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Research Article

Morphological and Yield Characterization of Different Wheat Genotypes

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ABSTRACT

A comprehensive morphological characterization was conducted to evaluate the agronomic performance of four wheat genotypes: Abaseen-21, Jauhar-16, Pirsabak-21, and Sulaiman-96. The study focused on key yield and yield-contributing traits, including plant height, days to heading, days to maturity, flag leaf area, tiller number, spike weight, grain weight per spike, number of seeds per spike, spike length, number of grains per spike, thousand grain weight (TGW), biomass yield, yield per plant, and harvest index. Significant variability was observed among the genotypes, with Abaseen-21 demonstrating superior performance in yield per plot (34.2 g) and TGW (66.9 g), while Jauhar-16 exhibited the highest harvest index (55.4%). Sulaiman-96, despite its moderate yield potential, showed the lowest TGW (53.8 g) and harvest index (48.5%). The study also highlighted the importance of biomass accumulation, with a mean biomass yield of 61.28 kg and yield per plot of 33.15 kg across genotypes. These findings underscore the genetic diversity present in wheat germplasm, which can be leveraged for breeding programs aimed at enhancing yield potential, disease resistance, and environmental adaptability. The study emphasizes the role of gene pyramiding and marker-assisted selection in developing high-yielding, multi-pathogen-resistant wheat cultivars, contributing to the sustainability of wheat production and reducing dependence on chemical control measures.

Keywords: Morphological Characterization, Wheat Genotypes, Genetic Diversity, Yield Potential.

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INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most widely cultivated food crops globally, serving as a primary source of nutrition for a significant portion of the world's population (Waqar et al., 2018). It ranks first in global crop production, providing essential nutrients, including proteins, carbohydrates, vitamins, and minerals (Imdad et al., 2022; Begum et al., 2019). Wheat contributes about 21% of the global food supply and accounts for over 20% of protein intake in human diets (Khattak et al., 2020). Due to its importance in various food products, including bread, cake, banana bread, muffins, pasta, and cereals, increasing wheat production is crucial to meet rising global demands (Farrukh et al., 2022; Rehman et al., 2020). Despite advancements brought by the Green Revolution, wheat production faces challenges due to biotic and abiotic stresses, particularly in countries like Pakistan, where yield remains below the global average (Jamil et al., 2022; Qaiser et al., 2022; Khattak[a] et al., 2022; Rehman[a] et al., 2020). Addressing these challenges requires an integrated approach focusing on yield potential, resource efficiency, and disease resistance strategies (Zahid et al., 2022). Among these, biological control through resistance genes has been a key strategy to combat yield losses. However, the emergence of new virulent pathogen races has necessitated continuous improvement in breeding programs (Tahir et al., 2023). Resistance in wheat against rust diseases is primarily mediated by two types of genes: seedling resistance (R) genes, which are race-specific and effective throughout growth, and adult plant resistance (APR) genes, which provide quantitative resistance at later growth stages (Marone et al., 2013). While R genes often confer strong resistance, they tend to lose effectiveness over time due to pathogen evolution (Periyannan et al., 2017). APR genes, though offering partial resistance, are more durable and can be combined with R genes to enhance long-term protection. Consequently, the introduction of multiple resistance genes into elite wheat cultivars has been a major focus in breeding programs (Kokhmetova et al., 2021). The challenge of maintaining durable resistance is further complicated by the "boom and bust" cycle, where resistant wheat varieties initially succeed but eventually become vulnerable as pathogens adapt to changing environment (Waqar et al., 2018). Breeding efforts now emphasize stacking multiple R and APR genes to enhance resistance durability (Zahid et al., 2022). For enhancing the durability, morphological characterization of parental lines used in breeding programs is essential for identifying complementary traits in hybridization programs. Specifically, selecting genotypes with diverse yield attributes (e.g., plant height, tiller capacity, grain weight) alongside rust resistance enables targeted genetic improvement. This approach has led to the identification of numerous rust resistance genes, including Sr, Yr, and Lr genes, which are crucial for developing rust-resistant wheat cultivars (Khattak et al., 2020; Waqar et al., 2018). As wheat breeding continues to evolve, deploying new resistance genes strategically remains essential to ensure sustainable wheat production and global food security (Shaheen et al., 2023).

Therefore, this study focuses on the morphological characterization of four strategically selected wheat genotypes—Abaseen-21, Jauhar-16, Pirsabak-21, and Sulaiman-96—chosen for their contrasting traits in yield potential and rust resistance. These include Jauhar-16 (high yield + triple rust resistance), Suleman-96 (moderate yield + chapati quality), Abaseen-21 (high yield + early maturity), and Pirsabak-21 (high yield + rainfed adaptability). Keeping in view of the importance of wheat breeding, the present study was designed to characterize these specific wheat genotypes based on a comprehensive morphological evaluation of economically critical traits—including plant architecture, phenology, spike characteristics, biomass partitioning, and yield components— necessary for breeding and improvement programs.

MATERIALS AND METHODS

Plant material

A total of four cultivated hexaploid bread wheat varieties: Jauhar-16, Sulaiman-96, Abaseen-21, and Pirsabak-21 (PS-21). These varieties were sourced from the Cereal Crops Research Institute (CCRI) in Nowshera, KP. They were selected for their contrasting agronomic traits relevant to wheat improvement programs. Research was conducted from October 2020 to October 2022 across multiple locations: Agricultural Research Farm, Hazara University Mansehra; Agriculture Research Institute Tarnab, Peshawar; *and* National Institute of Genomics and Advanced Biotechnology (NIGAB), NARC Islamabad.

Experimental design and crop management

Field trials employed an augmented design with existing varieties serving as replicated checks and test genotypes as unreplicated treatments. Standard agronomic practices were followed.

Morphological evaluation

Data on agronomic characteristics were collected at various crop growth stages, from germination to harvest. Following parameters were studied in present study i.e Days to heading (DTH), Days to maturity (DTM), Plant height (PH, cm), Flag leaf area (FLA, cm²) calculated as length × width × 0.75, Number of tillers per plant (NTPP), Spike weight per spike (SWPS, g), Grain weight per spike (GWPS, g), Spike length (SL, cm), Number of grains per spike (NGPS), Thousand grain weight (TGW, g), Biological yield (BY, kg/plot), Yield per plant (YPP, g), Harvest index (HI, %) [calculated as (YPP/BY)×100]

Statistical analysis.

All collected data were recorded in Microsoft Office Excel 2013 for statistical analysis. An analysis of variance

(ANOVA) for Augmented design was conducted to evaluate the variance and significance between different population groups based on morphological parameters.

RESULTS

Morphological characterization of parents

Morphological evaluation revealed significant variation among the four wheat genotypes (Table 1). Plant height (PH) ranged from 97.9 cm in Pirsabak-21 to 101.8 cm in Abaseen-21. For phenological traits, days to heading (DTH) varied between 113.6 days (Abaseen-21) and 116.8 days (Sulaiman-96), while days to maturity (DTM) spanned 153.8 days (Sulaiman-96) to 160.1 days (Pirsabak-21).

Yield-related traits showed notable differences among the studied traits. The flag leaf area (FLA) was highest in Jauhar-16 (27.8 cm²) and lowest in Sulaiman-96 (24.8 cm²). Tillers per plant (NTPP) ranged from 11.4 (Sulaiman-96) to 12.7 (Pirsabak-21). Spike characteristics included spike length (SL) from 13.7 cm (Pirsabak-21) to 14.7 cm (Abaseen-21), grains per spike (NGPS) from 49.1 (Sulaiman-96) to 55.1 (Jauhar-16), and seeds per spike (NSPS) from 17.1 (Sulaiman-96) to 19.3 (Jauhar-16). Spike weight (SWPS) varied (4.2–5.6 g), while grain weight per spike (GWPS) was 2.7–3.3 g.

Yield parameters demonstrated: Thousand grain weight (TGW) ranged from 53.8 g (Sulaiman-96) to 66.9 g (Abaseen-21). Biomass yield (BY) per plot varied narrowly (60.0–62.0 kg), yield per plant (YPP) ranged 32.4–34.2 g, and harvest index (HI) spanned 48.5–55.4%. Abaseen-21 and Jauhar-16 consistently showed superior performance across most measured traits.

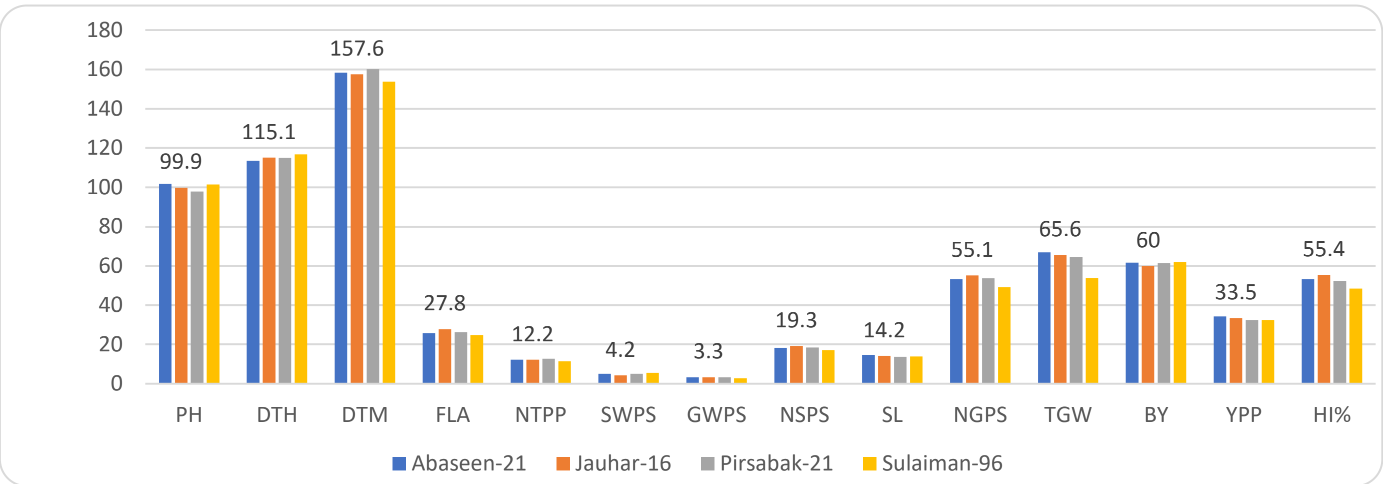

Figure 1. Comparison of parental lines based on morphological analysis.

DISCUSSION

The morphological characterization is first and important step to evaluate the germplasm prior to breeding strategy. The best and diversified parent may be selected based on trait specific performance for future study and incorporation in to breeding program. The present study also focused on this objective and four wheat genotypes were used for the study. The results revealed significant trait variability critical for breeding. Plant height (PH) ranged from 97.9 cm (Pirsabak-21) to 101.8 cm (Abaseen-21), reflecting genetic diversity exploitable for lodging resistance or biomass optimization (Aslam et al., 2018). This aligns with Khattak et al. (2020), though modern programs increasingly target semi-dwarfism for yield stability. Notably, Abaseen-21's height combined with early maturity (113.6 DTH) suggests adaptability to heat stress—a trait amplified by late-sowing-induced phenological compression (Singh et al., 2011; NWRP, 2017).

Phenology directly influenced climate resilience: Sulaiman-96's late heading (116.8 DTH) and early maturity (153.8 DTM) contrasted with Pirsabak-21's prolonged cycle (160.1 DTM). Genotypes like Abaseen-21 with earlier heading exhibited superior heat avoidance, consistent with Khattak et al. (2024). This underscores the urgency of breeding thermo-tolerant varieties as temperatures exceed 22°C during grain filling (Ahmed et al., 2014; Zampieri et al., 2023).

Flag leaf area (FLA), critical for photosynthesis, varied substantially (24.8–27.8 cm²), with Jauhar-16's high FLA likely supporting its yield despite rust pressure. Such architectural optimization enhances resource allocation—a trait linked to QTLs like QFlw-5A (Li et al., 2023). Conversely, Sulaiman-96's low FLA (24.8 cm²) coincided with poor harvest index (48.5%), highlighting photosynthetic limitations.

Table 1. Morphological Evaluation of Parental Lines Based on Yield and Yield-Contributing Traits.

S. No	Traits	Genotype			
		Abaseen-21	Jauhar-16	Pirsabak-21	Sulaiman-96
1	PH (cm)	101.8	99.9	97.9	101.4
2	DTH (days)	113.6	115.1	115.0	116.8
3	DTM (days)	158.3	157.6	160.1	153.8
4	FLA (cm^2)	25.8	27.8	26.2	24.8
5	NTPP (number count)	12.3	12.2	12.7	11.4
6	SWPS (g)	5.1	4.2	5.1	5.6
7	GWPS (g)	3.3	3.3	3.2	2.7
8	NSPS (number count)	18.3	19.3	18.5	17.1
9	SL (cm)	14.7	14.2	13.7	13.9
10	NGPS (number count)	53.1	55.1	53.7	49.1
11	TGW (g)	66.9	65.6	64.6	53.8
12	BY (Kg/plot)	61.7	60.0	61.4	62.0
13	YPP (g)	34.2	33.5	32.4	32.5
14	HI (%)	53.1	55.4	52.3	48.5

Yield components showed pronounced genotypic differences: Jauhar-16 excelled in grains per spike (NGPS: 55.1) and HI (55.4%), while Abaseen-21 dominated thousand-grain weight (TGW: 66.9 g). The TGW range (53.8–66.9 g) mirrors global diversity, with lower values in Sulaiman-96 (53.8 g) suggesting compromised grain filling. Recent GWAS identified alleles like TaCwi-4D that could ameliorate this under terminal heat (Qaiser et al., 2022). Biomass yield (BY: 60.0–62.0 kg/plot) was uniform, but yield per plant (YPP: 32.4–34.2 g) and HI (48.5–55.4%) reflected efficient partitioning in Abaseen-21 and Jauhar-16.

The selection of parents prioritized complementary traits: Jauhar-16 offered triple rust resistance and high HI, Abaseen-21 contributed early maturity and high TGW, Pirsabak-21 provided rainfed adaptability, and Sulaiman-96 added chapati quality. This strategic diversity mitigates the "boom-bust" cycle in rust resistance (Waqar et al., 2018) and enables stacking of APR/R genes (Zahid et al., 2022). Future crosses should leverage Abaseen-21's yield architecture and Jauhar-16's resilience to enrich allelic combinations for sustainable production.

CONCLUSIONS AND RECOMMENDATIONS

The morphological evaluation revealed significant diversity in yield-related traits among the four wheat genotypes. Abaseen-21 emerged as the top-performing genotype for yield per plant (34.2 g), supported by its superior thousand-grain weight (66.9 g) and early maturity (113.6 days to heading). Complementary strengths were observed in other genotypes: Jauhar-16 excelled in harvest index (55.4%) and grains per spike (55.1), Pirsabak-21 demonstrated the highest tillering capacity (12.7 tillers/plant), while Sulaiman-96 showed the greatest spike weight (5.6 g). This trait variability provides a strategic genetic foundation for hybridization programs, enabling the development of high-yielding wheat varieties through targeted crossing of parents with complementary agronomic advantages.

AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Validation and writing, B. Alam; I. Ullah; F. Ullah, Data curation & Funding acquisition; Analysis, M.A. Aslam; G. Zahid; S. Begum; M. Murtaza, Methodology, Investigation & reviewing and editing; Software & Validation, S.H. Khattak; F. Jabeen; F. Amin; R. Ikram, Resources, Supervision, Project administration, Funding acquisition and Resources, S.H. Khattak; G.M. Ali; Methodology, Reviewing and editing, S.H. Khattak; M.A. Aslam; S. Begum; A. Errum.

COMPETING OF INTEREST

The authors declare no competing interests.

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