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Combining Ability Analysis Of Bread Wheat For Grain Iron And Zinc Content Under Rainfed Conditions

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ABSTRACT
Iron (Fe) and zinc (Fe) deficiency is a significant global health concern, impacting a staggering two billion individuals across the globe. For the enhancement of grain minerals content, it is essential to evaluate the heterosis, gene action, grain yield potential, and Fe and Zn content in bread wheat using plant breeding techniques to understand the inheritance patterns of the traits under investigation. Therefore, the selection of best parent and offspring combinations relies heavily on the prevailing growing conditions to achieve the highest possible genetic progress. For this study, a group of ten different parents were selected to be crossbred, resulting in 25 F_1 progenies using a line X tester mating design. The F_1 progenies, along with their parents, were evaluated in a randomized block design with three replications at the University Research Farm koont in Rawalpindi during the Rabi season of 2018-2019. The results pertaining to variance component, specifically the effects of general combining ability (GCA) of parents, were found to be statistically significant ($P < 0.05$) for nearly all the traits that were studied. All morphological and quality traits showed significant effects in the progenies' specific combination ability (SCA). The grain yield mean was higher in the Galaxy and Aas11 x 11315 hybrids when compared to the parents. Aas11 and tester11135 showed excellent performance as combiners in terms of the number of grains per spike. Galaxy is an excellent choice when it comes to measuring the weight and quantity of 1000 kernels. If you're looking to shorten the vegetative growth period or control the height of your plants, Dharabi and Galaxy are excellent general combiners to consider. If you're looking to optimize your plant growth and increase grain production per spike, Dharabi x11156 is the perfect choice. For optimal results in achieving a shorter vegetative phase, taller plants, and increased Spikelets per spike, the ideal combination would be Galaxy x 11135. There was a significant amount of heterosis observed in the grain yield, number of fertile tillers, spike length, and days to maturity for the Aas-11 x 11135 combination. On the other hand, there was a negative heterosis observed for 1000-gram weight and days to maturity, while the other traits showed positive heterosis. The data provided low to moderate HB estimates, 2 gca/2 sca, (2 D/2 A) 1/2 low ratios, and the presence of both additive and nonadditive gene effects. It would be wise to delay expanding the plant selection until a later generation, as it is clear that non-additive gene activity is the prevailing factor.

Keyword: Wheat, Line X Tester, Heterosis, Combining ability, Gene action, Iron, Zinc

INTRODUCTION

Triticum aestivum L., often known as hexaploid bread wheat, is a widely cultivated cereal plant belonging to the Poaceae family (Levy and Feldman, 2002). Wheat is regarded as a vital food source since it is one of the fundamental grains in the world's diet. For over 10,000 years, humans have gathered grains from wild wheat relatives as a food source. Wheat and its related plants have been cultivated and tamed since ancient times (Khalid et al., 2014). Currently, wheat has become the predominant food crop worldwide, exceeding the production of all other crops. Wheat has a higher quantity of essential elements in comparison to other grains, perhaps establishing it as the most vital staple crop for humans (Garvin et al., 2006). More than two billion individuals globally, namely pregnant women and children under the age of five, have a deficiency in crucial micronutrients such as zinc and iron (Velu et al., 2013).

The composition of wheat grain consists of essential elements such as copper (Cu), zinc (Zn), iron (Fe), nickel (Ni), and manganese (Mn), as well as substantial amounts of proteins, vitamins, and cellulose fibers. These components play a crucial role in supporting many biological functions in the human body. These minerals are vital for bone formation and the production of vitamins since they have a critical function in the structure of enzymes and hormones. Several variables influence the uptake and retention of metals in plants, including soil characteristics, chemical makeup, soil fertility, root-soil interaction,

absorption mechanisms, and internal movement inside plants. Mineral shortages affect more than three billion people globally, particularly in areas where diets mostly consist of cereals. (Zuzana et al 2009).
Iron deficiency (ID) and iron deficiency anemia (IDA) are the prevailing conditions affecting a significant portion of the worldwide population. Iron deficiency has a negative effect on the brain development of a baby. Zinc is a vital element for the process of human growth and development. Zinc has a crucial role in supporting the immune system, promoting tissue repair, facilitating wound healing, ensuring appropriate insulation, aiding in reproduction, maintaining eyesight, enhancing taste, and influencing behavior. (Laze et al., 2015). Bio-fortification is an appealing and enduring choice, but it necessitates the creation of novel wheat cultivars with enhanced iron and zinc concentrations in their grains. By using modern agronomic techniques and growing high-yielding cultivars, it is possible to enhance wheat output. Enhancing the characteristics and yield of crops, as well as their ability to withstand both living and non-living environmental pressures. Genetically enhancing bread wheat to improve its resistance to heat and water stress during the latter stages of the growing season is expected to enhance grain yield. Breeders have difficulties when selecting parents and crosses to develop cultivars with exceptional productivity. Various breeding methods have been proposed in this domain. Kempthorne introduced the line tester analysis approach, which is a robust method for quantifying the impacts of combining ability and assisting in the identification of appropriate parents and crosses for pedigree breeding (Rashid et al., 2007; Jain et al., 2012). Performances do not accurately reflect a parent's aptitude for effective collaboration. We must overcome this obstacle. To overcome this challenge, it is essential to have a deeper understanding of gene function. General combining capacity is linked to the additive effects of genes, whereas specific combining ability is connected with nonadditive gene activities. Nonadditive gene activities exhibit inconsistent stability, while additive gene actions and complementary epistatic gene interactions demonstrate stability. (Xiang et al., 2001; Iqbal et al., 2006) Heterosis estimations are ascribed to both additive and nonadditive genetic influences for various morphological and yield-related characteristics. Heritability is a quantitative measure of the extent to which genetic differences contribute to the variation seen in a population, and it provides insight into how a population will respond to selective pressures in subsequent generations. The kind of gene activity influences the process of heredity (Swati et al., 2004; Chowdary, 2007).

MATERIALS AND METHODS

The research was conducted at the University research Farm Koont, located on Chakwal Road in Rawalpindi. Soil tests were performed to ascertain the amounts of electrical conductivity, pH, total nitrogen, extractable phosphorus.The current study used twenty-five F_1 wheat populations that were produced at the Department of Plant Breeding and Genetics. The line parents for the crosses were Chakwal-50, Aas-11, MANAL-1, PAK-13, Borlaug-14, AUR-809, AUR-810, and Dharabi-11-31, while the other parents included testers 11156, 11170, 11194, 11238, and 11272. The 2018-2019 Rabi season marked the period designated for sowing seeds. The individuals employed were 11156 and 11170, who were assigned the role of testers. Bandera et al. conducted research in 2011. Kempthorne used his line x tester mating method on the 10 parents to generate 25 F_1 hybrids. In 1957, F_1 seedlings were planted in the field alongside their parents using a randomized block design with three replications. Each plot consisted of a single row that was 3 meters long, with a spacing of 30 cm between rows and 15 cm between seeds. Strict adherence to recommended cultural procedures ensured a sufficient crop.

RESULTS AND DISCUSSIONS

TABLE: Analysis of variance for line-tester analysis.

Source of variation	Degree of freedom (df)	Mean square
Replication	(r) $(r-1)$	MS2
Genotypes	(g) $(g-1)$	
Parents	(p) $(p-1)$	MS1
Parents versus crosses	1	
Crosses	(c) $(c-1)$	
Lines	(l) $(l-1)$	Ml
Testers	(t) $(t-1)$	Mt
Lines × testers	$(l-1)(t-1)$	$Ml{\times}t$
Error	$(r-1)(t-1)$	MS1

The genotypic mean square, line mean square, tester mean square, line × tester mean square, and error mean square were represented by MS2, Ml, Mt, $Ml{\times}t$, and MS1, respectively.
The soil research revealed that the soil had a pH of 7.65, an electrical conductivity (EC) of 0.19 dS m-1, and a total organic carbon content of 0.41%. The data suggested that the soil exhibited a deficit, namely containing less than 1% organic matter. Observations indicated that the soil had a composition characterized by a sandy clay texture and contained a moisture content of 9.14%. Overall, the soil had a nitrogen concentration of 0.38 mg g-1. The soil included a concentration of 0.63 mg kg-1 of NO3-N, 1.9 mg kg-1 of Olsen P, and 83 mg kg-1 of extractable K. The fertilizer application included the use of 120 kilograms per acre of nitrogen and 60 kilograms per acre of phosphorus. All prescribed agronomic treatments, such as hoeing and weeding, were performed promptly as needed. The following characteristics were documented for five competitive plants: heading, anthesis, and maturity duration; plant height; spike length; number of fertile tillers per plant; number of grains per spike; 1000-kernel weight; ion, zinc, proline, cell membrane stability, osmotic potential, leaf area, canopy temperature depression, relative water content, and grain yield per plant. The research did not include Balaguer plants. Steel and Torrie's analysis of variance was used to assess the presence of significant differences across genotypes using the data collected in 1980.

When determining the next step in breeding endeavors, the consequences of combining ability are particularly valuable genetic factors to take into account. The line x tester approach was used to get these findings. In 1977, Singh and Chaudary. The line x tester analysis was conducted using the ANOVA table style shown in Table 1.
The variances for general and particular combining abilities were compared to their respective error variances, which were derived from the analysis of variance of the different qualities as follows:
The equation (1) represents the covariance of the half-sib of a line, denoted as Cov.H.S.(line). It is calculated as the difference between the mean of the line (Ml) and the product of the mean of the line and the transmission rate (Mlt), divided by the transmission rate (rt).
The covariance of the half-sibling of the tester may be calculated using the formula Cov.H.S.(tester) = $Mt - Ml{\times}t \ / \ rl$ (2). The covariance of full siblings is represented by the abbreviation Cov.F.S.
The expression is calculated by subtracting the value of Me from the value of Ml, adding the value of Mt minus Me, and finally adding the product of Ml and t minus Me. The expression is written as $3r + 6r$Cov.The expression H.S.$- \ r \ (l{+}t)$ represents a mathematical equation. Cov. is an abbreviation for the word "coverage".H.S. + 3r + $6r$Cov.The expression H.S.$- \ r \ (l{+}t)$ represents a mathematical equation. COVID-19.H3 (3)
The formula calculates the average covariance of H.S. (high school) using the following equation: Cov.H.S. (average) = $1/r$ * (2lt - l - t) * [(l-1)(Ml) + (t-1)(Mt) / (l+t-2) - Ml * Mt]. The calculation of the variation due to general combining ability ($\sigma 2$ gca) and the variance due to specific combining ability ($\sigma 2$ sca) is as follows:
The covariance between variables gca and H.S., denoted as Cov.H.S., is equal to (1+F 4) multiplied by the variance of gca, represented as $\sigma 2$. The product of (1+F 2) squared and the variance of variable A is equal to $\sigma 2$ multiplied by variable D. The input is the number 5.
To estimate the additive and dominant genetic variances ($\sigma 2$ A and $\sigma 2$ D), the inbreeding coefficient (F) was adjusted to one (F=1). This was done since both the lines and the testers were participating in the breeding process. The importance of the effects of general combining ability and specific combining ability was assessed using the t-test for statistical significance. Mid-parent heterosis, or HPM, refers to the enhanced vigour of the F1 generation compared to the average of the parental generations. The computation relied on mean values, and the significance was determined using the t-test (Oettle, 2005). An estimate of the narrow sense heritability was conducted after constructing the variance components (Singh & Chaudry, 1977). Verma et al. (2004) employed the ratios of ($\boldsymbol{\theta}2$ gca/$\sigma 2$ sca) and ($\sigma 2 \ D/\sigma 2 \ A$) $1/2$ to assess the extent of the relative influence of additive and nonadditive gene activity.

Table 2: Analysis of variance for the impact of different wheats on combining ability.

Source	DF	PH	TP	SL	SPS	GPS	GY	Fe	Zn	Pro	CTD	RWC	CMS	LA	1000GW	OSP	DHARABI-11	DA	DM
Replications	2	14.90*	1.98*	1.16*	25.87*	6.88*	0.31*	31.25*	25.28*	35.85*	26.40*	35.26*	34.01*	103.15*	13.74*	0.08*	131.43*	563.80*	157.83*
Treatments	34	8.89*	0.45*	0.74*	1.46*	6.89*	0.61*	73.64*	67.03*	28.69*	6.284*	57.75*	26.90*	46.98*	26.27*	0.07*	55.85*	153.02*	8.767*
Parents	9	12.57*	0.66*	0.19*	2.40*	3.29*	1.48*	48.24*	93.95*	17.27*	4.44*	33.09*	25.12*	49.93*	6.85*	0.10*	22.31*	139.35*	11.540*
Parents vs. Crosses	1	0.028*	0.19*	1.01*	0.43*	49.48*	0.54*	66.89*	7.11*	7.63*	91.54*	57.44*	51.79*	206.43*	53.27*	0.07*	10.10*	1.92*	4.14*
Crosses	24	7.87*	0.39*	0.94*	1.15*	6.46*	0.29*	58.53*	59.43*	33.85*	3.42*	79.10*	28.78*	39.23*	29.28*	0.06*	70.3*	164.4*	7.92*
Lines	8	7.14*	0.35*	0.84*	0.24*	4.19*	0.17*	13.69*	53.16*	25.39*	2.52*	44.32*	48.82*	93.44*	29.71*	0.05*	10.94*	337.83*	2.12*
Testers	4	9.87*	0.72*	1.02*	0.68*	10.15*	0.43*	89.50*	79.53*	33.28*	4.74*	39.12*	17.01*	39.43*	35.27*	0.10*	121.48*	190.13*	7.38*
Lines X Testers	12	7.6*	0.30*	0.92*	1.77*	4.76*	0.24*	52.83*	48.11*	37.05*	2.84*	11.01*	28.29*	21.03*	35.27*	0.03*	56.03*	89.51*	10.20*
Error	68	5.44	0.31	0.32	1.35	3.94	0.34	13.30	30.20	28.063	5.81	57.24	21.01	71.79	30.15	0.084	44.72	280.18	22.13

DF: degree of freedom, PH: plant height (cm), TP: number of tiller per plant, SL: spike length (cm), SPS: spikelet per spike, GPS: grain per spike, GY; grain yield, Fe: Iron, Zn: zinc, RWC: relative water content, Pro: proline, CTD: canopy temperature depression, RWC: relative water content, CMS: cell membrane stability, LA: leaf area, 1000GW: thousand grain weight, OSP: osmotic potential, DHARABI-11: days to heading, DA: days to anthesis, DM: days to maturity. * Significant effect at 0.05 probability

3. Results and Discussion

3.1. Parental and Hybrid Genetic Variability.

The analysis of variance revealed a significant genotypic influence for all of the studied variables. This enables a more in-depth examination of general combining ability studies, revealing ample genetic diversity across lines, tests, and hybrids. As shown in Table 2.

3.2. General and Specific Combining Ability Effects

Upon analysing the data about the days to heading and 1000-kernel weight, it was found that the mean squares attributed to lines and testers indicated that additive genetic impacts were the predominant factor of relevance. The analysis of mean squares for plant height, spike length, fertile tillers, number of grains per spike, and grain yield indicated that both additive and non-additive gene actions played a role in the genetic control of these traits. Similarly, the analysis of spike length, number of grains per spike, plant height, fertile tillers, and grain yield revealed that both additive and non-additive effects were seen in the mean squares due to lines x testers and lines x testers.
A strong negative connection was seen between Borlaug, Dharabi-11, FSD 2008, 11170, and 11238 GCA for grain yield in both the lines and the tester. 11280 introduced Galaxy, FSD 08, and the testers 11170, 11238, and 11280 GCA, resulting in a significant increase in the amount of grains each spike. Table 3. The combiner with the most favourable GCA effects for 1000-kernel weight, number of viable tillers per plant day, and heading is 11280, with GCA effects of 1.97, 0.345, and 3.50, respectively. 11280 is a very efficient universal combiner for reducing plant height. Table 3 demonstrates that the negative

impact of GCA on plant height is beneficial for the growth of shorter plant material. Tester11238 shown a significant and negative genetic association with the duration of time before flowering. This tester is an excellent tool for effectively shortening the duration of the vegetative development phase. Borlaug, Dharabi-11, and FSD 2008 have a detrimental general combining ability (gca) for Iron (Fe) content, but Aas11 and Galaxy indicate a favourable and significant outcome.11135, 11156, and 11238 exhibit a noteworthy and statistically significant concentration of iron. Aas -11 has a very significant positive overall combining ability effect. The male parents with the numbers 11135 and 11170 had a considerable negative general combining ability (gca) content, resulting in the same conclusion.

The GCA estimates for lines 11238(1.8.8) and 11238(1.332) were the most positive. Among the tests, Aas-11 had the highest proline concentration of 0.781. The GCA estimations for canopy temperature depression were highest for Lines Galaxy (0.486), and lowest for Aas11 and Borlaug (-0.605 and -0.536, respectively). An elevated general cognitive ability (GCA) of 0.678 was identified in a sample of 11,280 male parents. Galaxy (16.91) and tester 11238 (28.191) had the greatest negative GCA estimates. Among the lines evaluated, Borlaug and Aas11 had the lowest estimated values for leaf area, with measurements of 2.507 and 1.634, respectively. On the other hand, lines 11156 and Aas-11 had the greatest estimated values, measuring 2.020 and -1.243, respectively. Lines DHARABI-1111 had the highest positive forecasts, as shown by a maturity GCA estimate of 1.227. The testers maintained the high GCA estimates of 11170 (1.370).

The lines 11238(1.8.8) and 11238(1.332) had the greatest positive GCA estimations, whereas the tester Aas-11 (0.781) had the highest concentration of proline. Regarding the estimates for canopy temperature depression GCA, Lines Galaxy had the greatest positive value (0.486), whilst Aas11 and Borlaug displayed the most negative values (-0.605 and -0.536, respectively). A total of 11,280 male parents were identified with a high gca (general combining ability) value of 0.678. The GCA estimations with the greatest negative values were discovered between the lines Galaxy (16.91) and tester 11238 (28.191). The GCA estimations of leaf area indicate that lines Borlaug and Aas11 had the lowest estimates, measuring 2.507 and 1.634, respectively. Conversely, lines 11156 and Aas-11 exhibited the highest estimations, with values of 2.020 and -1.243, respectively. The lines DHARABI-1111 showed the most optimistic estimations, with a maturity GCA estimate of 1.227. The testers found that the high GCA estimations of 11170 (1.370) were maintained, as shown in Table 4.

According to Kanga et al (2004), the combination of features with high average values, positive special combining ability (SCA) estimations, and at least one parent with high general combining ability (GCA) is likely to result in the accumulation of beneficial alleles, hence enhancing desired qualities.During the current study, it was shown that 11135 had a notable and unfavourable impact on spike length due to its General Combining Ability (GCA). On the other hand, galaxy had a strong GCA effect on spike length, which was negative for spike length but positive for days to heading (Table 3). The Borlaug x11156 hybrid's parents had significant and undesirable General Combining Ability (GCA), resulting in a beneficial impact on spike length via Specific Combining Ability (SCA). This hybrid had a favourable overall combining ability (GCA) for days to maturity from one parent, but showed an unfavourable specific combining ability (SCA) for this trait. Tables 4 and 5. The Aas-11× 11156 variety had a notable and positive effect on the number of productive tillers per plant due to its high SCA impact. One of the parent plants, As11, has a notable and unfavourable General Combining Ability (GCA) in terms of the number of fertile tillers. Aas-11× 11238 had a notable impact on several plant characteristics. It had detrimental impacts on plant height, spike length, and fertile tillers, while having beneficial effects on 1000-kernel weight and the quantity of grains per spike (Table 3). Regarding plant height and the number of grains per spike, both parents involved in this cross, 11280 and Aas11, exhibited considerable General Combining Ability (GCA). However, when considering days to heading (FSD-2008), spike length, and number of fertile tillers, at least one parent, 11170, shown strong GCA. Table 4.

This hybrid plant is unusual because it combines the reduction in height with an increase in both the weight of the 1000-kernel plant and the amount of grains produced by each spike. Furthermore, this combination of crosses has the drawback of reducing the number of fertile tillers, which plays a crucial role in determining the quantity of grain produced (Adjabi et al., 2007). This is a drawback that arises in semiarid agricultural environments. Based on the 11135 Galaxy cross combination, the statistical analysis shows that there is a substantial and positive correlation between the plant height and weight per 1000 kernels. This cross is the most efficient specialised combiner for increasing plant height and kernel weight by a factor of one thousand. Conversely, the variety 11135x Borlaug had a significant and advantageous effect on the number of kernels per spike, while also having a significant and detrimental impact on the number of days before flowering and the plant's height. This specific cross, identified as the top specialised combiner (Table 3), has the ability to reduce the duration of the vegetative phase, enhance plant height, and improve the number of spikelets generated per spike. The absence of any discernible impact of SCA on grain production in all hybrid varieties indicates that despite significant variations in the grain yield of the parent plants, successful hybridization was achieved. Both 11156 X Borlaug (4.80) and 11135 X Aas-11 (4.26) have the highest estimated values for their iron Specific Combining Ability (SCA) when compared to other crosses. Parents Borlaug had significant positive general combining ability (GCA), Aas-11 exhibited little GCA, and the male parent showed negative GCA. Both crosses showed an adverse genetic correlation (sca) regarding plant height and a favourable genetic connection about days to maturity. This instrument is also the most effective for enhancing iron concentration. Positive significant correlations were observed for 100 grain weight in the crosses 11280 x FSD08, 11156 x Dharabi-11, and 11156 x FSD08. However, negative correlations were found for plant height, spike length, and tiller per plant. The crosses shown a detrimental specific combining ability in relation to the number of days required for maturity. Nevertheless, under semiarid settings, this process of hybridization leads to a reduction in the number of productive tillers, hence having a substantial effect on grain output. These methods effectively combine elevated zinc levels with enhanced grain yield while also decreasing the vegetative growth period. None of the crosses had a significant amount of proline. (Ahmad et al., 2019).

3.3. Gene Action.

The functions of dominance and heterosis, heredity, and total variation are significant factors to consider. Table 6 demonstrates that nonadditive gene activity is the primary factor in defining these qualities, since the variation attributed to general combining ability (gca) exceeds the variance attributed to specialised combining ability (sca) for all assessed characteristics. The disparity between dominance and additive genetic variance for each attribute was more pronounced. Table 6 demonstrates that these findings are substantiated by a degree of dominance (D/A) more than one-half and a ratio of general to specific combining ability (gca/sca) variance less than one. The inheritance of all the traits that were evaluated was mostly determined by nonadditive gene effects. This gene activity clearly indicates that the most favourable plants in terms of grain production, plant height, fertile tillers, and length of vegetative development phase should be preserved for the subsequent generation. By selecting among recombinants in distinct populations, these qualities may be enhanced. There is a correlation between the level of heredity and the efficacy of selection. The investigation revealed low estimates of broad-sense heredity for grain output and spike length, moderate estimates for the number of fertile tillers per plant, and high estimates for plant height, 1000-kernel weight, and number of grains per spike (Table 6).

Heterosis, also known as hybrid vigour, refers to the phenomenon when an offspring of two different parents (F1 individual) exhibits superior performance compared to the average performance of its parents. Out of the total of twenty-five hybrids, nine showed a notable increase in grain yield compared to their average parents. The hybrid 11280 x FSD08 demonstrates heterosis in terms of grain production. Table 7 shows significant heterosis in the number of days to heading, spike length, and viable tillers in the 11135 and Aas-11 varieties. According to Table 7, the hybrid 11280xFSD08 had the highest level of heterosis for grain yield. Additionally, it showed positive heterosis for the number of viable tillers and spike length, but negative heterosis for the 1000-kernel weight and the number of days before heading. The Aas-11 x 11156 hybrid had significant and favourable heterosis for both the number of grains per spike and spike length, in addition to grain yield heterosis. However, it displayed unfavourable heterosis for the number of days until heading, as shown in Table 7. The FSD2008 x11135 hybrid exhibited significant and advantageous heterosis for the quantity of grains per spike, spike length, and plant height, as seen in Table 7. The hybrid 11315 x Dharabi 11 showed significant positive heterosis in terms of relative water content, cell membrane integrity, and proline concentration.11135 x FSD08 exhibits substantial increases in iron, zinc, and spikelets per spike. The total sum square was mostly impacted by the following factors: plant height, number of grains per spike, number of days to maturity, iron and zinc concentration, cell membrane stability, relative water content, and proline content. Lines' contribution was inferior to that of testers, as well as the combined contributions of both groups, for all the characteristics examined. The average number of fertile tillers generated by a plant was equally affected by all three sources of variance. Table 8 indicates that the impact of the interaction between line and testers on grain output and spike length was somewhat more significant than the combined effect of testers and lines. The findings demonstrated significant variation in the expression of the evaluated features based on the tests conducted and the interaction between different lines and testers. The findings indicated a substantial difference between hybrids and parents for each of the sixteen criteria that were examined. The hybrid exhibited superior height, tiller efficiency, and grain production compared to its parental varieties. The Galaxy line and 11135 tests yielded a substantial amount of grain. The lines exhibited a reduced weight of 1000 grammes and a higher grain count per spike compared to the testers. However, they were characterised by shorter stature and lighter weight. The average values of the hybrids were similar to or fell within the parental averages for heading date, plant height, spike length, and grain production per spike. The grain yield values of the parents were lower than those of the offspring resulting from the cross between Galaxy and FSD08 X11135.

The concurrent significance of mean squares associated with lines, testers, and lines testers for different plant qualities suggests the existence of both additive and nonadditive gene activities in the genetic regulation of these features. The Aas-11 line and the tester 11135 shown strong compatibility in terms of the grain count per spike. The galaxy is a proficient amalgamator for the 1000-kernel weight and the amount of fruitful tillers. Aas-11 exhibits efficacy in decreasing plant height, whereas tester 11156 demonstrates efficacy in abbreviating the duration of vegetative growth. The Galaxy × 11135 hybrid exhibited significant effects of specific combining ability (SCA) on both the duration of heading and the length of the spike. This hybrid combination is optimal for choosing offspring in the early stages of development.

In conclusion.

The hybrids of Aas-11135, Borlaug x11516, and FSD 2008 x 1135 exhibited a higher average grain yield compared to their respective parents. The presence of both additive and nonadditive gene effects was verified using the ratios of 2 gca/2 sca, (2 D/2 A) 1/2 low, and low to intermediate estimations of H2 Bs. Nevertheless, the occurrence of nonadditive gene actions was more widespread than that of additive gene actions. The testers and interaction lines testers made the greatest contribution to the diverse appearance of various qualities. Both the Aas-11 line and the tester 11135 were efficient in combining the number of grains generated by each spike. Galaxy is an extraordinary combiner when it comes to merging 1000 kernels and a significant number of fertile tillers. 11156 is an excellent general combiner that has the potential to abbreviate the vegetative development phase, whereas Dharabi is an impressive general combiner that may decrease the plant's height. The Dharabi x 11156 combiner is very successful in reducing plant height, increasing the weight of 1000 kernels, and enhancing the quantity of grains per spike. Galaxy x 11135 is the most effective combination for achieving a shorter vegetative period, taller plants, and a higher number of kernels per spike. Aas-x11135 had the highest level of heterosis in terms of grain yield, along with positive heterosis in spike length and number of fertile tillers, and negative heterosis in 1000-kernel weight and days to maturity.The combination of 11280 x FSD 2008 is very effective in improving iron and zinc levels. The prevalence of nonadditive gene activity made it evident that prioritising advancements in plant selection in the future generation is necessary.

Table3 Effects of general combining ability (gi) on characters in wheat parents.

Parents	PH	TP	SL	SPS	GPS	GY	Fe	Zn	Pro	CTD	RWC	CMS	LA	100G	OSP	DM
AAS-11	0.973*	0.071	0.231*	-0.108	-0.82	0.071	0.69*	3.31*	0.78	-0.60*	-14.2	7.790	-1.63	1.64	-	-0.30
BORLOUG	-0.94*	0.044	-0.015	0.079	-0.93	-0.081	-1.64	-1.99	-0.73	-0.5*	22.43-	-0.38	-2.50	1.42	0.064	-0.30 1.22
DHARABI-	0.28	0.178*	-0.235	0.145*	0.28	0.271*	-0.35	0.39	-0.68	0.30	14.7	14.54	0.00	-.157	0.060	0.02
11	-0.80*	-0.250	-0.348	-0.088	0.85*	-0.229	-3.67	-2.30	0.625	0.35	23.74	-4.96	1.20	-0.13	.0809	-0.64
FSD08	0.48	-0.043	0.367*	-0.028	0.62*	-0.032	4.98*	0.644	0.010	0.48*	-17.2	-16.9	2.87	-0.79	-0.05	0.85
GALAXY	0.60	0.14	0.10	0.21	0.36	0.10	0.66	1.033	0.96	0.44	16.99	8.50	1.54	1.002	0.086	
gi															0.52	
11135	-0.806	0.345	0.160	0.152	0.172	-0.07	0.726	2.502	0.748	0.226	15.15	3.066	0.375	.385	-0.06	0.160
11156	0.756	0.154	0.020	-0.075	0.247	0 -0.1	0.331	0.476	0.152	0.408	-12.56	19.059	-2.020	0.197	-0.05	0.227
11170	0.670 -	-0.239	-0.366	0.092	-	-0.065	-1.205	-2.758	-1.072	0.041	23.62	9.210	4.166	-1.769	0.01	1.360
11238	1.169	-0.089	0.246	-0.001	0.912	0.036	1.159	0.267	1.808	-0.001	-13.28	-	-1.550	-0.783	0.02	-0.573
11280	0.549	-0.172	-0.060	-0.168	0.439	0.176	-1.010	-0.488	-1.332	-0.67*	-12.930	28.911	-0.970	1.970	0.08	-0.173
Gt	0.42	0.10	0.14	0.30	0.054	0.15	0.94	1.40	1.36	0.662	15.66	-2.424	2.17	1.41	0.74	1.21
					0.51							12.02				

DF: degree of freedom, PH: plant height (cm), TP: number of tiller per plant, SL: spike length (cm), SPS: spikelet per spike, GPS: grain per spike, GY; grain yield, Fe: Iron, Zn: zinc, RWC: relative water content, Pro: proline, CTD: canopy temperature depression, RWC: relative water content, CMS: cell membrane stability, LA: leaf area, 1000GW: thousand grain weight, OSP: osmotic potential, DHARABI-11: days to heading, DA:

Table: 4. shows the percentage of significant mid-parent heterosis for variables in bread wheat genotypes.

Parents	PH	TP	SL	SPS	GPS	GY	Fe	Zn	PRO	CTD	RWC	CMS	LA	1000GW	OSP	DM
11135X Aas-11	-5.71	13.74						3.40	4.70		408.21	334.13	-18.96	11.34	-75.74	
11135xBorloug	-3.76	0.14	2.15	4.05					21.22		-19.23	-70.99	-9.48		-60.59	
11135xDharabi-11	-2.09		4.42				41.20	16.6			-28.79	24.83	-18.38		-62.92	
11135X FSD08	-2.76		9.40	1.29							20.69	-10.35	-5.144	5.53	-59.40	
11135x Galaxyi				5.09	0.61					-37.16	-29.45	-15.86	-25.59	8.81	-53.28	-2.52
11156xAas-11	2.60	20.31			3.44	4.012			5.16	-5.21	-18.42	-15.80	-8.03		-74.27	-0.11
11156xBorloug	5.94	9.80				3.26		5.98		-1.28	-25.78	-21.83	-7.12		-60.42	-0.68 -1.94
11156xDharabi-11	2.31	3.49		1.18	1.13	6.16			79.45	-29.77	-12.89	-25.14	3.921		-50.81	-14
11156xFSD08	4.73		3.91					20.3		-40.89	-32.22	47.59	3.782		3.48	-1.72
11156xGalaxy	-3.34		2.02	2.62						11.08	-4.34	116.75	4.04		-16.49	-3.16
11170xAas-11	0.80	6.3					53.97		31.33	-13.66	-11.14	60.160	13.23		32.97	-2.98
111570xBorloug	-4.94	10.54			0.32					-42.29	-28.71	63.87	-9.56	2.30	-62.90	-2.28
11170xDharabi-11	2.21			0.52	2.93		39.25	11.3	90.99	-12.04	-13.84	85.380	-9.08		-6.32	
11170xFSD08	1.99	0.62		1.23						-34.78	24.81	25.38	-24.94	4.21	-56.71	-0.69
11170xGalaxy	2.81		2.38				61.76	24.7	25.24	-9.031	10.78	-36.86	1.94		232.35	-1.60
11238xAas-11	2.50	1.12	2.48				34.27	-13.		-53.36	10.81	8.85	4.15		-11.41	
11238xBorloug	-1.23							2.26		-6.51	-0.46	16.34	-3.21	10.95	261.58	
11238xDharabi-11								11.0		-42.09	13.54	49.66	-9.21	5	1.23	
11238xFSD08		5.55						0.03		-11.99	4.38	44.90	-10.40	9.83	-63.81	
11236xGalaxy		3.97						13.6	13.92	8.84	40.96	-12.98	9.98		4.51	
11280xAas-11																
11280xBorloug																
11280xDharabi-11																
11280xFSD08						12.99										
11280xGalaxy						10.22										

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