Framework for the selection of wheat varieties for arid agroecosystems

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Wheat production in arid and semi-arid regions faces critical challenges due to erratic climate conditions, soil degradation, and limited access to inputs such as nitrogen fertilizers. These constraints threaten food security and demand innovative approaches for selecting varieties that can perform reliably under resource-limited conditions. To address this, we developed and tested a multidimensional analytical framework aimed at identifying wheat genotypes that combine high yield, resource-use efficiency, and performance stability across variable environments. The study evaluated 33 bread wheat (*Triticum aestivum* L.) varieties across six environments in Afghanistan (three locations over two seasons). The framework integrated agronomic performance (grain yield, straw yield, thousand kernel weight), nitrogen use efficiency, statistical stability metrics (AMMI, Wricke's ecovalence), and economic return (Net Nitrogen-adjusted Margin, NNaM). This integrated approach allows a nuanced understanding of genotype behavior across diverse agro-ecological conditions, moving beyond average performance to include quality, resilience, and economic feasibility. Environmental conditions explained over 80% of the total variance in grain and straw yields, underscoring the influence of site-specific factors such as temperature, rainfall, and soil fertility. Nonetheless, significant genotype × environment interactions revealed the potential to identify broadly adapted and resilient genotypes. Varieties Lalmi−15 and Lalmi−17 consistently exceeded 4.0 t ha^{-1} in grain yield with high stability. Nitrogen uptake efficiency (Nt/Ns) ranged from 0.41 to 0.72, with varieties Muqawim−09, Dehdadi−13, and Amir−10 combining high uptake efficiency with consistent translocation and yield performance. Protein content, though primarily environment-driven, showed remarkable stability in variety MH0304–09, which also ranked among the top economic performers. The NNaM, an original economic index combining yield, grain protein value (via GOST classification), and nitrogen cost, was closely linked to both physiological and agronomic traits. A linear regression model explained 96.5% of NNaM variance, highlighting the critical roles of straw yield and Nt/Ns. Inclusion of stability metrics improved model robustness and interpretability, supporting selection decisions under variable conditions. A composite index, aggregating weighted trait means and stabilities, facilitated final varietal ranking. Only three genotypes, Lalmi−15, Lalmi−17, and MH0304–09, emerged as the most suitable candidates, offering high yield, nitrogen efficiency, and resilience. These results support the broader use of integrative, trait-based frameworks for guiding varietal selection in low-input systems. This approach is scalable and adaptable to dryland areas across Central Asia, the Mediterranean, and parts of Eastern and Southern Europe, where similar agro-climatic constraints exist. By combining physiological, agronomic, and economic indicators, this framework advances both scientific methodology and practical decision-making for sustainable crop improvement. It offers valuable guidance for breeding programs, extension services, and agricultural policy aiming to enhance productivity, profitability, and input-use efficiency in the face of increasing climate variability. Furthermore, the methodology has potential for adaptation to other crops and agro-systems where nitrogen use and stability are critical bottlenecks.

Keywords: Genotype-environment interaction; Nitrogen use efficiency; Nitrogen-adjusted profitability; Trait-based selection; AMMI and Wricke stability

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