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Original Article

" Agro-Ecological Evaluation of Wheat Varieties for Yield and Agronomic Efficiency in DI Khan Division"

Nasir Abbas Nayyar[1]

1 University of the Punjab, Lahore

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***Corresponding Author:**
Nasir Abbas Nayyar
(nasir.nayyar@pu.edu.pk)

ABSTRACT

Wheat is a staple crop in Pakistan, and the evaluation of newly released varieties under diverse agro-ecological conditions is critical to ensure food security and sustainable production. This study assessed the yield potential and agronomic performance of ten modern wheat varieties—AZRC-Dera, Shahid, Zarghoon-2021, Asrar Shaheed, PS-2021, Daman, Naurang-2023, Khyber-2023, Thanda-2023, and PS-2023—across two consecutive Rabi seasons (2022–23 and 2023–24) in DI Khan Division, Khyber Pakhtunkhwa. Field trials were conducted in a randomized complete block design with three replications, and data were collected on key traits, including phenology, plant height, spike length, grains per spike, 1000-grain weight, grain yield, biological yield, and harvest index. Significant variations ($p < 0.05$) were observed among varieties for all traits, indicating considerable genetic diversity. Early maturing varieties such as Thanda-2023 and Naurang-2023 recorded the shortest growth durations, while Khyber-2023 and PS-2023 produced longer spikes. Yield analysis revealed that Naurang-2023, PS-2023, and Khyber-2023 consistently outperformed others, with grain yields exceeding 6500 kg ha^{-1}, coupled with favorable harvest indices above 35%. In contrast, varieties like AZRC-Dera and Shahid showed moderate yield stability but lower harvest indices. The results suggest that newly released varieties, particularly Naurang-2023 and PS-2023, have strong potential for adoption under the agro-ecological conditions of DI Khan. These findings provide critical insights for wheat improvement programs, variety recommendation, and farmer adoption strategies to enhance productivity in the region.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most widely cultivated cereal crop in the world and forms the dietary backbone of nearly one-third of the global population [1,2]. It contributes significantly to daily calorie intake, with an estimated 20% of the total dietary energy and protein requirements derived from wheat-based foods [3]. Globally, wheat is cultivated across diverse agro-ecological regions, ranging from temperate to subtropical zones, highlighting its adaptability and strategic importance in ensuring food security [4,5]. With the global population expected to surpass 9.7 billion by 2050, demand for wheat is projected to increase by nearly 60%, necessitating sustainable yield enhancement through the development and adoption of improved varieties adapted to local conditions [6,7].

In Pakistan, wheat holds the status of a staple food crop and is deeply linked with food self-sufficiency and national stability [8,9]. It accounts for about 37% of the cropped area and contributes roughly 72% to daily caloric intake in the country [10]. Despite its importance, wheat productivity in Pakistan remains below the global average, with yields stagnating around 3.1–3.3 t ha^{-1}, compared to 5.5–6.0 t ha^{-1} achieved in advanced wheat-producing nations such as China, Germany, and France [11,12]. Several factors contribute to this yield gap, including erratic climatic patterns, water scarcity, soil fertility constraints, biotic stresses, and the cultivation of outdated varieties with limited genetic potential [13,14]. The adoption of new high-yielding, stress-tolerant, and agronomically efficient varieties is therefore considered a pivotal strategy to boost wheat productivity and sustain national food security [15,16].

The selection of wheat varieties for a given environment is a complex process, as performance is influenced by genotype × environment (G × E) interactions [15,16]. Varieties bred for high-input, irrigated systems may fail to perform under resource-limited or stress-prone conditions, while locally adapted lines may not express their full potential when introduced elsewhere [17]. Thus, agro-ecological evaluation allows researchers and farmers to identify wheat varieties that combine desirable agronomic traits—such as early vigor, optimal plant height, tillering capacity, disease resistance, and efficient resource utilization—with high yield potential under the prevailing conditions of a region. Such evaluations are not only essential for maximizing

productivity but also for ensuring resilience against climatic variability and emerging biotic stresses.

Recent efforts by national agricultural research systems and provincial institutes have resulted in the release of several new wheat varieties with claims of higher yield potential, resistance to rust diseases, and adaptability to diverse ecological zones [19]. However, before their widespread adoption, these varieties must be critically evaluated under localized field conditions to validate their performance. DI Khan Division, with its distinct soil and climatic profile, provides an ideal testing ground to assess the adaptability and productivity of these varieties. Systematic evaluation can help determine whether the new genotypes can outperform existing farmer-preferred varieties in terms of both yield and agronomic efficiency.

Agronomic traits serve as important determinants of yield and farmer acceptability [20]. For instance, medium-statured varieties are less prone to lodging while maintaining optimal biomass for grain filling. Similarly, varieties with efficient nutrient uptake and better water-use efficiency are more suitable for semi-arid environments such as DI Khan. Therefore, a comprehensive agro-ecological evaluation focusing on these traits provides not only yield data but also insights into the physiological and morphological characteristics that underlie varietal performance [21].

Furthermore, climate change poses an increasing challenge for wheat production in regions like DI Khan [22]. Rising temperatures, shortened growing periods, heat stress during grain filling, and unpredictable rainfall patterns threaten both yield and stability [23]. Developing and selecting varieties with heat tolerance, early maturity, and efficient resource utilization is becoming increasingly urgent [24]. Locally adapted varieties may play a crucial role in mitigating these risks while ensuring stable production. Thus, identifying wheat varieties that are both high-yielding and climate-resilient under DI Khan's agro-ecological conditions is aligned with national food security goals and international commitments such as the Sustainable Development Goals (SDGs), particularly Goal 2: Zero Hunger.

Against this backdrop, the present study was conducted to evaluate the yield potential and agronomic traits of new wheat varieties under the agro-ecological conditions of DI Khan Division, Khyber Pakhtunkhwa. The research aimed to: (i) compare the yield

performance of newly developed wheat varieties with existing ones, (ii) assess key agronomic traits that determine adaptability and efficiency, and (iii) identify the most promising varieties suited for large-scale cultivation in DI Khan's farming systems.

MATERIALS AND METHODS

The yield potential and agronomic performance of ten recently released wheat varieties, namely AZRC-Dera, Shahid, Zarghoon-2021, Asrar Shaheed, PS-2021, Daman, Naurang-2023, Khyber-2023, Thanda-2023, and PS-2023, were evaluated for two consecutive years (Rabi 2022–23 and 2023–24) at the Agricultural Research Station, DI Khan, DI Khan Division, Khyber Pakhtunkhwa.

During the Rabi season 2022–23 and 2023-24, the varieties AZRC-Dera, Shahid, Zarghoon-2021, Asrar Shaheed, PS-2021, Daman, Naurang-2023, Khyber-2023, Thanda-2023, and PS-2023 were tested and their mean values across the two seasons were considered for comparison of traits.

The experiments were laid out in a randomized complete block design (RCBD) with three replications. Each experimental plot measured 1.2 × 5.0 m, with rows spaced at 30 cm. The recommended fertilizer dose of 120 kg N ha^{-1} and 90 kg P_2O_5 ha^{-1} was applied. Phosphorus was incorporated during seedbed preparation, while nitrogen was applied in two to three equal splits at appropriate crop growth stages.

Weed control was achieved through the application of post-emergence weedicides Axil and Allymax during December and January. Standard agronomic practices were followed to ensure optimal crop growth, while regular field inspections were carried out for monitoring crop health and development.

Data were recorded on major phenological, agronomic, and yield-related traits, including:

- Days to 50% heading
- Days to maturity
- Plant height (cm)
- Spike length (cm)
- Number of grains per spike
- Thousand-grain weight (g)
- Grain yield (kg ha^{-1})
- Biological yield (kg ha^{-1})
- Harvest index (%)

The collected data were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for RCBD, and

treatment means were compared at a 5% level of significance.

RESULTS AND DISCUSSION

Phenological and Agronomic Traits

Significant variations ($p < 0.05$) were observed among the tested wheat varieties for days to 50% heading, days to maturity, plant height, and spike length (Figure 1). Days to 50% heading ranged from 112 days in Thanda-2023 to 121 days in PS-2021, with an LSD (5%) of 7.95. Early heading varieties such as Thanda-2023 (112 days) and Naurang-2023 (113 days) showed potential for escaping terminal heat stress, a critical trait under the semi-arid conditions of DI Khan. In contrast, PS-2021 and Zarghoon-2021 were relatively late heading (121 and 120 days, respectively), which may expose them to higher temperatures during grain filling.

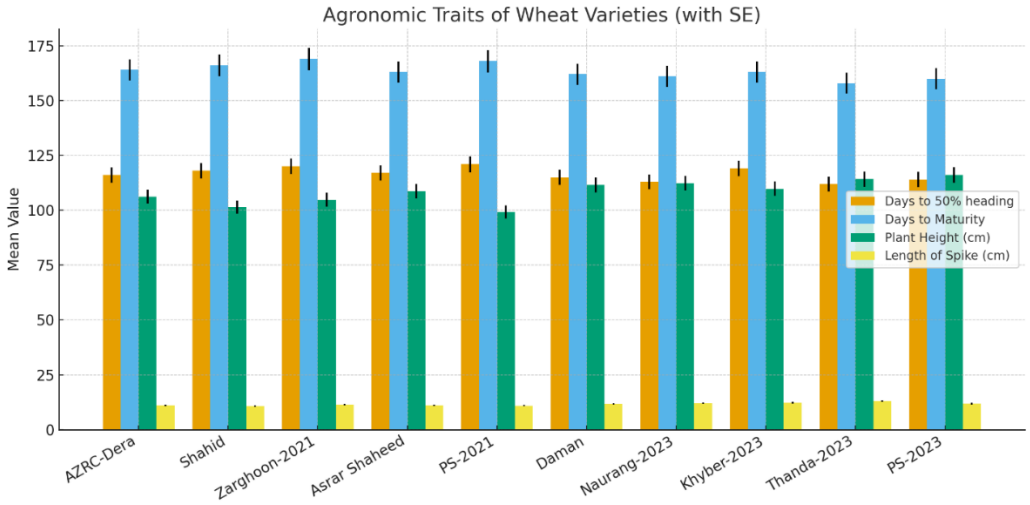

Figure 1: Phenological and agronomic traits of different wheat varieties under agro ecological conditions of DI Khan

A similar trend was observed for maturity. Thanda-2023 attained physiological maturity earliest (158 days), while Zarghoon-2021 matured latest (169 days). Early-maturing varieties are advantageous in water-limited environments as they reduce exposure to terminal drought stress [25]. Plant height varied significantly across varieties, with PS-2023 recording the tallest stature (116.1 cm), followed by Thanda-2023 (114.3 cm), whereas Shahid remained the shortest (101.4 cm). The LSD value of 7.20 confirmed

significant genotype effects. Medium plant height, as seen in Zarghoon-2021 (104.9 cm) and PS-2021 (99.3 cm), is desirable for balancing biomass accumulation with reduced lodging risks.

Spike length also differed markedly, ranging from 10.72 cm in Shahid to 13.10 cm in Thanda-2023 (Figure 1). Longer spikes were associated with higher grains per spike, as observed in Naurang-2023 (12.05 cm, 71 grains per spike) and Thanda-2023 (13.10 cm, 70 grains per spike). This suggests that spike morphology contributes significantly to yield determination under DI Khan's agro-ecological conditions, aligning with recent findings that spike length and grain number are highly correlated with yield potential [26].

Yield and Related Traits

Grains per spike varied significantly among varieties, with values ranging from 63 in Zarghoon-2021 to 71 in Naurang-2023 (Figure 2). The LSD (5%) of 4.25 confirmed statistical differences. Varieties such as Naurang-2023 (71 grains) and Thanda-2023 (70 grains) outperformed others, indicating superior sink capacity. On the contrary, Zarghoon-2021 (63 grains) exhibited relatively lower yield potential.

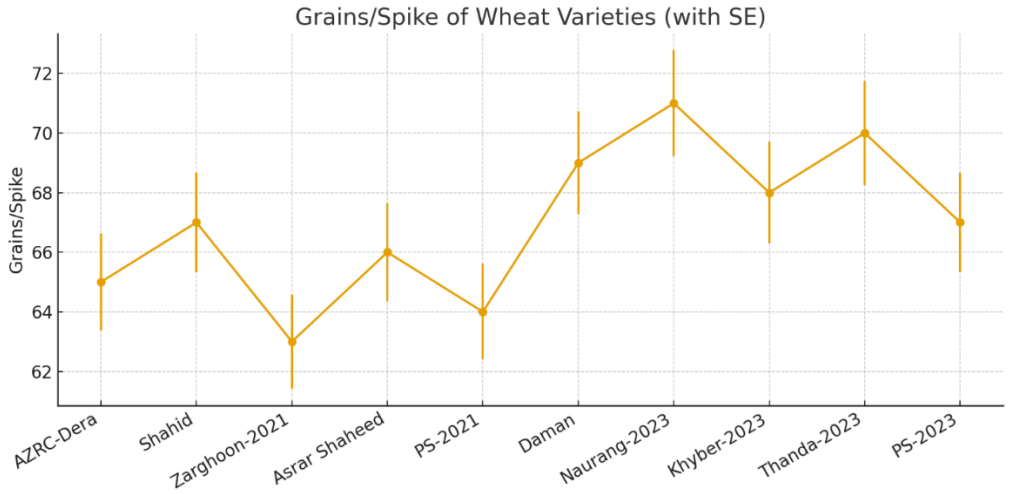

Figure 2: Variation in grains per spike of different wheat varieties under agro ecological conditions of DI Khan

Thousand-grain weight (TGW) ranged between 44.5 g (AZRC-Dera) and 50.0 g (Thanda-2023), with an LSD of 2.95 (Figure 3). Higher TGW in Thanda-2023 and Naurang-2023 (49.5 g) indicated better grain filling capacity, which is a critical yield

component under semi-arid conditions. Such variations are consistent with recent reports that grain weight contributes significantly to yield stability under climatic stress [27].

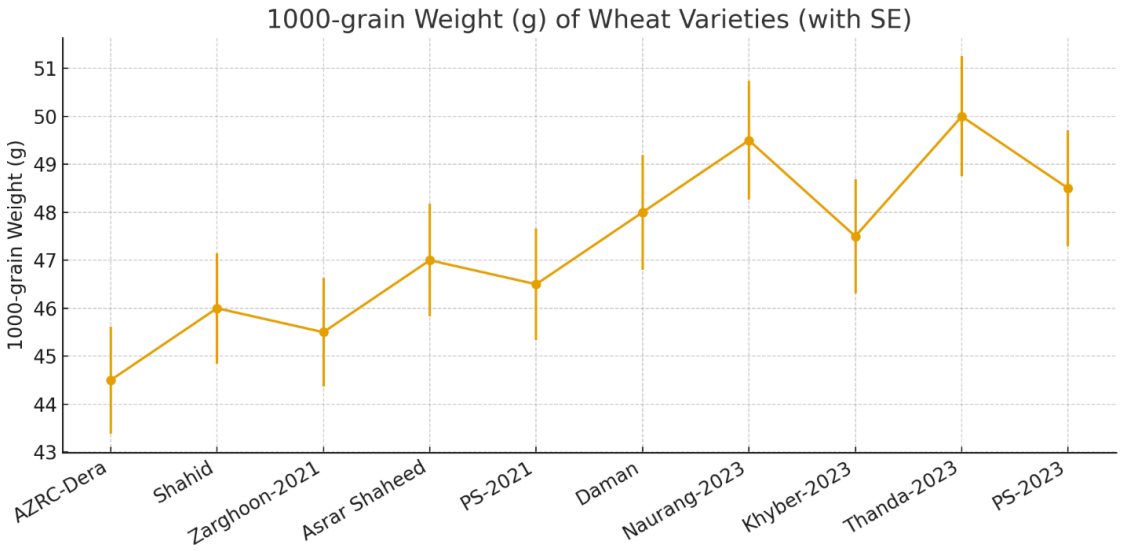

Figure 3: Variation in thousand grain weight of different wheat varieties under agro ecological conditions of DI Khan

Grain yield per hectare showed a wide variation, ranging from 6005 kg ha^{-1} in PS-2021 to 7025 kg ha^{-1} in Thanda-2023 (Figure 4). The LSD value (1650.12) confirmed significant genotype × environment effects. Thanda-2023 (7025 kg ha^{-1}) and Naurang-2023 (6950 kg ha^{-1}) were the most productive, outperforming standard checks such as Zarghoon-2021 (6100 kg ha^{-1}) and PS-2021 (6005 kg ha^{-1}). These findings highlight the genetic potential of newly released varieties, particularly Thanda-2023 and Naurang-2023, for enhancing productivity under DI Khan's agro-ecological conditions. Similar improvements in yield potential from newly released varieties have been documented in other agro-ecological zones of Pakistan [28].

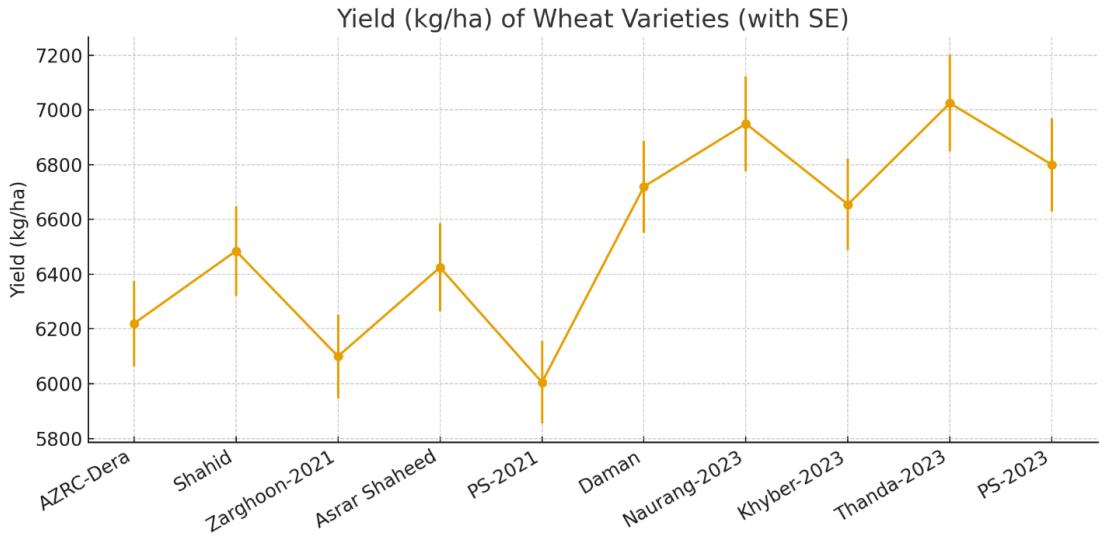

Figure 4: Variation in grain yield of different wheat varieties under agro ecological conditions of DI Khan

Biological yield varied significantly across varieties, ranging from 16,350 kg ha^{-1} in PS-2021 to 19,110 kg ha^{-1} in Thanda-2023 (Figure 5). High biological yield was observed in Thanda-2023 (19,110 kg ha^{-1}) and Naurang-2023 (18,950 kg ha^{-1}), reflecting robust vegetative growth. Biological yield plays a critical role in sustaining grain yield, as it serves as the primary source of assimilates for grain filling [29].

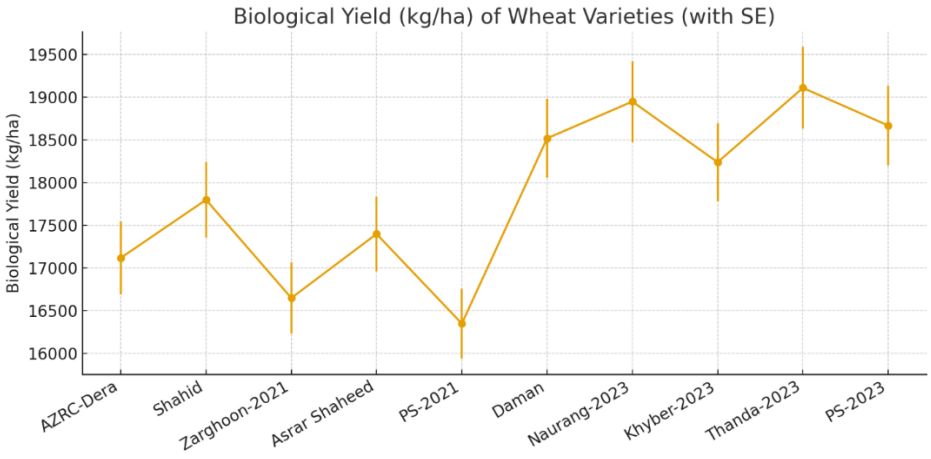

Figure 5: Variation in biological yield of different wheat varieties under agro ecological conditions of DI Khan

Harvest index (HI) values ranged narrowly between 36.3% (AZRC-Dera, Daman) and 36.9% (Asrar Shaheed), with an LSD of 2.25 (Figure 6). Although differences were statistically non-significant, the relatively higher HI in Asrar Shaheed (36.9%) and Thanda-2023 (36.8%) suggests efficient partitioning of assimilates to economic yield. A stable HI close to 37% across varieties indicates balanced source–sink relationships, consistent with recent findings that modern wheat cultivars maintain HI values around 35–38% under semi-arid conditions [30].

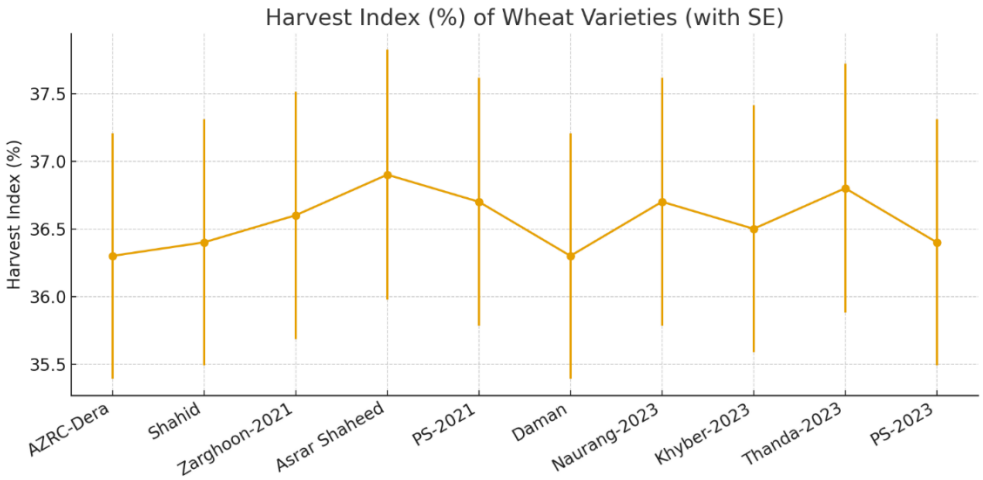

Figure 6: Variation in harvest index of different wheat varieties under agro ecological conditions of DI Khan

Performance Trends and Implications

Overall, Thanda-2023 and Naurang-2023 consistently outperformed other varieties in most agronomic and yield-related traits, including spike length, grains per spike, 1000-grain weight, grain yield, and biological yield. Zarghoon-2021 and PS-2021 lagged behind in both yield and supporting traits, suggesting limited adaptability to the DI Khan agro-ecological zone. The stability of harvest index across all varieties highlights that improvements in yield potential are largely due to enhanced biomass production and grain filling capacity rather than shifts in assimilate partitioning.

These findings emphasize the importance of locally adapted breeding programs that prioritize early maturity, high TGW, and large spike architecture. Adoption of varieties such as Thanda-2023 and Naurang-2023 could significantly enhance wheat productivity in DI Khan Division, thereby

strengthening food security. This is particularly relevant given the challenges posed by climate variability, where varieties with shorter crop cycles and stronger sink capacity are likely to perform better under heat and drought stresses [31].

CONCLUSION

The evaluation of ten newly released wheat varieties under the agro-ecological conditions of DI Khan revealed significant genetic variability in phenological, agronomic, and yield traits. Varieties such as Naurang-2023, PS-2023, and Khyber-2023 demonstrated superior yield potential and favorable harvest indices, whereas others like Shahid and AZRC-Dera showed moderate but stable performance. The results highlight the importance of varietal selection tailored to local environments for enhancing productivity and sustainability. Overall, Naurang-2023 and PS-2023 emerged as promising cultivars for future adoption, ensuring improved grain yield and resilience in DI Khan's wheat-based cropping systems.

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