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Research Article

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BIOMETRICAL ANALYSES OF ELITE WHEAT VARIETIES USING HALF DIALLEL METHOD IN HEXAPLOID WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Wheat is a major food grain crop grown around the world. Its importance lies in its grain quality and yield production towards various genotypes. The present research was conducted to assess genotypes at two locations viz. Barley and Wheat Research institute Tando Jam and Wheat Research institute Sakrand. This experiment was conducted under 6 x 6 half-diallel fashion design using six wheat parents as TD-1, TJ-83, Imdad-2005, Moomal-2002, SKD-1, and Mehran-89. The results showed that TJ-83 revealed early 75% heading and maturity. However, the genotype TD-1 provoked markable performance for different characters in both locations, including tillers plant^{-1}, spikelet's spike^{-1}, grains spike^{-1}, grain yield plant^{-1}, 1000 grain weight, and harvest index. Among F_1 hybrids, including TJ-83 × Moomal-2002 and TD-1 × TJ-83, displayed favorable characteristics, with the hybrid Imdad-2005 × Mehran-89 contributing more tillers plant^{-1} and TD-1 × Mehran-89 having longer spikes. For GCA effects, TD-1 demonstrated negative effects for heading and maturity revealing positive effects for other key traits, making it a promising parental material for improved wheat cultivar development. The cross TD-1 × TJ-83 proved positive SCA effects for distinctive characteristics. Correlation analysis depicted positive associations between spike length, spikelet's spike^{-1}, grains spike$^{-1,}$ and grain yield plant^{-1} underscoring their importance in high-yielding wheat cultivar development. Traits exhibited high heritability estimates, suggesting strong genetic control and early-generation improvement possibilities. Gene action analysis revealed an overall type of dominant gene action, confirming an over-dominant type for most traits. The concise findings indicate that the research provides valuable insights for enhancing wheat breeding programs, identifying superior genotypes, and understanding their desirable responses under diverse environmental conditions.

Keywords: Combining ability, Grain yield, Specific combining ability, Hexaploid wheat

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INTRODUCTION

Triticum aestivum L. is a hexaploidy wheat grown for grain purposes in Pakistan and contributes 72% of calories and protein in the human diet providing a primary food source for over one-third of the population. Wheat plays a significant role in the agricultural sector, contributing 11.36% to value-added and 2.0% to Pakistan's (Adel *et al*., 2013). With a production of 25482 thousand tons, cultivated over 9260 thousand hectares, and a yield of 2752 kg/ha, wheat faces challenges such as competing crops and water scarcity (GDP 2022-23). Cultivation of wheat area is a valid solution for increasing production, boosting yield, and other characteristics for grain quality. Diverse technologies may be used for achievable high-yielding wheat varieties and advanced management techniques (Adhikari *et al*., 2020). The combining ability studies and heterotic effects will provide suitable high-yielding wheat cultivars by crossing efficient genotypes (Schwarzwälder *et al*., 2022). Genes play a pivotal role in expressing beneficial traits and influencing breeding strategies (Thapa *et al*., 2019). Genetic diversity in wheat offers opportunities for creating superior genotypes through crossbreeding, emphasizing the importance of comprehending genetic factors governing yield components (Ali *et al*., 2009; Al-jana *et al*., 2020; Bagherikia *et al*., 2023). Researchers highlight combining ability effects, indicating the additive and non-additive genetic variances in manipulating yields (Zare-Kohan and Heidari, 2014; Rajput *et al*., 2018). The diallel mating design, commonly used for estimating general and specific combining ability, involves the same set of parents as both males and females (Pagliosa *et al*., 2017). General combining ability represents average performance in crossbreeding, while specific combining ability indicates instances where hybrids perform differently than expected based on parent averages. In hybrid crop improvement, specific combining ability is significant, while general combining ability guides hybridization and selection programs (Bagherikia *et al*., 2023; El Nahas *et al*., 2021; El Ameen *et al.*, 2020). Understanding the inheritance pattern of various cultivars is useful to provide genotypes through the efforts of breeders to discover new recombinants with potential yield and yield characters. The direct crosses using male and female parents, using the diallel mating design will support to find genetic combining ability of the parents and specialized combining ability through crosses. GCA reflects better performance in crosses, while SCA identifies instances where hybrids surpass or fall short of expectations. SCA plays a pivotal role in hybrid crop improvement, while GCA guides hybridization and selection programs (Chaudhary *et al*., 2023). The main aim of this research was to produce wheat genotypes that would be useful for meeting the demands of a growing population. The characterization through morphological and genetic analysis will support the research to bring useful material for increasing per unit area of wheat. Griffing's (Askander *et al*., 2021) methods will help us to assess the best combiners through additive and non-additive gene action and help in selecting appropriate genotypes of wheat, which would enhance yield production. Research by Hassan et al. (Burdak *et al*., 2023) and Anonyms (Chaudhary *et al*., 2023; Dedaniya *et al*., 2018; Devidas *et al*, 2015) revealed that plant parameters are influenced by both additive and non-additive gene effects. This study investigates the heritability and correlation of essential yield and yield components in wheat genotypes, aiming to understand the relative contributions of genetic and environmental factors to phenotypic variances in various morphological traits. Heritability analysis estimates the proportion of phenotypic change attributable to genetic factors, distinguishing them from environmental influences. Moreover, combining abilities of parents and hybrids will be evaluated in wheat genotypes.

MATERIAL AND METHODS

The present research was conducted at two locations, Wheat Research Institute Sakrand and Barley and Wheat Research Tando Jam during the Rabi season 2018-19. The experiment was laid in a factorial design (RCBD) with four replications using a diallel design. For this six diverse bread wheat elite varieties viz., TD-1, TJ-83, Imdad-2005, Moomal-2002, SKD-1, and Mehran-89 were used to attempt 6x6 half-diallel crosses as F_1 hybrids :TD-1 × TJ-83, TD-1 × Imdad-2005, TD-1 × Moomal-2002, TD-1 × SKD-1, TD-1 ×Mehran-89, TJ-83 × Imdad-2005, TJ-83 ×Moomal-2002, TJ-83 × SKD-1, TJ-83 × Mehran-89, Imdad-2005 × Moomal-2002, Imdad-2005 × SKD-1, Imdad-2005× Mehran-89, Moomal-2002 × SKD-1, Moomal-2002 ×Mehran-89 and SKD-1 ×Mehran-89

The characters days to 75% heading , days to 75% maturity, plant height (cm), peduncle length (cm), internode length (cm), number of tillers plant^{-1}, spike length (cm), number of spikelets spike^{-1} , number of grains spike^{-1}, grains yield plant^{-1} (g), 1000 grain weight plant^{-1} (g), and harvest index (%) were the variables that were observed.

Statistical Analysis

Analysis of Variance: As per Steel and Torrie's (1960) observation, analysis of variance, as per statistical framework, was employed to sort out the data on wheat genotype's yield-associated traits.

Yijk = u+pi+xj+yij+Bk+(xB) jk+Σ ijk

Dialel and Gene Analysis

Griffing's Method-2Model-1=n (n-1)/2 = parents + F_1 hybrids (Griffing, 1956)

Combining ability effects

Yij = u+gi+gi+sij+rij 1/bc ΣΣeijkl.

SS because of GCA = 1/n+2[Σ(Yi.+Yii)2 - 4/n Y2..].

SS because of CA = ΣΣ Yij2 - 1/n+2Σ (Yi.+Yii)2+2/(n+1)(n+2)Y2..

S.S. because of error = SS Error/r.

Estimation of component of variance

σ2g = 2/n+2(Mg – Me)

σ2s = Ms – Me

σ2e = Me

σ2s and σ2e are the estimates of variances.

GCA and SCA effects are as under: -

gi= 1/n+2[Σ(Yi.+Yii) -2/n Y..]

sij = Yij – 1/n+2(Yi.-Yii+Y.j+Yjj) + 2/(n+1)(n+2)Y:.

Heritability Estimates

Broad sense heritability on a mean basis was established from variance components as under:

$$H2 = \frac{\sigma^2 G}{\sigma^2 p + \sigma^2 e/r}$$

Phenotypic Correlation

The common formulas used to determine the relationship between physiological and yield attributes are as follows.:

$$r = \sqrt{\frac{\left[\sum xy - \frac{(\sum x)(\sum y)}{n}\right]^2}{\sum x^2 - \frac{(\sum x)^2}{n} \sum y^2 - \frac{(\sum y)^2}{n}}}$$

RESULT AND DISCUSSIONS

The results exhibited significant variation among various characters observed in both the locations (Wheat Research Institute Sakrand and Barley and Wheat Research Tando Jam) and the analysis of variance (ANOVA) declared that the parents and hybrids recorded highly significant at p≤0.01 probability level approximately to all the traits, significantly impacted by locations, according to mean squares obtained from analysis of variance (Table 1 and 2).

The yield and other components contributed to genetic variation among genotypes and interaction within locations, showing that there was substantial interaction between both. This research may lead to better hybrids and parents for choosing and selecting potential cultivars through the breeding program. Hence, these results having better yield through morpho-yield characters agree with the findings of many researchers (Kutlu & Olgun, 2015; Mohammadi *et al.*, 2019*;* Rajput *et al*., 2018; Raiyani *et al*., 2015).

Table 1. Analysis of variance for distinctive quantitative traits associated with 6x6 half-diallel fashion at Tando Jam

Source of variance	**Replication D.F. =3**	**Genotypes D.F. =20**	**Parents (P) D.F. =5**	**Hybrids (H) D.F. = 14**	**Error D.F. =60**
Days to 75% heading	0.286	175.260**	85.90**	160.30**	0.936
Days to 75% maturity	1.143	160.183**	135.85**	190.23**	0.993
Plant height	2.767	198.250**	110.00**	230.65**	2.165
Peduncle length	1.732	46.363**	35.68**	40.60**	0.641
Internode length	8.569	50.904**	40.85**	32.69**	2.268
No.of tillers plant^{-1}	1.409	16.136**	100.90**	108.90**	0.367
Spike length	0.048	5.677**	49.10**	85.95**	0.376
No. of spikelets spike^{-1}	3.936	19.757**	45.85**	25.63**	0.969
No. of grains spike^{-1}	2.900	54.475**	320.85**	310.80**	0.592
Grain yield plant^{-1}	8.361	28.845**	300.50**	450.10**	3.807
1000 grain weight (g)	0.706	24.579**	170.45**	189.85**	1.294
Harvest index (%)	2.424	22.572**	198.60**	210.60**	1.799

**, * Significant at p<0.01 and 0.05 and non-significant=ns

Table 2. Analysis of variance for various quantitative traits of 6x6 half-diallel genotypes at Sakrand

Characters	**Replication D.F. =**	**Genotypes D.F. =**	**Parents (P) D.F. =**	**Hybrids (H) D.F. =**	**Error D.F. = 60**
Days until 75% heading	0.552	154.779**	230.65**	242.10**	0.652
Days until 75% maturity	0.476	141.629**	190.63**	185.00**	0.676
Plant height	1.924	171.334**	195.68**	210.10**	0.500
Peduncle length	0.996	43.502**	45.69**	55.90**	0.448
Internode length	0.582	52.503**	36.90**	48.10**	0.482
No. of tillers plant^{-1}	3.317	15.332**	210.16**	225.10**	1.359
Spike length	0.074	7.959**	77.63**	80.95**	0.303
No. of spikelets spike^{-1}	2.222	11.222**	30.78**	39.65**	2.031
No. of grains spike^{-1}	2.365	64.253**	215.18**	225.63**	1.390
Grain yield plant^{-1}	4.249	41.449**	210.33**	310.11**	0.841
1000 grain weight (g)	9.317	24.972**	180.59**	190.65**	2.672
Harvest index (%)	2.381	22.082**	200.98**	211.00**	0.406

**, * Significant at p<0.01 and 0.05 and non-significant=ns

Combining Ability analysis for various quantitative traits in *Triticum aestivum* L.

Days to 75% heading: Tando Jam and Sakrand environments showed negative general combining ability (GCA) for days to 75% heading in the genotypes TD-1 and TJ-83 resembling desirable characters conferring yield. Resultantly, hybrids: TJ-83 x Mehran-89 and TD-1 × Moomal-2002 also possessed negative SCA effects for the same character (Table 2). Many researchers found similar results and conveyed that negative GCA and SCA may be considered positive and desirable effects on yield (El-Nahas & Ali 2021; Ijaz *et al*., 2017).

Days to 75% maturity: Moomal-2002 and TD-1, distinctly different parents, resulted in negative GCA effects, (Table 2) resembling desirable effects in the wheat crop. The unfavorable SCA effect on hybrids of F_1, including TJ-83 x Mehran-89 and iImdad-2005 × SKD-1, during days until 75% maturity under the Tandojam area and localities of Sakrand.

At both locations, Moomal-2002 and TD-1, the parents, showed adverse GCA effects up to 75% maturity days (Table 2). The SCA had a negative impression for days until 75% maturity of F_1 hybrids such as TJ-83 x Mehran-89 and Imdad-2005 × SKD-1 under the Tandojam area and Sakrand locations. The results corroborated those of (Griffing 1956; Ijaz & Kaukab *et al*., 2017; Kaukab *et al*., 2013; Kamaluddin *et al*., 2011; Kamal *et al*., 2023).

Plant height (cm): At both locations, I–II, hybrids like SKD-1, TJ-83, and TD-1 observed GCA tilted towards negative impacts for the height of the plant (Table 2). The hybrids of F_1, eImdad-2005 x iSKD-1, on the other hand, saw the greatest SCA impact for plant height at both sites (Table 5). According to various researchers (Ljubičić *et al*. 2016; Dedaniya *et al*. 2018; Nagar *et al*., 2019; Bagherikia *et al*., 2023) both additive and non-additive gene effects were recorded.

Peduncle length (cm): Positive GCA effects were shown by Moomal-2002 and Imdad at both SKD-1 and TD-1 cultivars' GCA effect was tilted towards the negative aspect of the peduncle length (Table 2). Eight F_1 crossings and F_1 hybrids of five showed SCA effects toward positivity directly to the length of the peduncle at location II (Sakrand) as well as at location I (Tandojam), respectively. The Imdad-2005 × SKD-1, TD-1×Imdad-2005, and TD-1× Mehran-89 were the top scorers. For early maturing wheat cultivars, peduncle length is an important morphological characteristic, and breeders usually choose plants with longer peduncles. Our data support the impact of additive gene activity on this characteristic, as reported by Hassan *et al*., 2007 and Farooq *et al*., 2010.

Internode length (cm): When it came to GCA impacts were negative for this trait, SKD-1, Moomal-2002, TJ-83, and TD-1 parents, while Imdad and Mehran-89 hybrids reflected favorable effects related to GCA (Table 2 mentioned). For the internode length impacts of SCA, they were largest for F_1 hybrids TD-1 × SKD-1 and TJ-83 × SKD-1 at sites I - II respectively. Previous research by Sharma *et al.,* (2022) and Kaur *et al*., (2022) showed a favorable relationship between plant height and different internode lengths, with peduncle length playing a major role in determining overall plant height.

Number of tillers plant^{-1} : A critical yield feature that directly affects grain yield is the tillers plant^{-1}SKD-1 and Moomal-2002 portrayed GCA impacts as negative for tillers plant^{-1} at respective localities, whereas TJ-83, TD-1, Imdad-2005, and Mehran-89 were tilted towards optimistic GCA effects (Table 2). Tables 3a, 3b, and Table 4a, 4b show that at both locations, the F_1 hybrids Imdad-2005 × Mehran-89 and TD-1 × TJ-83 portrayed the largest SCA impact in this trait. The results, indeed, are consistent with researchers (Kumar *et al*., 2018; Kutlu & Olgun, 2015; Ljubičić *et al*., 2021).

Spike length (cm): Wheat spikes have a major impact on grain output overall and are essential for yield. At location I– II, hybrids: Moomal-2002, SKD-1, and TJ-83 displayed adverse impacts concerning GCA for spike length, However, positive GCA effects were demonstrated by TD-1, Imdad, and Mehran-89 (Table 2). SKD-1, TJ-83, and Moomal-2002 all showed favorable GCA effects during the spike length. And of all F_1 hybrids, five in numbers exhibited effects with negative SCA effects. F_1 hybrids, thirteen in number, showed SCA effects aligned towards positivity related to the length of the spike at both locations I-II. Our findings confirm those of other studies by (Mahdiyeh & Bahram 2014; Hassan *et al*., 2018; Mohammad & Khalil, 2017; Natasa *et al*., 2016).

Number of spikelets spike^{-1}: Imdad-2005 altogether with TJ-83, TD-1, and Mehran-89, the varieties of wheat, at a number of spikelet's spike^{-1} had positive GCA effects for the number of spikelets, but Moomal-2002 along with the hybrid SKD-1 showed negative influences related to GCA. Imdad-2005, TJ-83, TD-1, SKD-1, Mehran-89, and Moomal-2002 demonstrated negative GCA effects at site II (Table 2). Spikelets spike^{-1} for Tando Jam, the F_1 hybrids, nine in numbers, exhibited SCA effects in terms to positive and six in terms to SCA impacts were negative. Ten F_1 hybrids at site II displayed SCA effects with a positive bent for the no. of spikelets spike^{-1}, whereas five showed negative SCA effects. At Tando Jam, the cross of F_1TD-1 × TJ-83 resulted in highest effects of SCA, whereas the cross TJ-83 × Moomal-2002 showed fewer impacts related to combining ability. Our results are in agreement with those of Zare-Kohan & Heidari, 2015 and Pagliosa *et al*., 2017.

Number of grains spike^{-1}: Negative GCA effects for grains spike^{-1} were demonstrated by TJ-83, Moomal-2002, and SKD-1 at both locations. Imdad-2005, TD-1, and Mehran-89 all had favorable GCA effects (Table 2). Six of the nine F_1 hybrids showed negative SCA effects for grains spike^{-1} at both locations, while nine had favorable effects on SCA. The results indicate that the F_1 hybrid TJ-83 × Moomal-2002 exhibited greater SCA effects for this trait at Tandojam, whereas the hybrid TD-1 × TJ-83 showed the highest SCA effects for this trait at

Sakrand. According to Sami-ul-Allah *et al*.,2010; Nagar *et al*., 2019; Saeed *et al*., 2017; Poudel *et al*., 2021, our results are consistent with their research.

Grain yield plant^{-1} (g): Mehran-89, Imdad-2005, and TD-1 were the cultivars with the strongest GCA effects for grain yield plant^{-1} at site 1 and location II. On the other hand, TD × TJ-83 had the largest influence on SCA for grain yield plant^{-1} in both the Sakrand and Tandojam locations (Table 2). These findings were supported by many researchers (Thapa *et al*., 2019; Schwarzwälder *et al*., 2022).

Seed index (g): Higher GCA effects were found by Mehran-89 and TD-1, and at location II by SKD-1, TJ-83, and Moomal-2002. In terms of seed index at location, I (Tandojam) and Position-II (Sakrand) for TD-1 × TJ-83, the hybrid TJ-83 ×Moomal-2002 showed the highest SCA (Table 2). Our results agreed with those of (Mohammadi *et al*., 2019; Saeed *et al*., 2017; Raiyani *et al*., 2015).

Harvest index (%): At both locations, the harvest index (%) showed the largest GCA effects for Moomal-2002, TJ-83, and TD-1. At locations I–II, the F_1 hybrids TD-1 × TJ-83 displayed greater GCA SCA impacts related to the respective parameter (Schwarzwalder *et al*., 2022; Kalhoro *et al*., 2015; Mohammadi *et al*., 2019; Rajput *et al*., 2018). All things considered, our findings are in line with those of Kumar *et al.,* (2018), who likewise noted increased GCA and SCA impacts in wheat genotypes for different attributes. These researchers include (Ljubičić *et al*., 2016; Dedaniya *et al*., 2018; Pagliosa *et al*., 2017; Poudle *et al*., 2021)

Correlation among morphological and yield traits: Correlation analysis was observed to have plant height with significant and positive association (r=0.227**) along with correlation coefficient r^2= (0.975) and b=0.360, respectively (Figure.1). Peduncle length showed significant and positive correlation as (r=0.32**) having correlation coefficient as r^2=0.571 and b=0.865, resembling peduncle increases photosynthesis hence providing good yield towards more reproductive traits (Figure. 2). Similarly, internode length showed a correlation as r=0.19** yield (y=0.845), respectively (Figure 3). However, tiller plant^{-1} also resulted in a positive combined with a correlation of significance with r=0.66** and r^2=0.99 and b=2.199, respectively (Figure 4). Tillers may produce more spikelets with maximum tillers and the yield will be raised (Figure 5). The length of the spike displayed a positive and significant correlation with yield as r=0.22** and coefficient determination as r^2=0.992 along with b=0.499, respectively (Figure. 6). Similarly, the grains spike depicted a positive and significant correlation with grain yield as r=0.59** with significant correlation coefficient values as r^2=0.004 and b=0.375, respectively (Fig 7). The character 1000 grain weight was found to be significant in relation and positively linked to yield as r=0.50** with correlation determination as r^2=0.994 and b=0.618, respectively (Figure 8). Harvest index also proved to be in positive terms and significance with grain yield (r=0.71**, r^2=0.990 and b=0.575) (Figure 9). These results are consistent with various researchers (Ali *et al*., 2009; Sharma *et al*., 2022; Thapa *et al*., 2019).

Genetic variability morphological and yield traits: Genetic variety through selection and hybridization served as the foundation for research into the creation of new wheat types. Gene activity and inheritance mode determine genetic variation in physical characteristics and yield. days until 75% heading, days until 75% maturity (99.72), plant height (98.31), peduncle length (98.60), internode length (98.58), number of tillers plant^{-1} (96.99), spike length (97.57), spikelet's spike^{-1} (91.43), grains spike^{-1} (91.80), grain yield plant^{-1} (95.53), seed index (93.56), and harvest index (%) (90.60) were certain variables with the highest percentage of heritability (Table 9). Results supported the conclusions made by (El-Nahas & Ali, 2021; Pagliosa *et al*., 2017; Kalhoro *et al.*, 2015).

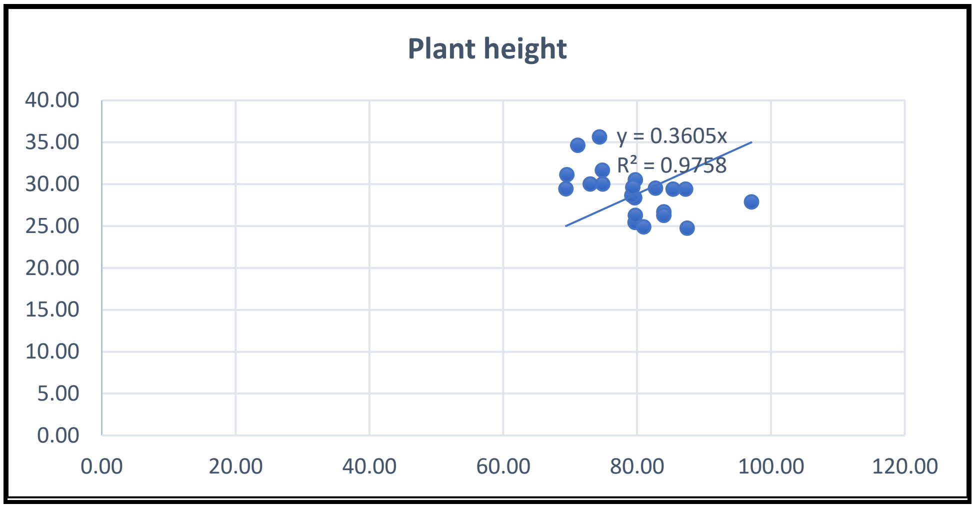

Figure 1. Correlation (r) for plant height in wheat genotypes under various environments

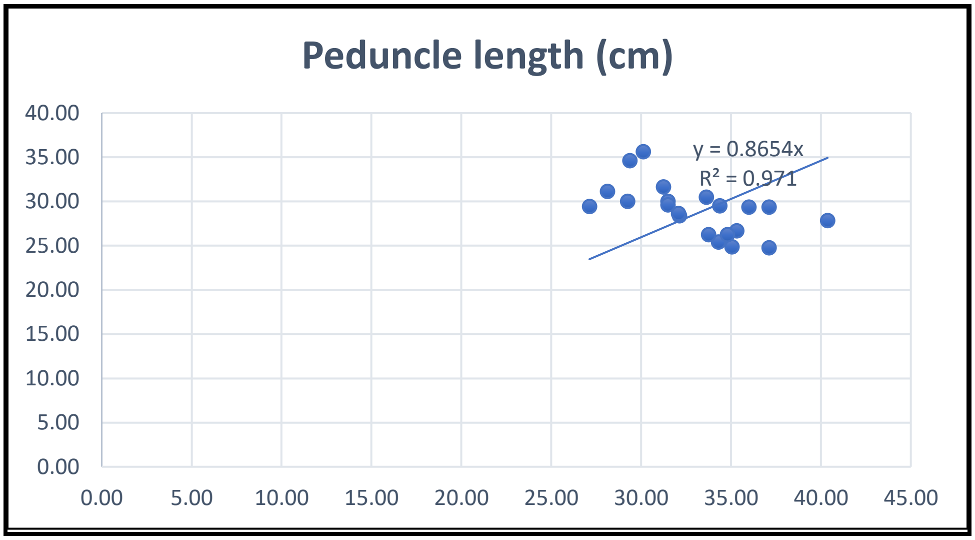

Figure 2. Correlation (r) for peduncle length in genotypes of wheat under various environments

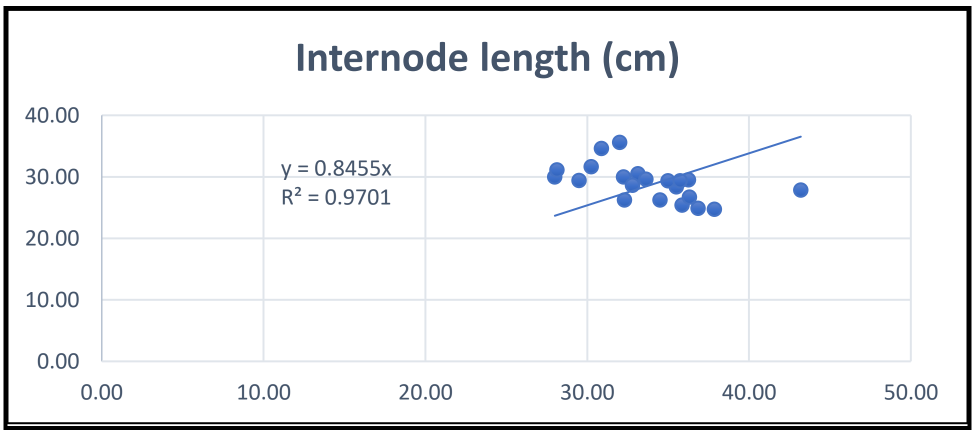

Figure 3. Correlation (r) for internode length in wheat genotypes under various environments

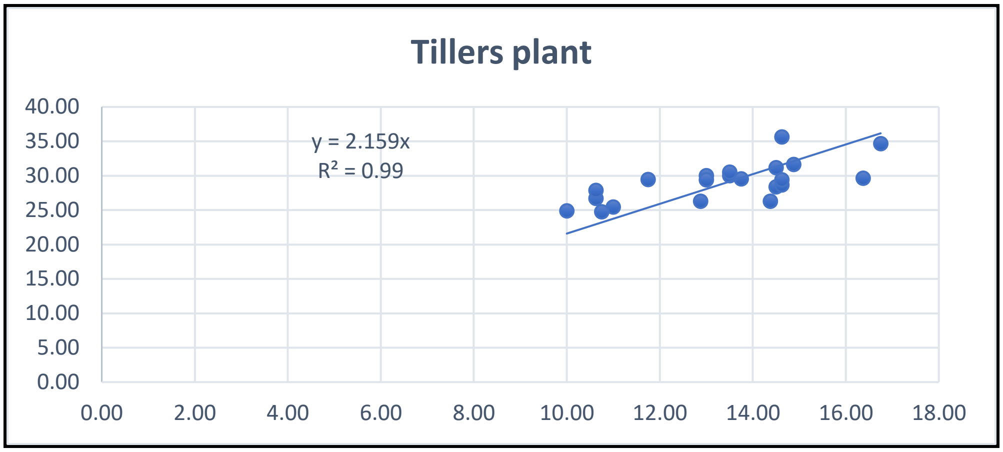

Figure 5. Correlation (r) for spike length in wheat genotypes under various environments

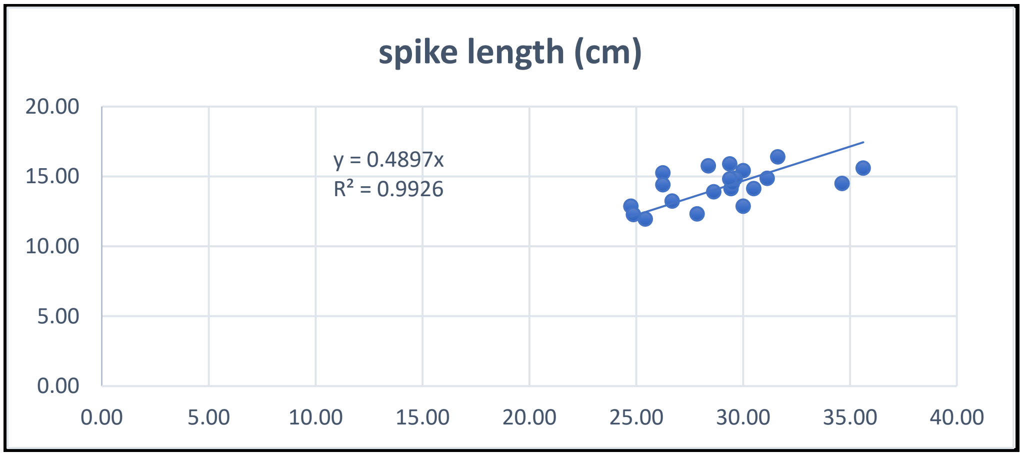

Figure. 4. Correlation (r) for tillers plant in wheat genotypes under various environments

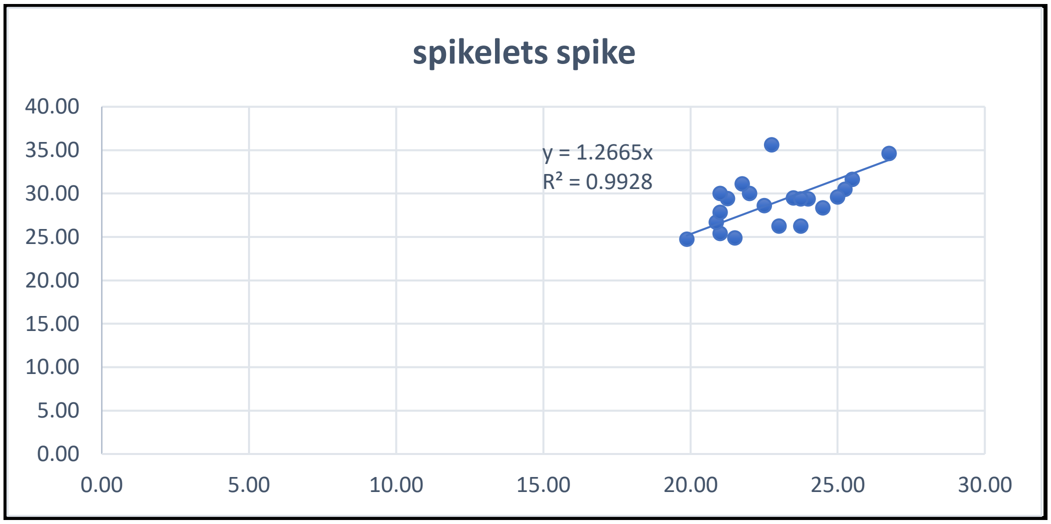

Figure 6. Correlation (r) for spikelet's spike in wheat genotypes under various environments

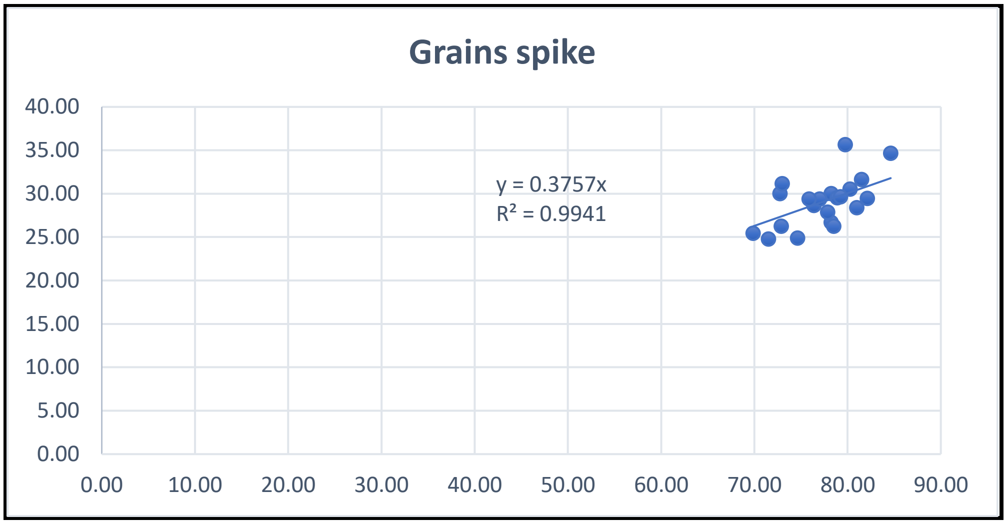

Figure. 7. Correlation (r) for grains spike in wheat genotypes under various environments

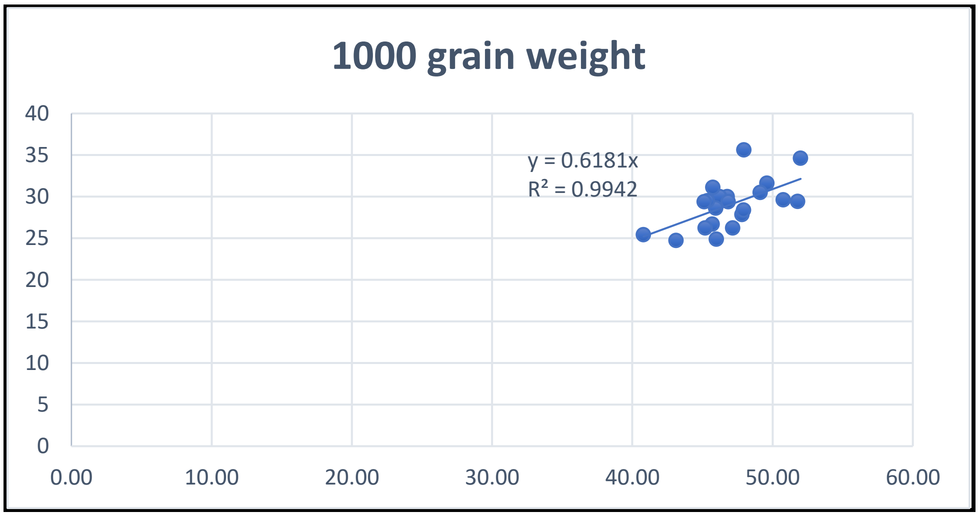

Figure 8. Correlation (r) for 1000 grain weight (g) in wheat genotypes under various environments

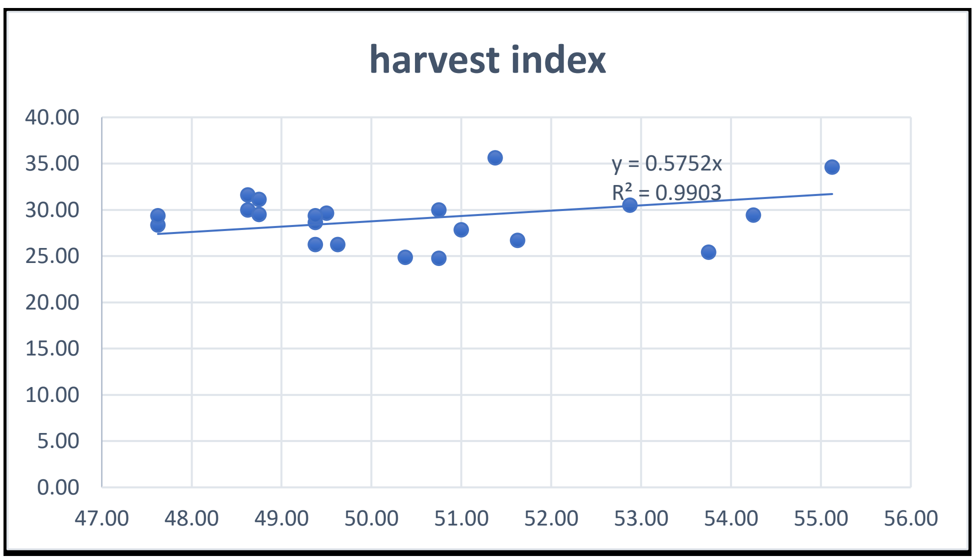

Figure 9. Correlation (r) for harvest index in wheat genotypes under various environments

Table 3. General combining ability (GCA) effects in various parents for different quantitative traits related to genotypes of wheat (*Triticum aestivum* L.)

	TD-1		TJ-83		Imdad-2005		Moomal-2002		
Characters	**Env 1.**	**Env 2.**	**Env 1.**	**Env 2.**	**Env 1.**	**Env 2.**	**Env 1.**	**Env 2.**	**SE (gi)**
Days to 75% heading	-2.87	-2.41	-6.22	-6.22	4.44	3.81	1.28	1.56	0.10
Days to 75% maturity	-2.47	-2.26	-4.56	-4.56	4.38	4.18	-0.81	-0.01	0.14
Plant height	-6.89	-5.90	-0.93	-0.93	1.14	1.79	3.08	3.38	0.20
Peduncle length	-3.47	-6.47	0.52	0.52	0.44	1.12	1.74	2.00	0.10
Internode length	-3.72	-2.98	-0.52	-0.52	0.50	0.96	-0.09	0.58	0.20
Tillers plant^{-1}	0.26	4.00	0.17	0.17	0.32	1.25	-0.77	-2.00	2.52
Spike length (cm)	0.32	0.45	0.18	0.18	0.35	0.43	-0.12	-0.13	2.56
Spikelets spike^{-1}	0.25	-0.17	0.19	0.19	0.13	0.21	-0.19	-0.35	0.14
Grains spike^{-1}	2.38	2.59	-0.59	-0.59	1.41	1.38	-0.74	-0.94	0.10
Grain yield plant^{-1}	1.79	2.53	-0.15	-0.15	0.42	0.18	-0.74	-1.07	0.26
Seed index	1.97	2.33	-0.75	-0.75	-0.23	0.11	-0.87	-1.01	0.14
Harvest index (%)	1.42	1.07	0.89	0.89	-0.74	-0.49	0.17	-0.27	0.18

S.E= Standard error; Location I=Tando Jam and Location II=Sakrand

Table 4: General combining ability (GCA) effects in various parents for different quantitative traits of genotypes of wheat (*Triticum aestivum* L.)

	SKD-1		Mehran-89		
Characters	**Env 1.**	**Env 2.**	**Env 1.**	**Env 2.**	**SE (gi)**
Days to 75% heading	1.03	0.03	3.06	2.50	0.10
Days to 75% maturity	0.13	-0.64	3.34	3.08	0.14
Plant height	-0.05	-0.99	3.65	3.01	0.20
Peduncle length	-0.11	1.00	0.88	1.65	0.10
Inter node length	-0.06	-0.17	4.49	1.21	0.20
Tillers plant^{-1}	-0.30	-4.25	0.32	0.25	2.52
Spike length (cm)	-0.24	-0. 30	-0.13	0.02	2.56
Spikelets spike^{-1}	-0.69	-0.23	0.31	-0.23	0.14
Grains spike^{-1}	-2.46	-0.06	0.001	0.03	0.10
Grain yield plant^{-1}	-1.39	-1.29	0.05	0.56	0.26
Seed index	-0.80	-1.08	0.68	0.69	0.14
Harvest index (%)	-0.99	-1.08	-0.74	-0.62	0.18

S.E= Standard error; Location I=Tando Jam and Location II=Sakrand

Table 5. Specific combining ability (SCA) effects in 6 x 6 F_1 hybrids for different quantitative traits of genotypes of wheat (*Triticum aestivum* L.)

Characters	TD-1 × TJ-83		TD-1 × Imdad-2005		TD-1 × Moomal-2002		TD-1 × SKD-1		SE (gi)
	Env 1.	Env 2.	Env 1.	Env 2.	Env 1.	Env 2.	Env 1.	Env 2.	
Days to 75% heading	-2.86	5.58	3.49	1.52	4.08	4.02	3.40	3.30	0.70
Days to 75% maturity	-3.64	-0.97	1.42	-0.25	0.35	1.19	-1.58	-1.44	0.72
Plant height	-0.86	-1.27	-1.94	0.64	2.19	-2.94	0.88	0.18	1.06
Peduncle length	-1.08	2.93	-1.00	4.03	0.20	3.40	-0.46	2.40	0.58
Internode length	0.49	-0.26	-0.04	0.93	2.94	-3.19	3.02	0.56	1.09
Tillers plant^{-1}	2.22	3.62	1.07	0.31	-0.09	-0.29	0.69	-0.25	0.44
Spike length (cm)	0.16	0.15	0.33	0.75	-1.65	0.74	1.73	1.91	0.44
Spikelets spike^{-1}	4.27	2.42	-0.67	-0.02	-0.35	-0.95	-1.85	1.92	0.71
Grains spike^{-1}	4.25	6.98	-1.00	-1.89	-1.37	-0.58	-3.88	1.95	0.56
Grain yield plant^{-1}	2.70	5.17	3.88	4.32	1.54	-2.18	0.94	0.45	1.41
Seed index	3.40	4.11	-0.67	-1.59	-1.33	-1.53	-1.60	-0.13	0.82
Harvest index (%)	2.39	2.23	0.26	0.35	-0.27	-0.36	-2.24	4.32	0.97

S. E= Standard error; Location I=Tando Jam and Location II=Sakrand

Table 6. Specific combining ability (SCA) effects in 6 x 6 F_1 hybrids for different quantitative traits of genotypes of wheat (*Triticum aestivum* L.)

Characters	TD-1 × Mehran-89		TJ-83 × Imdad-2005		TJ-83 × SKD-1		TJ-83 × Mehran-89		SE (gi)
	Env 1.	Env 2.	Env 1.	Env 2.	Env 1.	Env 2.	Env 1.	Env 2.	
Days to 75% heading	-1.63	-3.42	-3.13	-2.64	-1.47	-4.07	-1.63	8.68	0.44
Days to 75% maturity	-1.08	-0.40	-6.24	-4.65	-2.74	-2.09	-1.08	6.69	0.71
Plant height	-2.77	-0.82	-0.87	0.02	1.32	2.07	-2.77	-2.93	0.56
Peduncle length	0.56	3.74	-1.99	-2.16	-0.94	0.71	0.56	-2.20	1.41
Internode length	-5.02	-1.82	0.76	0.55	0.42	1.18	-5.02	-2.20	0.82
Tillers plant^{-1}	0.82	1.18	0.23	1.46	0.54	-0.85	0.82	0.84	0.97
Spike length (cm)	1.12	1.91	1.38	1.41	1.35	0.35	0.22	1.77	0.58
Spikelets spike^{-1}	3.15	1.92	1.40	0.55	-1.29	2.61	-0.79	1.48	0.59
Grains spike^{-1}	1.44	1.95	2.47	3.70	-0.90	4.01	0.63	-1.86	0.51
Grain yield plant^{-1}	-0.26	1.45	1.82	-1.81	-0.11	3.01	-0.06	-0.77	0.48
Seed index	0.37	-0.13	1.77	2.01	0.12	3.94	-0.62	-0.03	0.50
Harvest index (%)	-2.74	4.32	-3.96	-2.71	-1.21	1.07	-1.71	-0.30	0.84

S. E= Standard error; Location I=Tando Jam and Location II=Sakrand

Table 7. Specific combining ability (SCA) effects in 6 x 6 F_1 hybrids for different quantitative traits of genotypes of wheat (*Triticum aestivum* L.)

Characters	Imdad-2005 × Moomal 2002		Imdad-2005 × SKD-1		Imdad-2005 × Mehran-89		Moomal-2002 × SKD-1		SE (gi)
	Env 1.	Env 2.	Env 1.	Env 2.	Env 1.	Env 2.	Env 1.	Env 2.	
Days to 75% heading	1.52	1.80	3.37	2.83	2.59	2.36	-1.32	-1.67	0.40
Days to 75% maturity	2.26	3.75	5.82	5.88	3.60	1.16	2.49	-1.69	1.03
Plant height	-3.51	0.88	5.25	4.25	-4.45	-5.72	1.82	1.41	0.85
Peduncle length	-0.96	-1.19	3.43	2.81	-3.35	-3.35	1.47	-2.07	0.66
Internode length	1.59	0.62	0.65	0.37	-5.74	-2.50	-1.37	-2.00	1.18
Tillers plant^{-1}	0.10	1.31	1.38	1.59	4.25	2.03	2.22	1.75	0.46
Spike length (cm)	1.52	-0.30	1.59	1.39	-0.41	-1.77	0.31	0.70	0.11
Spikelets spike^{-1}	2.26	1.17	1.77	1.05	2.27	1.55	2.58	1.06	0.76
Grains spike^{-1}	-3.51	0.64	0.34	0.76	0.87	0.17	3.75	4.32	1.17
Grain yield plant^{-1}	-0.96	2.17	1.32	1.39	0.37	-0.46	-1.28	0.14	0.33
Seed index	1.59	-0.74	-0.86	-0.88	2.90	3.34	1.93	2.13	1.31
Harvest index (%)	0.10	-0.80	-1.58	-0.74	0.67	6.29	0.01	0.04	0.34

S. E= Standard error; Location I=Tando Jam and Location II=Sakrand

able 8: Specific combining ability (SCA) effects in 6 x 6 F_1 hybrids for different quantitative traits of genotypes of wheat (*Triticum aestivum* L.)

Characters	Imdad-2005 × Moomal-2002		Imdad-2005 × SKD-1		SE (gi)
	Env 1.	Env 2.	Env 1.	Env 2.	
Days to 75% heading	-3.10	1.80	-5.00	2.83	0.58
Days to 75% maturity	-4.71	3.75	-8.15	5.88	0.59
Plant height	1.12	0.88	-13.50	4.25	0.51
Peduncle length	0.11	-1.19	-5.55	2.81	0.48
Internode length	0.11	0.62	-9.33	0.37	0.50
Tillers plant^{-1}	-3.64	1.31	0.63	1.59	0.84
Spike length (cm)	0.60	-0.30	0.93	1.39	0.40
Spikelets spike^{-1}	0.68	1.17	-0.42	1.05	1.03
Grains spike^{-1}	1.58	0.64	-2.75	0.76	0.85
Grain yield plant^{-1}	-0.97	2.17	2.43	1.39	0.66
Seed index	1.02	-0.74	1.30	-0.88	1.18
Harvest index (%)	-0.05	-0.74	-0.33	-0.74	0.46
SE(si)					

S. E= Standard error; Location I=Tando Jam and Location II=Sakrand

Table 9. Heritability estimates for various characters in *Triticum aestivum* L.

Characters	σ^2p	σ^2g	Heritability	Heritability (h^2 b.s%)
Days until 75% heading	301	8.61	0.9723	98.11
Days until 75% maturity	280.12	70.12	0.9861	98.13
Plant height	289.81	79.40	0.9722	97.23
Peduncle length	82.75	20.40	0.9860	97.30
Internode length	99.75	23.01	0.9754	98.58
No. of tillers plant^{-1}	27.12	6.5	0.9734	96.99
Spike length e e	13.16	3.21	0.9757	93.23
Spikelets spike^{-1}	28.16	4.43	0.9232	90.11
Grains spike^{-1}	101.23	1.90	0.9011	91.80
Grain yield plant^{-1}	l63.49	15.16	0.9553	95.53
Seed index (1000 grain wt.) i	44.70	1046	0.9356	93.56
Harvest index (%) (%)	33.20	7.52	0.9060	90.60

Conclusion

The analysis of variance demonstrated significant effects of locations and genotypes on various morphological and yield traits, with notable interaction effects between locations and genotypes. Significant contributions of parents, hybrids, and their interactions, as well as general and specific combining ability variances, underscore the potential for selecting superior F_1 hybrids at different locations. Specific gene actions, including dominance, partial dominance, and over-dominance, were observed for all yield traits, confirming the complex genetic regulation. Correlation analyses revealed significant associations among traits, providing valuable insights for specific or better put, targeted breeding efforts. Overall, the obtained findings hold immense potential to contribute valuable information for optimizing wheat hybrid selection and breeding strategies across diverse environments.

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