REVIEW

on a dissertation for obtaining the educational and scientific degree **"doctor"** by : field of higher education 6. Agricultural Sciences and Veterinary Medicine, Professional Field 6.1 Crop science, scientific specialty: Field crops.

Author of the dissertation: Georgi Stoyanov Raykov – PhD student in independent training at the Department of Crop science at the Agricultural University, Plovdiv.

Topic of the dissertation: An effective methodology for identification of highly productive and stable winter wheat genotypes by combining traditional and innovative statistical approaches.

Reviewer: Prof. Dr. Hristofor Kirchev Kirchev , Agrarian University, field of higher education 6. Agricultural Sciences and Veterinary Medicine, Professional Field 6.1 Crop science, scientific specialty: Field crops.
Appointed as a member of the scientific jury by order No. RD-16-208/ 02.02.2026 by the Rector of Agricultural University.

1. Brief presentation of the candidate.

Georgi Stoyanov Raykov was born on 29.07.1982 in the town of Gen. Toshevo. He graduated from secondary education at "Nikola Vaptsarov" Secondary School - Gen. Toshevo in 2000, after which he studied at the Agricultural University - Plovdiv as a bachelor with a specialty in Agronomy - Field Production and as a master in Plant Biotechnology. During the period 2012-2015 he worked as a soft wheat breeder at the Dobrudzha Agricultural Institute, Gen. Toshevo, after which he continued with the same activity at the Agronom company - Dobrich. Since 2018 he has been an agricultural producer. In 2025 he was enrolled as a PhD student in independent training at the Department of Crop science at the Agricultural University, Plovdiv.

2. Relevance of the problem.

Wheat (*Triticum aestivum* L.) is the most widely grown crop worldwide and plays a central role in human food security. It provides approximately one fifth of the caloric intake and a significant share of the protein balance in the global diet, thus making an indispensable contribution to feeding the population. Its importance is particularly pronounced in developing countries, where wheat is often the main source of income and employment for smallholder farmers. The expected population growth to over 10 billion people by 2050 implies a need to increase global food production by at least 35–60% to ensure food security. This places wheat at the center of sustainable agricultural policies. Historical experience clearly shows that genetic progress in wheat is highly dependent on the combination of biological opportunities, agronomic practices and socio-economic factors. While CIMMYT and ICARDA programs continue to introduce new varieties with increased resistance and adaptability, regional institutes in Europe and Australia struggle to overcome climate constraints. This divergence in the pace of progress highlights the need for new methodological solutions and an integrated approach that combines traditional breeding practices with modern statistical and biotechnological tools.

3. Purpose, tasks, hypotheses and research methods.

The aim of this study is to establish the possibility of combined application of traditional and innovative statistical approaches for complex evaluation of winter wheat varieties while simultaneously determining productivity, stability and adaptability under contrasting growing conditions.

To achieve the goal, the following specific tasks have been set:

1. To analyze the influence of the genotype × environment interaction on the yield and stability of winter wheat.
2. To study the relationships between the main components of productivity and final yield.
3. To apply multivariate statistical methods for grouping genotypes based on yield and structural traits.
4. To assess the stability of the productivity of the samples through integrated indicators that combine them.
5. To apply multi-trait approaches for grouping and classification of the studied genotypes in order to formulate recommendations for breeding practice.

Working hypotheses

1. The interaction between genotype and environment has a significant impact on the yield of winter wheat, determining the stability and adaptability of individual varieties.
2. The relationships between the main traits of productivity and yield change in strength and direction depending on the combined impact of environmental factors and their interaction with the genotype.
3. Grouping genotypes through multivariate analysis reveals real differences in phenotypic and genetic potential and supports the development of effective selection strategies.
4. Winter wheat varieties can be evaluated reliably, with combined traits for productivity and stability.
5. The integration of multi-trait indices (MGIDI, MTSI, WAASBY) and their comparison through consensus approaches provides a more precise and reproducible assessment of genotypes.

4. Visualization and presentation of the results obtained.

The scientific paper submitted for review contains 187 pages, 19 tables, 8 figures and 5 appendices. The list of cited literature contains a total of 195 literary sources, all in Latin.

The dissertation contains all the sections generally accepted for this type of presentation, namely: Table of Contents – 1 page; List of abbreviations – 2 pages; Introduction – 3 pages; Literature review – 45 pages; Purpose, tasks and working hypotheses – 2 pages; Material and methods – 23 pages; Soil and climatic characteristics – 13 pages; Results and discussion – 47 pages; Conclusions – 3 pages; Contributions – 2 pages and Literature – 23 pages.

The literature review is divided into subsections describing studies on genetic progress and climatic constraints, theoretical basis: Genotype × Environment Interaction (GEI), traditional statistical methods for estimating GEI, modern multivariate methods, cluster, factor and PCA methods, critical analysis of the methodologies used and finally concludes with a justified need for the study.

The agro climatic characteristics include the general climatic characteristics of the experimental area - Dobrudzha Agricultural Institute - Gen. Toshevo, the soil characteristics of the field, as well as an analysis of the agrometeorological conditions during the study period.

5. Discussion of the results and literature used.

As a result of the precisely performed experimental work, the obtained data are described in the Results and Discussion section, which occupies almost 30% of the volume of the presented dissertation work. For better systematicity, the section is divided into 6 subsections.

In the first subsection, descriptive statistics were performed, including boxplot diagrams and descriptive statistics.

An assessment of the influence of environment, genotype and their interaction on yield and its elements was performed in the second subsection. AMMI analysis was performed on grain yield and its components and a bi-plot of a principal component analysis of the studied traits and climatic factors during the study period.

The third subsection analyzes the relationships between the traits and their effect on productivity. Linear (LMM) and nonlinear (RF) models and structural equation models (SEM) were performed.

In the fourth subsection, a cluster analysis was performed, in which the number of clusters was determined using the elbow method (WCSS) and the Silhouette coefficient.

The fifth subsection - assessment of the stability and productivity of genotypes includes BLUP analysis, and a full list of BLUP estimates is presented in the annexes (Annex 3). The WAASB index, which is a new statistical approach that allows assessing the stability of genotypes by combining information from interactions (GEI) and BLUP estimates. In the study, the index in question differentiates genotypes not only by their stability, but also by their interaction with different agro-ecological conditions. The WAASBY index is an integral selection index that combines the stability and productivity of genotypes in multi-year trials, applying set weights for each of the two characteristics. The yield stability index (YSI) is not so much related to stability in a broad sense as to the ability of genotypes to maintain their productivity in the presence of stress factors. In this context, YSI is closer to the concept of stress tolerance than to universal stability. In the present study, the index was calculated based on two contrasting years: 2014 (reported as a stressful environment due to the lowest average yields) and 2013 (a favorable environment with the highest yields). In this way, the maximum response of genotypes to the agro-ecological contrast is assessed. In the present analysis, varieties originating from Romania, Moldova and southern Ukraine stand out as examples of higher resistance under stress conditions, which confirms the importance of geographical origin for tolerance to adverse conditions. The superiority index (Pi) is used to simultaneously assess the average productivity and stability of genotypes in multiple environments. Essentially, it measures the deviation of each genotype from the highest yields achieved in each environment, with lower index values reflecting closer performance to the optimum in all conditions. Based on Pi, primary selection of genotypes with proven yield potential can be made, regardless of variations in environmental conditions. The Kang Stability Index (KSI) has been introduced as a combined indicator that integrates both yield and stability of genotypes. The method uses non-parametric ranking, in which each genotype is separately ranked by average yield and stability, and the final score (KSI) is their sum. Genotypes with the lowest KSI values are considered to be both productive and stable, making it applicable to breeding programs with multiple environments. Analysis of the data from the three years showed distinct differences between genotypes in KSI values. The variety Nota takes first place, followed by the varieties Bohemia, Kantata, Azimut and Grom, which also show yields above 8.0 t ha^{-1} and stable performance. In this subsection, a comparative assessment of grain yield and stability indices is also made. The full set of indices and their ranks is presented in the annexes (Annex 4).

The last subsection includes m multi-trait selection indices. In the evaluation of genotypes using the Multi-Trait Stability Index (MTSI), priority was given to the three traits that have a leading contribution to the formation of winter wheat yield: grain yield (GY), number of grains per m^2 (NGM) and 1000-grain weight (TGW). All of them are considered indicators with a desired increase, since their higher values directly reflect better productivity. The MTSI genotype ranking highlights ten leading varieties that combine high productivity and stability according to the selected indicators. Among them, the Bohemia variety takes first place. The application of the Multi-trait Genotype-Ideotype Distance Index (MGIDI) in the analysis of the studied genotypes allowed a clear distinction of the genotypes according to their proximity to the defined ideotype. The results show that the Midas variety takes a leading position. Close to it are PKB Vizelka and PKB Rodika, which also combine high yield and favorable values of the main yield components. The Bulgarian variety Nakhodka is distinguished by competitive values, which emphasizes the selection potential of the local genetic plasma. A comparative ranking of the genotypes by the rank of the indices was performed. In this comparison, the three independent rankings MGIDI, MTSI and WAASBY were used with a 50:50 weight between productivity and stability to assess how resistant the leading genotypes are to index selection. Only the Bohemia variety is present simultaneously among the top 20 in all three indices, which confirms its combination of high productivity, stability and a balanced multi-trait profile. Ultimately, a consensus ranking was achieved, which serves as a practical tool for the final selection of genotypes in full form presented in Appendix 5. The developed methodology can be applied in future multi-environmental trials, including expanding the set of traits such as quality and technological indicators. Based on the obtained and analyzed results, the doctoral student formulates 15 conclusions, which summarize the study in a concise form.

The cited literature, including 195 literary sources, demonstrates the excellent theoretical preparation of the doctoral student and his high level of awareness of the fundamental and latest scientific achievements on the researched problems.

6. Contributions of the dissertation work.

The excellent theoretical and practical preparation of the doctoral student, as well as the precisely conducted experiments and analyses of the data from them, enable him to form 11 contributions, divided into two groups (scientific-theoretical - 6 pcs. and scientific-applied - 5 pcs.) as follows:

Scientific and theoretical contributions

1. It has been clearly shown and statistically proven that against the background of the genotype x environment interaction in basic productivity traits, a multi-layered assessment of the variety is possible against the background of a large group of studied samples.
2. An integrated methodology for evaluating winter wheat varieties has been introduced, which combines multivariate statistics (ANOVA, AMMI, REML), yield component analysis and multitrait integration (MGIDI, MTSI, WAASBY 50:50), summarized by the rank-order aggregation (RRA) method.
3. NGM has proven its leading role in consistently high productivity in various environments.
4. Three fundamentally distinct, but mutually complementary statistical approaches for objective assessment have been identified, which can serve as the basis for a targeted assessment of the variety in a given group, depending on the specific goal set.

5. A protocol has been developed whose logical step-by-step reproduction, even when changing the specific parameters, leads to similar rankings of the analyzed varieties.
6. Grouping genotypes based on combinations of their specific trait levels is a significantly more precise assessment than one based solely on yield or a trait directly influencing it.

Scientific and applied contributions

1. Genotypes with high productivity and stability have been identified, suitable for introduction and use as starting material in crosses.
2. Specific guidelines are provided for selection choices based on prioritizing NGM under maintained TGW, which optimizes selection in different environments.
3. A transparent and easily reproducible evaluation protocol has been developed, which reduces data processing time and increases reproducibility in breeding practice.
4. A specific statistical approach for balanced evaluation by combining productivity and stability is illustrated.
5. The application of integrated indices leads to a different ranking of genotypes compared to a classification based only on average yield, and this reordering reflects the real influence of the genotype × environment interaction.

7. Critical notes and questions.

I have no critical remarks or questions for the doctoral student. I recommend that he continue his work on the problems of the interaction of common wheat varieties and the environment, not only from a breeding point of view, but also in the direction of variety agro technics in wheat. Since in the conditions of climatic and genetic changes the problem will become increasingly relevant, if possible, he should expand the research to other points in the country as a large-scale national project.

8. Published articles and citations.

According to the minimum scientometric requirements specified in the Regulations for the Implementation of the Academic Staff Development Act, 2 publications related to the dissertation are specified, which fully cover the required number of required points. One article is co-authored, and the other is independent.

The submitted abstract objectively reflects the structure and content of the dissertation. Although citations are not required, the doctoral student has submitted a reference for the presence of 5 citations.

CONCLUSION:

Based on the various research methods learned and applied by the PhD student, the correctly conducted experiments, the generalizations and conclusions made, I believe that the presented dissertation meets the requirements of the Law and the Regulations of the Agricultural University for its application, which gives me reason to evaluate it **POSITIVELY**.

I would like to propose to the esteemed Scientific Jury to also vote positively and award Georgi Stoyanov Raykov the educational and scientific degree of " ***Doctor*** " in the scientific specialty of Field crops.

Date: 16.02.2026
city of Plovdiv

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