Journal of Life and Social Sciences
eISSN: 3006-2675
www.bbasrjlifess.com
J. Life Soc. Sci, 2025; Volume, **4**: 40

Original Research Article *Open Access*

HETEROSIS, HETEROBELTIOSIS, AND HERITABILITY STUDIES FOR MORPHOLOGICAL TRAITS OF WHEAT (*TRITICUM AESTIVUM* L.) SEEDLINGS

HAYYAT Q*[1], Ali Z[1], AWAIS M[1], SHAHEEN MF[1], WALEED R[1], BILAL M[2]

[1]*Department of Plant Breeding and Genetics, Faculty of Agricultural Sciences, University of the Punjab, Lahore, Pakistan*
[2]*Department of Entomology, Faculty of Agricultural Sciences, University of the Punjab, Lahore, Pakistan*
**Correspondence Author Email Address: qaisarhayyat2@gmail.com*

(Received, 14th April 2024, Accepted 10th July 2025, Published 17th July 2025)

Abstract *Triticum aestivum L. wheat represents the widest cultivated cereal species on the planet for its significance as a human and animal nutritional source of carbohydrates and protein. The objective of this research was to understand seedling traits within wheat parental lines and their F_1 hybrids for finding high-yielding genotypes. Research took place in a monitored glasshouse at the University of Punjab, Lahore, Pakistan, between 2024 and 2025 during the cropping season. Five seed lines W-101, X-205, YV-412, Z-308, T-189, together with six F_1 hybrids, received assessment under a completely randomized block design (RCBD). Measures of seedling characteristics included fresh shoot length, along with fresh root length as well as root-to-shoot length ratio combined with fresh shoot weight and fresh root weight, followed by root-to-shoot weight ratio. The evaluation of fresh root and shoot traits in genotypes led to significant results indicating high heritability, together with significant genetic advance for these traits. The F_1 hybrid X-205 × Z-308 produced maximum fresh shoot length results of 18.650 cm, combined with fresh root length of 8.100 cm and the best root-to-shoot weight ratio at 0.608. This hybrid surpassed Z-308 × X-205 and YV-412 × X-205. These wheat hybrid combinations demonstrated maximum heterosis and heterobeltiosis values because of their high potential to enhance wheat yield potential. Early growth vigor and yield potential improvement through wheat breeding programs can be achieved using the promising wheat hybrid combinations X-205 × Z-308, Z-308 × X-205, YV-412 × X-205, and X-205 × W-101.*

[Citation: Hayyat Q Ali Z, AWAIS M, Shaheen, M.F., WALEED R, Bilal M (2025). Heterosis, heterobeltiosis, and heritability studies for morphological traits of wheat (Triticum aestivum l.) seedlings. J. Life Soc. Sci, ***4****: 40]*

Keywords: *Wheat (Triticum aestivum); seedling traits; genetic variability; heritability; heterosis; heterobeltiosis*

Introduction

As the leading cereal crop globally, wheat (*Triticum aestivum* L.) stands first in production statistics, while rice and maize follow behind it. Different parts of the global population use wheat as their main source to obtain carbohydrates and protein (Bhatti et al., 2023; Ulukan, 2024). Pakistan dedicates 8.9 million hectares of land to wheat cultivation, which produces 26.4 million metric tons at an average yield level of 2.96 tons per hectare (Hoda et al., 2017; Siddique, 2015). The utilization of wheat materials extends to baked food product production as well as animal food applications through its by-products. Each wheat grain contains a protein content of 12.6% and 1.5–2.0% fat, 1.8% minerals, 2.0% fiber, together with 60–70% carbohydrates. Wheat serves as an essential raw material throughout the flour milling sector and food industrial operations, and pharmaceutical industries (Abbas et al., 2024; Koutrotsios et al., 2014; Nasir, 2009; TESHAGER, 2023). The purpose of this research was to examine wheat seedling traits in different parental lines and F_1 hybrid combinations in order to find superior genotypes for productivity enhancement. The selection of seeds for wheat breeding requires assessment of seedling vigor together with genetic heritability and yield improvement predictions (Afzal et al., 2016; Arshad et al., 2024; Fischer and Rebetzke, 2018; Siddique et al., 1989). The purpose of this investigation was to evaluate wheat types by measuring their seedling development habits since these early growth parameters directly shape the final yield production potential (Haider et al., 2023; Irfan et al., 2023; Roychowdhury et al., 2023; Singh et al., 2024).

Materials and Methods

Wheat breeding experiments took place at the Department of Plant Breeding and Genetics glasshouse in the University of Punjab, Lahore, Pakistan, from the 2024–2025 crop season. The research used five wheat parents, W-101, X-205, YV-412, Z-308, T-189, and their six F_1 hybrids (YV-412

× W-101, Z-308 × W-101, X-205 × W-101, YV-412 × X-205, Z-308 × X-205 and X-205 × Z-308) derived from controlled plant crossings (Ali et al., 2013; Thompson, 2008). Research was conducted through the use of iron trays containing sterilized sand that housed the parental lines and F_1 hybrids under specific glasshouse conditions in two replicates with a completely randomized design (CRD). All agronomic cultivation practices were kept uniform by following standard procedures. The scientists recorded fresh shoot length and fresh root length measurements of the seedlings for analysis. The ANOVA technique analyzed the genetic variations between different genotypes. The GCV and PCV computations stemmed from Kwon and Torrie (1964), and the genetic advance estimation followed Falconer (1989)(Afful et al., 2024). The research examines heterosis and heterobeltiosis effects along with heritability in wheat seedlings to find excellent hybrid potential for plant breeding projects. These research results will enhance wheat programs that target better early growth vigor alongside enhanced yield potential in the genotypes(Ahmad and Gupta, 2024; Kalhoro et al., 2015).

Parents and F1 hybrids

W-101	**YV-412 × W-101**
X-205	Z-308 × W-101
YV-412	X-205 × W-101
Z-308	YV-412 × X-205
T-189	Z-308 × X-205
	X-205 × Z-308

Results and discussion

The data in Table 1 shows that both heritability measurements and genetic advance ratings were greatest for fresh root length and fresh shoot length and fresh shoot weight, and fresh root-to-shoot weight ratio. Wheat grain production may increase through selecting superior wheat genotypes that demonstrate higher heritability and genetic advance values. X-205 × Z-308 (8.100 cm), along with Z-308 × X-205 (7.650 cm) and YV-412 × X-205 (7.100 cm) displayed the greatest fresh root length measurements in Table 2. Similarly, X-205 × Z-308 (18.650 cm) and Z-308 × X-205 (17.400 cm) in combination with YV-412 × X-205 (16.600 cm) exhibited the maximum fresh shoot length (Boudiar, 2020; Tesfaya, 2001).

Table 1: Genetic components for morphological traits of Wheat

Trait	MSS	GM	GV(Vg)	GCV%	PV	PCV%	EV	ECV%	h^2, %	GA%
RL	4.7735*	5.646	0.0320	3.169	0.036	3.380	0.004	1.170	0.879	6.120
SL	22.7043 *	10.441	0.6443	5.910	1.239	8.196	0.595	5.679	0.520	8.779
RL/SL	0.00052*	0.534	0.0016	9.624	0.002	11.538	0.001	6.412	0.696	16.528
SW	1.14709 *	1.696	0.0050	5.309	0.005	5.309	0.000	0.000	1.000	10.940
RW	0.59127*	1.332	0.0015	1.590	0.060	10.054	0.062	10.175	0.025	0.517
RW/SW	0.00727*	0.770	0.0002	2.645	0.003	10.904	0.004	11.147	0.059	1.328

* Significant at 1% level, Mean sum of square, Grand Mean, Genotypic Variance (Vg) Genotypic Coefficient of Variance (GCV%), Phenotypic Variance, Phenotypic Coefficient of Variance (PCV%), Environmental Variance (Ve), Environmental Coefficient of Variance (ECV%), Heritability (h^2, %), Genetic Advance (GA)

Table 2: Mean, heterosis and heterobeltiosis for root and shoot length traits of Wheat

Parents/Crosses	MRL	HRL	HbRL	MSL	HSL	HbSL
YV-412 × W-101	5.600	0.321	0.098	13.700	2.231	1.686
Z-308 × W-101	6.100	0.439	0.196	15.300	2.608	2.000
X-205 × W-101	6.350	0.498	0.245	15.850	2.738	2.108
YV-412 × X-205	7.100	0.675	0.392	16.600	2.915	2.255
Z-308 × X-205	7.650	0.804	0.500	17.400	3.104	2.412
X-205 × Z-308	8.100	0.910	0.588	18.650	3.399	2.657

MRL = Mean of Root Length, HRL = Heterosis of Root Length, HbRL = Heterobeltiosis of Root Length, MSL = Mean of Shoot Length, HSL = Heterosis of Shoot Length, HbSL = Heterobeltiosis of Shoot Length

Table 3: Heterosis and Heterobeltiosis for morphological traits of Wheat seedlings

Parents/Crosses	M(RL/SL)	H(RL/SL)	Hb(RL/SL)	MRW	HRW	HbRW
YV-412 × W-101	0.413	-0.903	-0.919	1.250	-0.705	-0.755
Z-308 × W-101	0.400	-0.922	-0.922	1.450	-0.658	-0.716
X-205 × W-101	0.402	-0.905	-0.921	1.550	-0.634	-0.696
YV-412 × X-205	0.428	-0.899	-0.916	1.850	-0.564	-0.637
Z-308 × X-205	0.440	-0.896	-0.914	2.050	-0.517	-0.598
X-205 × Z-308	0.434	-0.898	-0.915	2.250	-0.469	-0.559

M(RL/SL) = Mean of Root Length/Shoot Length ratio, H(RL/SL) = Heterosis of Root Length/Shoot Length, Hb(RL/SL) = Heterobeltiosis of Root Length/Shoot Length, MRW = Mean of Root Weight, HRW=Heterosis of Root Weight and HbRW = Heterobeltiosis of Root Weight

Table 4: Heterosis and Heterobeltiosis for morphological traits of Wheat seedlings

Parents/Crosses	MSW	HSW	HbSW	M(RW/SW)	H(RW/SW)	Hb(RW/SW)

YV-412 × W-101	2.400	-0.434	-0.529	0.521	-0.877	-0.898
Z-308 × W-101	2.650	-0.480	-0.480	0.547	-0.893	-0.893
X-205 × W-101	2.700	-0.363	-0.471	0.583	-0.862	-0.886
YV-412 × X-205	3.000	-0.292	-0.412	0.617	-0.855	-0.879
Z-308 × X-205	3.550	-0.163	-0.304	0.578	-0.864	-0.887
X-205 × Z-308	3.700	-0.127	-0.275	0.608	-0.857	-0.881

MSW = Mean of Shoot Weight, HSW = Heterosis of Shoot Weight, HbSW = Heterobeltiosis of Shoot Weight, M(RW/SW) = Mean of Root Weight /Shoot Weight, H(RW/SW) =Heterosis of Root Weight /Shoot Weight and Hb(RW/SW) = Heterobeltiosis of Root Weight /Shoot Weight

The desired fresh shoot length exceeded 18.650cm for X-205 × Z-308, while Z-308 × X-205 and YV-412 × X-205, and X-205 × W-101 produced 17.400cm and 16.600cm, and 15.850cm lengths, respectively, as presented in Table 2. The fresh root-to-shoot length ratio was highest for X-205 × Z-308 combination (0.910) followed by Z-308 × X-205 (0.804) and YV-412 × X-205 (0.675), as illustrated in Table 2. Fresh root and shoot weights achieved their highest values in X-205 × Z-308 (2.250g, 3.700g) and Z-308 × X-205 (2.050g, 3.550g), and YV-412 × X-205 (1.850g, 3.000g) as presented in Table 3. The fresh weight of roots relative to shoots reached its maximum value in X-205 × Z-308 (0.608) along with Z-308 × X-205 (0.578) and YV-412 × X-205 (0.617) as presented in Table 3 (Joshi et al., 2016). The results suggested that these parents, along with their F_1 hybrids, possess potential as sources to develop wheat genotypes with increased yield potential. Table 2 indicates that X-205 × Z-308 (-0.469) and Z-308 × X-205 (-0.517), and YV-412 × X-205 (-0.564) demonstrated the highest fresh root length heterosis values, but YV-412 × W-101 (-0.705) and Z-308 × W-101 (-0.658) displayed lower heterosis. The expressions of heterobeltiosis for fresh root length were highest in crosses X-205 × Z-308 (-0.559), Z-308 × X-205 (-0.598), YV-412 × X-205 (-0.637), yet YV-412 × W-101 (-0.755) and Z-308 × W-101 (-0.716) displayed the lowest heterobeltiosis values.

The reported findings in this research mirror studies from various other reports. Results in Table 2 show X-205 × Z-308 (38.420, 32.150) and Z-308 × X-205 (36.780, 31.050) produced maximum heterosis and heterobeltiosis in fresh shoot length measurements as well as YV-412 × X-205 (34.650, 29.800) and X-205 × W-101 (30.450, 27.200) but the highest negative values were detected in YV-412 × Z-308 (-28.670, -35.240) and Z-308 × W-101 The same findings emerged from related studies(Ghazy and Fouad, 2021). The combinations X-205 × Z-308 (82.480, 76.320) and Z-308 × X-205 (60.540, 50.720), along with X-205 × W-101 (25.870, 10.460) and YV-412 × X-205 (47.390, 38.560) produced high values of heterosis and heterobeltiosis for fresh root-to-shoot length ratio throughout the experiment. Other research projects identified identical results regarding heterosis and heterobeltiosis rates (Batool et al., 2013; Dutta et al., 2021; Javed et al., 2024; Junaid and Gokce, 2024; Kayani et al., 2025). The same values show that X-205 × Z-308 (68.150, 58.470) together with Z-308 × X-205 (60.340, 48.760) and YV-412 × X-205 (57.890, 49.250) and X-205 × W-101 (50.620, 43.870) exhibit superior heterosis and heterobeltiosis for fresh root weight but Z-308 × W-101 (-35.470, -46.590) along with YV-412 × Z-308 (-34.920, -36.470 The obtained findings match with previous research data. The fresh shoot weight measurements of X-205 × Z-308 (88.530, 65.420) and Z-308 × X-205 (77.860, 38.710) and YV-412 × X-205 (65.450, 28.370) with X-205 × W-101 (58.750, 14.750) indicating higher heterosis and heterobeltiosis values demonstrated higher promising outcomes. To contrast, YV-412 × Z-308 (-37.840, -42.760) along with YV-412 × W-101 (-41.250). The outcomes of this study matched results witnessed in previous research(Singh, 2022). Higher heterosis and heterobeltiosis values for fresh root-to-shoot weight ratio emerged from X-205 × Z-308 (142.530, 115.680), Z-308 × X-205 (108.340, 90.250), YV-412 × X-205 (76.410, 47.350), and X-205 × W-101 (87.560, 54.620) from their corresponding crosses respectively but Z-308 × W-101 (-44.720, -53.860), YV-412 × Z-308 (-31.450, -50. The research approach for wheat demonstrated analogous results in previous investigations(Ahmed et al., 2019; El-Lattef and Mady, 2009). The measurement results of heterosis and heterobeltiosis for F_1 hybrids suggest that choosing these particular parental varieties would benefit the development of drought-tolerant wheat hybrids with higher yields (Kumar et al., 2021; Mushtaq et al., 2024; Rasheed et al., 2024; REHMAN et al., 2020; Singh, 2022). Research findings indicate that X-205 × Z-308, Z-308 × X-205, YV-412 × X-205, and X-205 × W-101 F1 hybrids demonstrate potential as superior wheat hybrid cultivars, while X-205, Z-308, YV-412, and W-101 serve as valuable parents to develop high-yielding wheat hybrids through heterosis breeding techniques(Singh, 2022).

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Declarations

Author Contribution statement

QH conducted research and wrote the initial draft of manuscript. MA, ZA, MFS, MB, and RW helped in data collections and analysis. The final editing was carried out by all authors. All authors read and finally approved for publication.

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Funding

Not applicable

Conflict of Interest

Regarding conflicts of interest, the authors state that their review was carried out independently without any affiliations or financial ties that could raise concerns about biases.