

Analysis of variance

The results (Table 2) revealed that all the characters like Days to 75% maturity, plant height, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index, grain yield plant^{-1}, harvest index and total dry matter among the genotypes varied significantly ($p < 0.01$). Genotypes were further divided into F_1 hybrids and parents. The average of squares from the variance of results suggested that hybrids and parents changed significantly for whole plant characters except that grain yield plant^{-1}, which was non-significant between the parents only. Important mean squares for parents versus F_1 hybrids suggested the significance of heterotic effects.

3.1. The Mean Percentage of F_1 Hybrids and Parents

Data on the average percentage of parents indicated parental performance as shown in (Table 3). On average, parents took more days (115.43) to reach 75% maturity, whereas the F_1 hybrids took significantly fewer days (109.12) to 75% maturity. The results revealed that parent Prodip took maximum days to 75% full development (119.50), whereas parent Sonalika took minimum days to reach 75% maturity (108.90). Regarding plant height, the parents on average, attained 78.41 cm plant height against 58.20 cm of F_1 hybrids, thus F_1 hybrids were shorter as compared to parents and were more desirable and can be regarded as resistant to lodging. From parents, Balaka produced taller plants measuring 85.55 cm; however, the shorter plants were noted by the parent Agrahani (64.20 cm).

For the spike length, the parents on an average produced shorter spikes (11.46 cm) as compared to longer spikes of F_1 hybrids (12.10 cm). Among the parents, Agrahani produced the longest spikes (12.40 cm), and the minimum spike

Table 2. Mean squares from analysis of variance for various traits in different wheat varieties and F_1 hybrids.

Characters	Mean squares					
	Replication D.F. = 3	Genotypes D.F. = 8	Parents (P) D.F. = 5	F_1 hybrids (H) D.F. = 8	P vs H D.F. = 1	Error D.F. = 42
Days to 75% maturity	20.00	53.65**	62.18**	6.86	385.33**	5.28
Plant height	340.401	412.70**	222.77**	3.83	4323.42**	39.52
Spike length	0.94	2.61**	2.35**	3.83**	33.23**	0.39
Spikelet's spike^{-1}	2.11	14.84**	5.71**	16.16**	49.96**	1.76
Grains spike^{-1}	586.4	891.23**	88.22**	196.66**	10,462.82**	70.99
Seed index	1.825	200.06**	47.23**	306.96**	108.96**	11.06
Grain yield plant^{-1}	586.4	891.23**	8.54	62.87**	2052.32**	12.06
Harvest index	14.9	20.76**	6.88**	32.28**	23.04**	2.62
Total dry matter	227.93	838.54**	22.47**	418.53**	827.97**	43.69

* = Significant at 5% level, ** = Highly Significant at 1% level.

Table 3. Mean performance of F_1 hybrids along with their parents for various quantitative traits in bread wheat genotypes.

Parents	Days to 75% maturity	Plant height (cm)	Spike length (cm)	Spikelet's spike	Grains spike^{-1}	Seed index (g)	Yield plant^{-1}	Yield plant^{-1}	Total dry Matter (g)
Sonalika	108.90	78.45	12.15	17.10	42.15	45.21	15.75	41.23	38.20
Balaka	114.90	85.55	11.80	15.10	44.00	40.95	16.25	38.78	41.90
Kanchan	113.30	78.40	10.60	14.00	35.35	36.61	19.30	44.47	43.40
Agrahani	117.50	64.20	12.40	17.00	42.30	37.67	18.30	41.59	44.00
Prodip	119.50	82.45	11.20	15.90	49.65	35.97	17.50	44.13	39.65
Protiva	118.50	81.45	10.65	16.40	40.05	40.01	19.05	46.46	41.00
Average	**115.43**	**78.41**	**11.46**	**15.91**	**42.25**	**39.40**	**17.69**	**42.78**	**41.35**
				F_1 hybrids					
Prodip × Agrahani	107.8	58.90	13.75	20.90	75.15	40.46	32.50	49.77	65.30
Balaka × Agrahani	107.85	61.45	11.60	15.10	63.45	41.61	26.00	49.80	52.20
Prodip × Sonalika	108.15	54.95	12.60	19.70	74.85	44.19	31.60	49.12	64.33
Protiva × Agrahani	109.45	56.00	12.65	19.80	75.95	27.40	31.35	44.21	70.90
Agrahani × Kanchan	108.50	58.40	13.15	20.80	82.90	43.16	35.45	46.92	75.55
Kanchan × Sonalika	108.25	59.75	11.85	16.90	73.45	40.93	26.10	46.44	56.20
Prodip × Kanchan	110.55	64.15	11.20	19.90	84.20	21.41	36.45	43.83	83.15
Protiva × Prodip	111.35	54.20	10.90	17.00	64.40	26.18	28.40	43.96	64.60
Sonalika × Agrahani	110.20	56.00	11.25	19.40	73.15	29.18	35.45	44.87	79.00
Average	**109.12**	**58.20**	**12.10**	**18.83**	**74.04**	**34.94**	**31.47**	**46.34**	**67.91**
LSD (5%)	**3.28**	**8.97**	**0.89**	**1.89**	**12.02**	**5.42**	**4.95**	**2.31**	**9.43**

length (10.60 cm) was noted for parent Kanchan. While the parents produced 15.91 spikelets on average as compared to 18.83 spikelets produced by F_1 hybrids. Among the parents, Sonalika produced the highest numbers of spikelets spike^{-1} (17.10), while Kanchan produced the lowest (14.00) number of spikelets spike^{-1}. For grains spike^{-1}, the parents averagely recorded 42.25 grains spike^{-1} against a huge increase in grains per spike of F_1 hybrids (74.04). The maximum grains spike^{-1} (49.65) were recorded in parent Prodip while minimum grains spike^{-1} (35.35) was noted in parent Kanchan.

On an average basis, the seed index of parents was 39.40 g, whereas the F_1 hybrids gave less seed index weighing 34.94 g. This large difference in parents and hybrids may be due to a greater number of grains in hybrids which ended up in less seed index. Among the parents, the highest seed index (45.21 g) was observed in Sonalika and lowest seed index (35.97 g) in Prodip. Regarding grain yield plant^{-1}, the parents on an average produced 17.69 g as compared to 31.47g of F_1 hybrids. Thus, F_1 hybrids showed a big increase in grain yield due to their heterotic effects. From parents, the maximum yield per plant was recorded in Kanchan (19.30 g) and minimum in Sonalika (15.75 g). Harvest index in parents, on an average, was recorded as 42.78% as compared to 46.34% of F_1 hybrids. The highest yield index among parents was given by Kanchan (45.97%) and the lowest harvest index was recorded in Protiva (42.63%). On average, total dry matter recorded for parents was 14.00 g, whereas F_1 hybrids produced considerably higher biomass (67.91 g) against the average of parents. These results suggested that due to heterotic effects the hybrids accumulated more total dry matter as compared to their parents. Among the parents, Agrahani weighed maximum total dry matter per plant (44.00 g), while less biomass was weighed by Sonalika (38.20 g).

The average percentage of F_1 hybrids is given in (**Table 3**). The data revealed that cross Protiva × Prodip took maximum days (111.35) to reach 75% maturity, while cross Prodip × Agrahani took minimum days for 75% maturity (107.8) as compared to rest of the hybrids. For plant height, Prodip × Kanchan cross produced taller plants measuring 64.15 cm, and the shorter plants of 54.20 cm were observed in Protiva × Prodip cross. However, for the spike length, the maximum value was noted in Agrahani × Kanchan cross (13.15), while cross Protiva × Prodip showed minimum value (10.90) against the other crosses. For spikelets spike^{-1}, Prodip × Agrahani developed a greater amount (20.90), whereas Balaka × Agrahani produced the lowest amount (15.10) for this trait. For grains/spike, the cross Prodip × Kanchan developed a greater number of grains spike^{-1} (84.20) against other crosses, yet minimum (63.45) amount of grains spike^{-1} were achieved from cross Balaka × Agrahani. The cross Prodip × Protiva gave a higher seed index (44.19 g); however, the lower seed index (21.41g) was recorded in Prodip × Kanchan cross. The Prodip × Kanchan cross-produced maximum grains yield plant^{-1} (36.45 g), whereas the cross Balaka × Agrahani gave the lowest yield plant^{-1} (26.00 g). The maximum harvest index (%) was noted for Prodip × Agrahani cross (51.66) while minimum value was observed in Protiva × Prodip cross (43.23). In the case of total dry matter, hybrid Prodip × Kanchan produced plants, which weighed more biomass plant^{-1} (83.15 g), while less biomass plant^{-1} (52.20 g) was recorded for Balaka × Agrahani.

3.2. Heterotic Effects in F_1 Hybrids

The hybrid vigor of various traits was calculated, and the potential of F_1 hybrids to improve various yields and their related traits were determined by using the hybrid vigor. The results of the hybrid heterotic effect of days to 75% in the F_1 hybrid are shown in (**Table 4**). Results showed that all F_1 hybrids showed negative comparative heterosis and hetero-beltiosis. The destructive comparative heterosis is between −2.65% and −9.11%, while the heterosis is between −6.21% and −9.97%. The highest negative relative heterosis was recorded in the cross Prodip × Sonalika (−9.11%) as compared to Prodip × Agrahani (−9.02%). The cross Prodip × Agrahani showed a greater hetero-beltiosis (−9.79%), followed by Prodip × Sonalika (−9.49%). All hybrids showing negative effects were considered to take 7 days to reach 75% maturity, as such hybrids produce premature hybrids.

Table 4. Heterotic effects of F_1 hybrids over their mid and better parents for days 75% maturity in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero-beltiosis (%)
Prodip × Agrahani	119.5	117.5	118.5	107.80	−9.02	−9.79
Balaka × Agrahani	114.9	117.5	116.2	107.85	−7.18	−8.21
Prodip × Sonalika	119.5	118.5	119.0	108.15	−9.11	−9.49
Protiva × Agrahani	118.5	117.5	118.0	109.45	−7.24	−7.63
Agrahani × Kanchan	117.5	113.3	115.4	108.50	−5.97	−7.65
Kanchan × Sonalika	113.3	117.5	115.4	108.25	−6.19	−7.87
Prodip × Kanchan	119.5	113.3	116.4	110.55	−5.02	−7.48
Protiva × Prodip	118.5	119.5	119	111.35	−6.42	−6.82
Sonalika × Agrahani	108.9	117.5	113.2	110.20	−2.65	−6.21

The heterotic effects of F_1 crosses on the height of the plant are shown in (Table 5). The results showed that the relative mid-parent heterosis and hetero-beltiosis of all hybrids are expressed as negative values. Negative relative mid-parent heterosis ranges from −16.19 to 36.64, and hetero-beltiosis ranges from −22.19 to −43.35. The maximum relative value for heterosis was calculated in cross Protiva × Agrahani (−36.64) followed by Prodip × Sonalika (−32.94). The maximum hetero-beltiosis value was recorded by Protiva × Prodip (−43.35%) followed by Balaka × Agrahani (−41.30%). The negative hetero-beltiosis is considered desirable for plant height.

The spike length has a direct impact on grains plant^{-1} because elongated spikes have extra spikelets, so there are more grains spike^{-1} and therefore, improved grain yield. The wheat flower is an important for efficient production of hybrid seed. Wheat flowers are composed of spikelets; it is a complex procedure (Figure 1). The relative heterosis and hetero-belitiosis of F_1 hybrids present are shown in (Table 6). The relative heterosis of spike length ranged from 16.52% to 8.35%, while hetero-beltiosis ranged from 12.50% to −9.27%. However, the maximum value of relative heterosis was noted in the cross Prodip × Agrahani (16.52%), while the minimum value was recorded in Sonalika × Agrahani (8.35%). For the hetero-belitiosis, the maximum and minimum values recorded in Prodip × Sonalika and Sonalika × Agrahani had a hybrid effect of 12.50% to −9.27%, respectively. The heterotic effects of spikelets for spike^{-1} are shown in (Table 7). Eight out of nine hybrids and two out of nine hybrids exhibited a positive relative effect of heterosis and hetero-beltiotics, ranging from 33.11% to −5.91% and 25.15% to −11.17%, respectively. It was observed that the crosse Agrahani × Kanchan showed greater relative heterosis of 34.19%, while the minimum value (5.91%) was recorded in Balaka × Agrahani. For hetero-beltiosis,

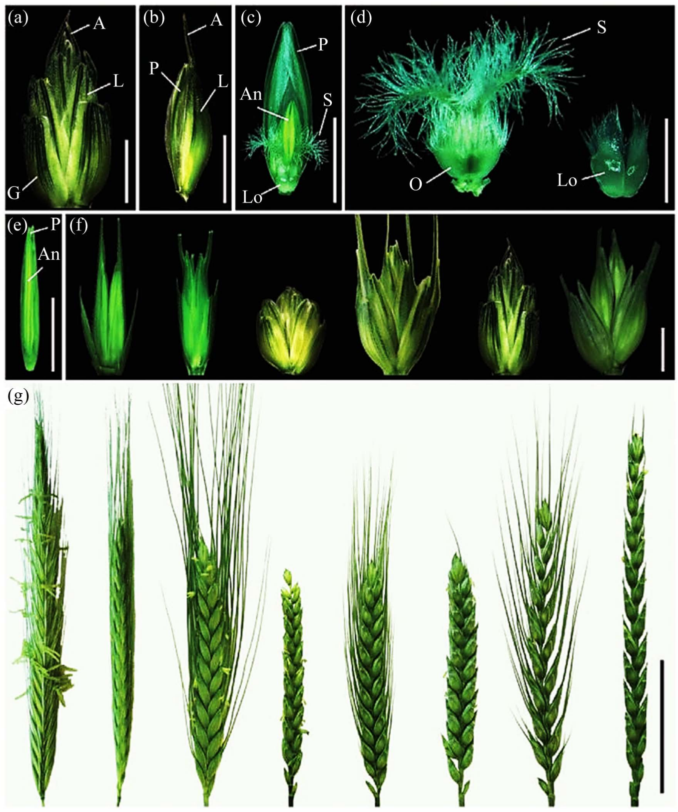

Figure 1. Structure of wheat flowers and spikes. (a) Wheat spikelet. (b) Floret. (c) Palea and reproductive tissues. (d) Lodicule and female reproductive tissues. (e) *Secale cereale* (rye) floret. (f) Spikelets of various Triticeae species, from left to right: rye, *T. monococcum* ssp. *boeticum*, three *T. aestivum* varieties (Chinese spring, Magenta, and Kite) and *T. aestivum* landrace. (g) Spikes of various Triticeae species, from left to right: rye, *T. monococcum* ssp. *oeticum*, *T. turgidum* ssp. Durum, and five *T. aestivum* (bread wheat) varieties (Chinese Spring, Cadoux, Ghurka, and Sentinel, Kite). Bars, 5 mm ((a)-(c), (e), (f)); 2 mm (d); 5 cm (g). An awn; An, anther; G, glume; L, lemma; Lo, lodicule; O, ovary; P, palea; S, stigma [13].

Table 5. Heterotic effects of F_1 hybrids over their mid and better parents for plant height in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero-beltiosis (%)
Prodip × Agrahani	82.45	64.20	73.32	58.90	−19.67	−28.56
Balaka × Agrahani	85.55	64.20	74.87	50.21	−32.94	−41.30
Protiva × Sonalika	82.45	81.45	81.95	54.95	−32.94	−33.35
Protiva × Agrahani	81.45	64.20	72.82	46.14	−36.64	−43.35
Agrahani × Kanchan	64.2	78.40	71.30	58.40	−18.09	−25.51
Kanchan × Sonalika	78.4	64.20	71.30	59.75	−16.19	−23.78
Protiva × Kanchan	82.45	78.40	80.42	64.15	−20.23	−22.19
Protiva × Prodip	81.45	82.45	81.95	54.20	−33.86	−34.26
Sonalika × Agrahani	78.45	64.20	71.32	56.00	−21.48	−28.61

Table 6. Heterotic effects of F_1 hybrids over their mid and better parents for spike length in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero beltiosis (%)
Prodip × Agrahani	11.2	12.4	11.80	13.75	16.52	10.88
Balaka × Agrahani	11.8	12.4	12.10	11.60	−4.13	−6.45
Prodip × Sonalika	11.2	10.6	10.92	12.60	15.33	12.5
Protiva × Agrahani	10.65	12.4	11.52	12.65	9.76	2.01
Agrahani × Kanchan	12.4	10.6	11.50	13.15	14.34	6.04
Kanchan × Sonalika	10.6	12.4	11.50	11.85	3.04	−4.43
Prodip × Kanchan	11.2	10.6	10.90	11.20	2.75	1.23
Protiva × Prodip	10.6	11.2	10.92	10.90	−0.22	−2.67
Sonalika × Agrahani	12.15	12.4	12.27	11.25	−8.35	−9.27

Table 7. Heterotic effects of F_1 hybrids over their mid and better parents for spikelet's spike^{-1} in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero-beltiosis (%)
Prodip × Agrahani	15.9	17.0	16.45	20.9	27.05	22.94
Balaka × Agrahani	15.1	17.0	16.05	15.1	−5.91	−11.17
Prodip × Sonalika	15.9	16.4	16.15	19.7	21.98	20.12
Protiva × Agrahani	16.4	17.0	16.70	19.8	18.56	16.47
Agrahani × Kanchan	17	14.0	15.50	20.8	34.19	22.35
Kanchan × Sonalika	14	17.0	15.50	16.9	9.03	−0.58
Prodip × Kanchan	15.9	14.0	14.95	19.9	33.11	25.15
Protiva × Prodip	16.4	15.9	16.15	17.0	5.26	3.65
Sonalika × Agrahani	17.1	17.0	17.05	19.4	13.78	13.45

the highest value was recorded for cross Prodip × Kanchan (25.15%), while the minimum value was noted for cross Balaka × Agrahani (−11.17%). The results showed that two hybrids, Prodip × Agrahani, and Prodip × Kanchan showed the highest heterotic effect and were the most ideal hybrids among the remaining crosses. The hybrid effects of average hybrids of F_1 hybrids and improved parents on number of grains spike^{-1} in hexaploid wheat are shown in (Table 8). Interestingly, all nine hybrids showed positive relative and hetero-biotic effects which are different from 43.58 to 113.52 and 29.70% to 95.98%, respectively. Many hybrids showed excellent heterosis effects, but the Agrahani × Kanchan

Table 8. Heterotic effects of F_1 hybrids over their mid and better parents for number of grains spike^{-1} in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero-beltiosis (%)
Prodip × Agrahani	49.65	42.30	45.97	75.15	63.45	51.35
Balaka × Agrahani	44.00	42.30	43.15	63.45	47.04	44.2
Prodip × Sonalika	49.65	40.05	44.85	74.85	66.88	50.75
Protiva × Agrahani	40.05	42.30	41.17	75.95	84.45	79.55
Agrahani × Kanchan	42.3.0	35.35	38.82	82.9	113.52	95.98
Kanchan × Sonalika	35.35	42.30	38.82	73.45	89.18	73.64
Prodip × Kanchan	49.65	35.35	42.5	84.2	98.11	69.58
Protiva × Prodip	40.05	49.65	44.85	64.4	43.58	29.7
Sonalika × Agrahani	42.15	42.30	42.22	73.15	73.23	72.93

showed greater relative heterosis (113.52%), and for hetero-beltiosis cross, Agrahani × Kanchan showed the greatest heterosis (95.98%).

The effect of heterosis of F_1 hybrids in hexaploid wheat on the seed index of middle and superior parents is given in (Table 9). Among nine hybrids, five showed positive relative heterosis and hetero-beltiosis. Hybrids showing the greatest relative heterosis accordingly exhibited higher hetero-beltiosis. Prodip × Sonalika and Prodip × Kanchan indicated that the relative heterosis of the seed index was between 16.32% and −41.84%. For hetero-beltiosis, the ranges recorded for Agrahani × Kanchan and Prodip × Kanchan were between 14.60% and −43.15%, respectively. The two highest-ranked hybrids were: Prodip × Sonalika and Prodip × Kanchan, which showed higher relative heterosis and hetero-beltiosis effects, and may, therefore, be the first choice to increase wheat seed index. The effect of heterosis for F_1 hybrids in hexaploid over their mid and better parents of yield plant^{-1} is given in (Table 10). The results showed that all nine hybrids showed considerable positive relative heterosis and hetero-beltiosis. However, the relative heterosis ranged from 38.82 to 108.22, while the influence of hetero-beltiosis ranged from 35.23% to 93.71%. Six hybrids showed that the maximum value for relative heterosis (108.22) was shown by cross Sonalika × Prodip, while minimum heterosis (38.82) was recorded for Kanchan × Sonalika. While, for hetero-beltiosis, cross Sonalika × Agrahani and Kanchan × Sonalika showed greater and minimum values of 93.71 and 35.23, respectively. At least six hybrids exhibited above 65% hetero-beltiotic effects.

Heterotic effects of F_1 hybrids on improved and better parents for harvest index in hexaploid wheat are shown in (Table 11). Eight out of nine hybrids exhibited positive relative heterosis while only six hybrids showed positive hetero-beltiotic effects. In the case of relative heterosis, the value varied from 0.03%

Table 9. Heterotic effects of F_1 hybrids over their mid and better parents for seed index in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero-beltiosis (%)
Prodip × Agrahani	35.97	37.66	36.81	40.46	9.88	7.41
Balaka × Agrahani	40.94	37.66	39.3	41.61	5.85	1.61
Prodip × Sonalika	35.97	40.01	37.99	44.19	16.32	10.45
Protiva × Agrahani	40.01	37.66	38.83	27.4	−29.44	−31.51
Agrahani × Kanchan	37.66	36.6	37.13	43.16	16.23	14.6
Kanchan × Sonalika	36.6	37.66	37.13	40.93	10.22	8.67
Prodip × Kanchan	35.97	37.66	36.81	21.41	−41.84	−43.15
Protiva × Prodip	40.01	35.97	37.99	26.18	−31.09	−34.57
Sonalika × Agrahani	45.2	37.66	41.43	29.18	−29.59	−35.46

Table 10. Heterotic effects of F_1 hybrids over their mid and better parents for grain yield plant^{-1} in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero beltiosis (%)
Prodip × Agrahani	17.5	18.30	17.90	32.50	81.56	77.59
Balaka × Agrahani	16.25	18.30	17.27	26.00	50.50	42.07
Prodip × Sonalika	17.5	19.05	18.27	31.60	72.91	65.87
Protiva × Agrahani	19.05	18.30	18.67	31.35	67.87	64.56
Agrahani × Kanchan	18.3	19.30	18.80	35.45	88.56	83.67
Kanchan × Sonalika	19.3	18.30	18.80	26.10	38.82	35.23
Prodip × Kanchan	17.5	19.30	18.40	36.45	98.09	88.86
Protiva × Prodip	19.05	17.50	18.27	28.40	55.40	49.08
Sonalika × Agrahani	15.75	18.30	17.02	35.45	108.22	93.71

Table 11. Heterotic effects of F_1 hybrids over their mid and better parents for harvest index in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero-beltiosis (%)
Prodip × Agrahani	45.17	42.83	44	51.66	17.39	14.35
Balaka × Agrahani	43.68	42.83	43.26	49.38	14.13	13.03
Prodip × Sonalika	45.17	42.62	43.9	49.02	11.66	8.52
Protiva × Agrahani	42.62	42.83	42.73	44.03	3.03	2.78
Agrahani × Kanchan	42.83	45.97	44.4	44.42	0.03	−3.37
Kanchan × Sonalika	45.97	42.83	44.4	47.59	7.18	3.52
Prodip × Kanchan	45.17	45.97	45.57	45.64	0.15	−0.71
Protiva × Prodip	42.62	45.17	43.9	43.23	−1.52	−4.30
Sonalika × Agrahani	44.26	42.83	43.55	45.64	4.79	3.10

to 17.39% and positive hetero-beltiosis varied from 14.35% to −3.37%. It was also observed that the greatest value for the trait of grain yield plant^{-1} (17.39) was obtained in cross Prodip × Agrahani of and the lowest was recorded in cross Protiva × Prodip (−1.52).

The results regarding relative heterosis and hetero-beltiosis are presented in (Table 12). The results showed that the relative heterosis in F_1 hybrids ranged from 21.53% to 100.24%. However, the maximum value of relative heterosis was recorded in cross Prodip × Kanchan (100.24%) followed by the cross Sonalika × Agrahani (92.21%). The minimum value for the relative heterosis was recorded in cross Balaka × Agrahani (21.53%) for total dry matter. As far as hetero-beltiosis is concerned, the maximum value was recorded for the cross Prodip × Kanchan (91.58%) and the minimum value was shown by the cross Balaka × Agrahani (18.63%).

Correlations

The correlation coefficients were worked-out among the grain yield and its mechanisms, so as to determine one or several traits highly correlated with yield and can be improved through indirect selection. The outcomes are presented in (**Table 13**).

Days to 75% maturity

Number of days to 75% maturity was significant but negative correlation with grains spike^{-1} (r = −0.747**), harvest-index (r = −0.600**), spike length (r = 0.444**), spikelets spike^{-1} (r = −0.504**) grains production plant^{-1} (r = −0.682**) and total dry matter (r = −0.617**). Nevertheless, by 75% of maturity days and the seed index (r = 0.362**) revealed significant-positive correlation through height of plant (r = 0.720**).

Table 12. Heterotic effects of F_1 hybrids over their mid and better parents for total dry matter in hexaploid wheat.

Hybrids	Male parent	Female parent	Mid parent	F_1 hybrids	% increase (+) or decrease (−) of F_1s over	
					Relative heterosis (%)	Hetero beltiosis (%)
Prodip × Agrahani	39.65	44.0	41.82	65.3	56.12	48.4
Balaka × Agrahani	41.90	44.0	42.95	52.2	21.53	18.63
Prodip × Sonalika	39.65	39.3	39.47	64.3	62.96	62.24
Protiva × Agrahani	39.30	44.0	41.65	70.9	70.22	61.13
Agrahani × Kanchan	44.00	43.4	43.70	75.6	72.88	71.7
Kanchan × Sonalika	43.40	44.0	43.70	56.2	28.60	27.72
Prodip × Kanchan	39.65	43.4	41.52	83.2	100.24	91.58
Protiva × Prodip	39.30	39.6	39.47	64.6	63.64	62.92
Sonalika × Agrahani	38.20	44.0	41.10	79.0	92.21	79.54

Table 13. Correlations coefficient (r) between yield traits of parents and F_1 hybrids in wheat.

Characters	Days to 75% maturity	Grains spike^{-1}	Harvest index	Plant height	Seed index	Spike length	Spikelets spike^{-1}	Total dry matter	Yield plant^{-1}
Days to 75% maturity	-	−0.747**	−0.600**	0.720**	0.362*	−0.444**	−0.504**	−0.617**	0.682**
Grains spike^{-1}		-	0.388**	−0.738**	−0.642**	0.362**	0.779**	0.895**	0.930**
Harvest index			-	−0.257*	0.015	0.340**	0.203	0.191	0.323**
Plant height				-	0.580**	−0.339**	−0.540**	0.716**	0.747**
Seed index					-	0.105	−0.418**	−0.717**	0.630**
Spike length						-	0.527**	0.14	0.206
Spikelet's spike^{-1}							-	0.765**	0.786**
Total dry matter								-	0.970**
Yield plant^{-1}				-					-

* = Significant at 5% level, ** = Highly Significant at 1% level.

Grains spike^{-1}

Grain spike^{-1} was significant and positively correlated with harvest-index (r = 0.388**) and yield plant^{-1} (r = 0.362**), spikelet spike^{-1} (r = 0.779**), grains yield plant^{-1} (r = 0.930**), total dry matter (r = 0.895**), but this characteristic did not prove ideally correlated with plant height (r = −0.738**) and seed index (r = −0.642**).

Harvest index

There was a positive and significant correlation between the harvest index and spike length (r = 0.340**) and grain yield plant^{-1} (r = 0.323**), while this parameter was only negatively related to plant height (r = −0.257*).

Plant height

Plant height was positively correlated with seed index (r = 0.580**), total dry matter (r = 0.716**) and grains yield plant^{-1} (r = 0.747**). While a negative but significant interrelationship was observed through characters such as spike length (r = −0.339**) and spike^{-1} (r = −0.54**).

Seed index

The seed index was negatively but significantly correlated with spikelets spike^{-1} (r = −0.418**), total dry matter (r = −0.717**) and grain yield plant^{-1} (r = −0.63**).

Length of spike

The length of the spike was only positively correlated with spikelets spike^{-1} (r = 0.527**). It was positively correlated but non-significant with total dry matter (r = 0.140) and grain yield plant^{-1} (r = 0.206).

Spikelets spike^{-1}

This trait confirmed a positive and significant correlation with total dry matter (r = 0.765**) and grain production plant^{-1} (r = 0.786**).

Total dry matter

Total dry matter showed a positive correlation in grain yield plant^{-1} (r = 0.97**).

3.3. Mean Performance of Parents and F_1 Hybrids

Yield related characters, as well as other complex traits, are regulated by various genetics factors. Due to the genetic complexity of traits and interaction among genotypes and the environment, the selection of parents becomes difficult, which provides hybrids with a higher yield [32]. ANOVA analysis showed that the genotypes change significantly with all production characteristics analyzed in this study ($p \leq 0.01$), for example, days to 75% maturity to, height of plant, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index, grains yield plant^{-1}, harvest-index and total dry matter (**Table 2**). The average percentages obtained by the analysis of parameter suggested significant changes in parents and hybrids of all traits except grains yield plant^{-1}, which is not significant only in the parents. On average, however, parents took many days to reach 75% maturity, whereas the F_1 hybrids took significantly fewer days to 75% maturity. Similarly [33] described that parents took more days to 75% maturity compared to F_1 wheat hybrids. Regarding plant height, the parents attained 78.41 cm plant height against 58.20 cm by F_1 hybrids, thus F_1 hybrids were shorter as compared to parents and were more desirable and resistant to lodging. With respect to the length of the spike, the parents produced shorter spikes (11.46 cm) as compared to longer spikes by F_1 hybrids (12.10 cm). For the number of spikelets spike^{-1}, the parents produced 15.91 as compared to 18.83 spikelets spike^{-1} in F_1 hybrids. As far as grains spike^{-1} is concerned, the parents recorded 42.25 grains/spike against a huge proliferation in grains/spike of F_1 hybrids (74.04) (**Table 2**). Similarly, [20] revealed that parents comparatively showed higher plant length, shorter spikes, lesser spikelets spike^{-1} as well as grains spike^{-1} than F_1 hybrids.

On an average basis, the seed index of parents was 39.40 g, whereas the F_1 hybrids revealed less seed index weighing 34.94 g. This large difference in parents and hybrids may be attributable to the higher number of grains in hybrids which ended up in less seed index. Regarding grain yield plant^{-1}, the parents on an average gave 17.69 g as compared to 31.47 g of F_1 hybrids. Thus, F_1 hybrids showed a big increase in grain yield due to their heterotic effects. [34] reported higher grain yield plant^{-1} for maize hybrids LM-13 × IC-32809. Harvest index in parents was recorded as 42.78% as compared to 46.34% of F_1 hybrids. Similarly, the harvest index in F_1 wheat hybrids (Prodip × Kanchan) was higher as compared to parents [33]. The total dry matter of parents stood at 14.00 g, whereas F_1 hybrids produced considerably higher biomass (67.91 g) against the average of parents. These results suggest that due to heterotic effects, the hybrids accumulated more total dry matter as compared to their parents (**Table 3**).

3.4. Heterotic Effects of F_1 Hybrids

The heterotic effects in F_1 hybrids and parents for 75% days to maturity are presented in (**Table 5**), which showed that all the hybrids indicated a positive association for heterosis and hetero-beltiosis. The negative heterosis varied from −2.65% to −9.11%, and hetero-beltiosis ranged from −6.21% to −9.79%. The highest but desirable negative relative heterosis (−9.11%) was observed for the cross of Prodip × Agrahani, followed by Prodip × Sonalika (−9.02). While the cross Prodip × Agrahani showed greater hetero-beltiosis (−9.79%), followed by Prodip × Sonalika (−9.49%).The results of heterotic effects in F_1 hybrids for plant height are in (**Table 4**). The negative heterosis is desirable because plants with shorter heights are considered as resistant to lodging. Results showed negative effects for both relative heterosis and hetero-beltiosis. The negative relative heterosis varied from −16.1992 to −36.6426, while hetero-beltiosis ranged from −22.19 to −43.35. The maximum value of relative heterosis was calculated for cross Protiva × Agrahani followed by Prodip × Sonalika. For hetero-beltiosis, the maximum value was observed in Protiva × Agrahani followed by Balaka × Agrahani. Similar to present findings [35] [36] [37] observed negative heterosis for plant height. Spike length had a direct effect on individual plants for seed yield because longer spikes had more spikelets. The relative heterosis ranged from 16.52 to −8.35, and the hetero-beltiosis ranged from 12.50 to −9.27. The largest heterosis of the spike length was observed in cross Prodip × Agrahani and the smallest heterosis was observed in cross Sonalika × Agrahani. For hetero-beltiosis, the maximum (12.50) and minimum (−9.27) peak lengths were recorded in Prodip × Sonalika and Sonalika × Agrahani, respectively. Our results are consistent with those of [38] [39] [40] who reported highly significant and maximum heterosis of the spike length.

Heterotic effects showed that the cross Agrahani × Kanchan exhibited the highest relative heterosis (34.19%) while minimum value was recorded in Balaka × Agrahani (−5.91%). For hetero-beltiosis, the cross Prodip × Kanchan expressed higher value (25.15%), nevertheless, minimum hetero-beltiosis was recorded in cross Balaka × Agrahani (−11.17) respectively. [16] [41] [42] also reported positive heterosis for spikelets spike^{-1}. Heterotic effects of F_1 hybrids over their mid and better parents for grains spike^{-1} in hexaploid wheat indicated that the cross Agrahani × Kanchan indicated a higher amount for relative heterosis (113.52%) while minimum relative heterosis was expressed by Protiva × Prodip of 43.58. Regarding hetero-beltiosis, the higher hetero-beltiotic effects were observed in cross Agrahani × Kanchan (95.98) and minimum effects in cross Protiva × Prodip (29.70%). Our findings are in conformity with those of [12] and [16] who also observed significant positive heterosis for grains per spike. Heterotic effects of F_1 hybrids over their mid and better parents for seed index in bread wheat indicated that relative heterosis ranged from 16.32 to −41.84 in hybrids Prodip × Sonalika and Prodip × Kanchan respectively. While for hetero-beltiosis it ranges from 14.60 to −43.15 of Agrahani × Kanchan and Prodip × Kanchan, respectively. Like our findings, [35] found a significant and fair amount of mid parent as well as better parent heterosis for seed index. The heterotic effects of F_1 hybrids over their mid and better parents for grains yield plant^{-1} indicated that the maximum relative heterosis was shown by cross Sonalika × Agrahani (108.22%) while minimum heterosis was recorded by Kanchan × Sonalika of (38.82%). As far as hetero-beltiosis is concerned, the hybrids Sonalika × Agrahani and Kanchan × Sonalika showed maximum and minimum heterotic effects (93.71% and 35.23% respectively). [12] [40] [41] also reported significantly high relative heterosis and better parent heterosis for grain yield plant^{-1}.

However, the maximum relative heterosis was recorded in cross Prodip × Agrahani and minimum in cross Protiva × Prodip of −1.52. In the case of heterobeltiosis, the values varied from 14.35% to −3.37% in Prodip × Agrahani and Agrahani × Kanchan respectively. The results regarding relative heterosis and hetero-beltiosis for total dry matter are presented in (**Table 12**). The relative heterosis in F_1 hybrids ranged from 21.53% to 100.24%. Nonetheless, the maximum relative heterosis was recorded in hybrid Prodip × Kanchan (100.24) followed by Sonalika × Agrahani (92.21%). The minimum relative heterosis was recorded in cross Prodip × Agrahani (21.53%) for the trait total dry matter. As far as hetero-beltiosis is concerned, the maximum value was recorded for cross Prodip × Kanchan (91.58%) and minimum value in cross Balaka × Agrahani (18.63%) for total dry matter plant^{-1}.

3.5. Correlations

Correlation coefficients played a role among the nine yields and their related characteristics. Days to 75% maturity were significant and positively correlated with grains yield plant^{-1}. Plant height showed a positive correlation with grains yield plant^{-1}. Spikelets spike^{-1} was positively associated with grains yield plant^{-1}. The results of the current study were confirmed by [3] and [43] who described that the grains yield plant^{-1} is critical, and the yield is divided by the tillers plant^{-1}, spikelets spike^{-1} and grain spike^{-1}. [37] also showed a significant positive correlation between grains yield plant^{-1} and its mechanisms (such as the production of tillers plant^{-1}, spike length, spikelets spike^{-1}, grain spike^{-1} and 1000 grains weight g). [44] observed genotype and phenotypic correlations between grain yield and other yield components, such as tillers plant^{-1}, number of spike per square meter, number of grains spike^{-1}, total biomass plant^{-1}, and harvest index and 1000 grains weight (g). [45] pointed out that plant height has a significant positive correlation with the spike length, spikelets spike^{-1}, grain spike^{-1} and grains yield spike^{-1}.

Generally, the correlation coefficient revealed that days to 75% maturity had negative associations with the majority of yield traits suggesting that the genotypes that mature earlier could be low yielding. Grains spike^{-1} increased by increasing the spike length, and harvest index; consequently, grains yield will increase, thus grains spike^{-1} presented the positive association with all of these yield characters. On the contrary, the increase in grains number will cause a reduction in speed index because of the negative association between these traits. As with 75% maturity and plant height present negative association to grains yield plant^{-1} and its components. Similar to our findings [27] demonstrated that grains yield plant^{-1} is positively correlated with grains number spike^{-1}, but is different from current results. They observed a positive correlation between grains yield and 75% of maturity days. Our results showed a negative correlation between grain yield and plant height, spike length, and 1000 grains weight (g). Grain yield was significantly and positively correlated with all characteristics (plant height, spike length, spikelets spike^{-1}, grains spike^{-1}, and grains spikelets^{-1}), which suggested that other positive correlations could be obtained through traits that increased grains yield and good selection criteria for wheat improvement.

4. Conclusion

The outbreeding enhancement and correlation were examined for various traits of economic importance, including days to 75% development, plant height, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index, harvest index and total dry matter in hexaploid wheat genotypes. The six parents (Sonalika, Balaka, Prodip, Kanchan, Agrahani and Protiva) were crossed and nine possible cross combinations (F_1 hybrids) (Prodip × Agrahani, Balaka × Agrahani, Prodip × Protiva, Protiva × Agrahani, Agrahani × Kanchan, Kanchan × Sonalika, Protiva × Prodip, Sonalika × Agrahani, and Prodip × Kanchan) were obtained. The F_1 hybrids genotypes were varied expressively ($p \leq 0.01$) statistically analyzed using analysis of variance (ANOVA) all studied characters. The average performance of parents and F_1 hybrids was presented, great importance that indicated considerable heterosis from F_1 hybrids. The experimental results effects for the characters days to 75% development, plant height, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index, harvest index and total dry matter recorded. In view of the above hypothesis, the heterosis and correlation form this study are considered to be useful, to increase grain production and which can be used to selected plants with desirable traits and high yielding plants.

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Authors' Contributions

S. K planned, designed and performed this research. A. B. M. K, M. M. R, M. M, I, M. S. U and M. A. L. A helped to analyze the experimental data. S.K revised the whole manuscript.

Conflicts of Interest

All authors declare that there is no conflict of interest either financially or otherwise.

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