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HR EXCELLENCE IN RESEARCH

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Review of the PhD Dissertation

Reviewer
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1. Introduction

The dissertation submitted by **MSc Abu Zar Ghafoor**, entitled **'Evaluation of genotype × environment interaction for grain crop quality',** was prepared at the Doctoral School of the Warsaw University of Life Sciences (SGGW), under the supervision of Dr. hab. Marcin Studnicki, Prof. SGGW, with the support of Dr. Adriana Derejko. The dissertation addresses the very timely and relevant issue of genotype by environment (G×E) interaction in cereals, with special attention to yield stability and technological grain quality under varying environmental conditions and farming intensities. Given the increasing climate variability and its implications for agricultural production and food security, this dissertation makes a significant contribution to both agricultural science and practice.

2. Formal Characteristics of the Dissertation (“collection of publications”) and Quality of the Included Papers

The dissertation is structured as a collection of three peer-reviewed scientific articles, complemented by a coherent introduction, an up-to-date literature review, a detailed materials and methods section, a synthetic discussion, and concluding remarks. The list of publications (with DOI, Impact Factor, and national point evaluation) is included in the main body of the thesis, while full-text versions of the articles and signed statements from co-authors are presented in the appendices.

Publications included in the dissertation:

Agriculture (2024) — study on spring wheat (grain yield and bread-making quality) with an analysis of stability depending on the intensity of agronomic practices; IF = 3.3, 100 points (Polish MNiSW system).

Agronomy (2024) — identification of plant and soil predictors of stability in winter wheat cultivars grown under temperate climate conditions; IF = 3.3, 100 points MNiSW.
Agronomy Journal (2024) — study on winter rye: the impact of crop management on yield stability and selected quality traits; IF = 2.0, 100 points MNiSW.
Assessment of journals and articles: All three papers were published in indexed, peer-reviewed journals. Two articles appeared in MDPI journals (Agriculture and Agronomy), while one was published in Agronomy Journal (Wiley/ASA). The dissertation provides up-to-date indicators (Impact Factors, MNiSW point values), confirming their formal value within the Polish academic evaluation system.
Copies of the articles and the signed co-author declarations (Appendices 1–2) have been attached, which meets the formal requirements for a “stapled collection of publications” at SGGW.
Compliance with SGGW regulations: According to the regulations, a doctoral dissertation may take the form of a “collection of published and thematically related scientific articles accompanied by a descriptive overview” (§9.3). It must also include abstracts in both English and Polish and co-author statements (§10). All these elements are present in the dissertation (English and Polish abstracts in the main body, co-author declarations in the appendices).

3. Scientific Relevance, Originality, and Added Value

The dissertation addresses a highly relevant and timely scientific problem: the multi-trait stability and genotype × environment (G×E) interaction in cereals — specifically spring wheat, winter wheat, and winter rye — under the conditions of climatic variability and contrasting levels of agronomic intensity. The growing unpredictability of weather patterns, coupled with the need to sustain both yield and technological grain quality, makes this line of research particularly important for plant breeding and food security in Europe.
The originality and added value of the dissertation lie in the consistent and innovative application of a suite of modern multivariate methodologies. Alongside conventional approaches such as Linear Mixed Models (LMM) and Shukla’s stability variance, the candidate systematically employed the Multi-Trait Stability Index (MTSI), Classification and Regression Trees (CART), and Canonical Correspondence Analysis (CCA). This methodological package allowed for the simultaneous assessment of yield performance and technological quality across multi-environment trials (MET), providing a more holistic and robust evaluation of genotype adaptability.

By integrating these diverse tools, the dissertation not only confirms the limitations of traditional univariate models but also demonstrates the power of multivariate approaches for capturing complex trait–environment interactions. This constitutes an important methodological advancement in the study of cereal stability and quality under conditions of climate change and varied crop management.

4. Materials and Methods

The empirical material analyzed in this dissertation is both extensive and representative. It consists of 74 multi-environment field trials covering three major cereals: spring wheat (7 cultivars, 4 locations × 2 seasons, with contrasting management levels), winter wheat (55 cultivars, 12 locations × 5 seasons, 60 environments, within the COBORU system), and winter rye (16 cultivars including both population and hybrid types, across 3 locations × 2 seasons). Agronomic details, such as nitrogen fertilization, fungicide applications, and growth regulators, were precisely recorded, and quality traits were measured using recognized methods (e.g., farinograph, sedimentation tests, gluten index, falling number, 3. D. loaf volume analysis). Statistical analyses included linear mixed models (LMM), Shukla's variance for univariate stability, MTSI for multi-trait selection, CART for predictor identification, and CCA for linking environmental variables with varietal performance. The analyses were performed in R, using appropriate packages (metan, vegan, rpart).

The methods applied in the dissertation are fully adequate to the research questions posed and are consistent with the current state of the art in the scientific literature. The combination of traditional approaches (LMM, Shukla's variance) with advanced multivariate techniques (MTSI, CART, CCA) reflects both methodological rigor and awareness of recent developments in quantitative genetics and biometrics. The candidate demonstrated not only the ability to apply these methods correctly but also to interpret their outcomes in a meaningful biological and agronomic context.

5. Research Objectives and Hypotheses

The primary objective of the dissertation was to determine the phenotypic stability of spring wheat, winter wheat, and winter rye cultivars in multi-environment trials, while explicitly accounting for contrasting levels of agronomic intensity. This aim reflects the growing importance of identifying cultivars that can maintain both yield and technological quality under diverse and changing conditions of crop management.

The author formulated the following hypotheses:

1. **Stability and yield performance of cultivars vary significantly** depending on the environment and the level of agronomic input.

2. **The Multi-Trait Stability Index (MTSI) and other multivariate tools** provide a more accurate characterization of the adaptive capacity of cultivars than conventional single-criterion models.

3. **Key determinants of stability** include spike morphology, resistance to fungal diseases, tolerance to soil-related stresses (e.g., aluminium toxicity), winter hardiness, and resistance to lodging.

These hypotheses were appropriately tested within the experimental framework and directly addressed the central research question concerning the multi-trait stability of cereals under variable environmental and management conditions.

6. Main Results, Conclusions, and Contribution to Science and Practice

i. Spring wheat. The cultivars *Bombona* and *Izera* exhibited the highest stability under medium-input management (MIM) and high-input management (HIM), respectively. The main determinants of stability were spike morphology traits and bread-making quality parameters, particularly loaf volume. Genotypic effects played a decisive role in shaping key quality traits, such as gluten index and falling number.

ii. Winter wheat. Shukla's stability variance identified cultivars *SY Yukon* and *Bataja* as the most stable, while the Multi-Trait Stability Index (MTSI) highlighted *Medalistka* and *KWS Spencer*. Yield stability was strongly associated with resistance to powdery mildew and brown rust, while quality stability correlated with winter hardiness and lodging resistance. Canonical Correspondence Analysis (CCA) confirmed that stability was closely dependent on soil properties and site fertility.

iii. Winter rye. Hybrid cultivars yielded on average 24% more than population cultivars but displayed lower stability and lower grain protein content. CART analysis revealed that the most critical predictors of stability were resistance to septoria (under MIM) and tolerance to aluminium toxicity (under HIM).

iv. Reliability and validity. The dataset originates from well-designed multi-environment trials (MET), with competent measurement of quality traits (AACC 54-21, LV 3D, texture analysis). The environmental and management variability was sufficiently broad to allow reliable conclusions about stability. The study confirmed the usefulness of the Multi-Trait Stability Index (MTSI) and other multivariate approaches for assessing the stability of

cereal cultivars. The findings carry important practical implications for plant breeding, clearly indicating that cultivar selection should be made in reference to specific environmental and agronomic conditions rather than assuming a notion of “universal stability.” The dissertation makes a valuable contribution to the development of G×E evaluation methodology and provides guidance for breeding practices oriented toward climate resilience and food security.

v. Contribution to science and practice. The most significant contribution of the dissertation lies in the operationalization of multi-trait stability selection, while simultaneously capturing G×E×M (genotype × environment × management) interactions. This enables targeted cultivar recommendations for specific production systems, instead of relying on a generalized concept of universal adaptability. Such findings provide real value for plant breeding (selection criteria) as well as for agricultural extension and advisory services (profiling cultivars for medium- and high-input systems).

7. Formal Assessment (Language, Structure, References)

Language and editing: The main body of the dissertation is written in English, accompanied by a Polish abstract. The style is scientific, precise, and stylistically consistent. The structure follows the classical format: Introduction, Literature Review, Materials and Methods, Results, Discussion, Conclusions, Recommendations, References, Supplements, Curriculum Vitae, and Appendices (including full-text articles and co-author declarations). The table of contents confirms the clarity and transparency of the overall layout.

Methodological and graphical apparatus: The description of statistical tools (R software, including the packages *metan*, *vegan*, *rpart*) is complete. Definitions of abbreviations and keywords facilitate comprehension. Tables and figures are appropriate, informative, and adequately captioned.

References: The bibliography is extensive and up to date, ranging from classical works (e.g., Shukla 1972) to the most recent contributions on multi-environment trials, MTSI methodology, cereal stability, and the effects of climate variability. Citations in the discussion and methods are appropriate and relevant.

Formal compliance: Author and supervisor declarations are included; abstracts in both English and Polish are present, along with copies of publications and co-author statements, thus meeting the requirements of §§ 9–10 of the SGGW regulations.

7. Critical Remarks and Constructive Suggestions

i. Reproducibility and data/code availability: It would be valuable to provide a repository (e.g., R scripts and metadata) for the MTSI, CART, and CCA analyses, thereby enhancing transparency and enabling cross-laboratory validation. While the body of the thesis reports the R version and packages used, sharing code would further strengthen reproducibility.

ii. Effect sizes and uncertainty measures: Beyond presenting stability rankings, the inclusion of uncertainty distributions for MTSI would be desirable. Moreover, comparing results with alternative indices (e.g., MGIDI, WAASBY) could demonstrate the robustness of the findings.

iii. Resolution of the “management” factor: In the case of spring wheat, the HIM and MIM systems represent packages of agronomic practices. The author correctly notes that disentangling the specific contributions of nitrogen fertilization, fungicides, and growth regulators would require a different experimental setup. Highlighting this limitation more explicitly in the practical recommendations would be beneficial.

iv. Trade-offs between bread-making quality and yield: An interesting observation is that HIM resulted in higher yield and protein content, while MIM favored superior loaf volume. Expanding the discussion to include economic and sensory trade-offs (higher cost of HIM vs. bread-making quality) could enrich the practical dimension, although this understandably goes beyond the methodological scope of the dissertation.

v. Spatial generalizability: The data are representative for Poland (temperate climate). Including a short paragraph on the transferability of findings to other temperate regions (e.g., Scandinavia, Baltic countries), along with potential methodological adaptations (such as envirotyping or mega-environment zoning), would increase the international relevance of the study.

vi. Editorial consistency of appendices: Minor inconsistencies were observed in Appendix 2, where page numbers and publication years in reproduced references differ slightly between versions. Standardizing the reference formatting would improve the formal coherence of the appendices.

8. Final Assessment and Recommendation

The dissertation meets the requirements of originality and independent scientific contribution. It presents a coherent body of results based on long-term multi-environment trials (MET) and advanced multi-trait analytics. The work makes a clear contribution to agricultural sciences by providing:

- methodological advancements in the assessment of G×E×M stability,
- practical recommendations for the selection and allocation of cultivars to medium-input (MIM) and high-input (HIM) management regimes.

From a formal perspective, the dissertation fully complies with the requirements of the Warsaw University of Life Sciences (SGGW) for dissertations in the form of a “collection of publications accompanied by a descriptive overview” as well as with the associated appendices (§9–10 of the Regulations). It includes the necessary abstracts and co-author declarations.

The doctoral candidate, MSc Abu Zar Ghafoor, demonstrated comprehensive theoretical knowledge in the discipline of agriculture and horticulture, as well as the ability to conduct independent scientific research. He also presented an original solution to a scientific problem by applying the results of his own research, which have clear potential for implementation in the economic sphere. **Recommendation:** I hereby recommend that the dissertation be admitted to public defense. I confirm that it meets the requirements of the Polish Law on Higher Education and Science (Ustawa z dn. 20 lipca 2018 r., Dz . U. z 2024 r. poz. 1571 z późn. zm.) as well as the Resolution No. 89-2022/2023 of the Senate of SGGW with regard to content, form, and documentation of the doctoral procedure (Uchwała Nr 89-2022/2023 Senatu SGGW z dnia 26 czerwca 2023 w sprawie uchwalenia Regulaminów przeprowadzania postępowań w sprawie nadania stopnia doktora w Szkole Głównej Gospodarstwa Wiejskiego w Warszawie). In view of the originality and complementarity of the solution to the multifaceted problem of *genotype × environment interaction for grain crop quality*, and recognizing the significant contribution of the dissertation to the advancement of methodological approaches in agricultural sciences, I recommend that the Scientific Council of the Discipline of Agriculture and Horticulture at the Warsaw University of Life Sciences (SGGW) award this doctoral dissertation with distinction.

Signed by / Podpisano przez:

Anna Wenda-Piesik

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