REVIEW

For PhD thesis elaborated in the higher aducation field 6. Agricultural Sciences and Veterinary Medicine, professional direction 6.1. Crop production, scientific speciality "Fodder production, meadow cultivation".

Author of the dissertation: Georgi Stoyanov Stoyanov, part-time doctoral student at the Department of Crop production, Agricultural University - Plovdiv, in the doctoral program "Fodder production, meadow cultivation", professional field 6.1 Crop production, higher aducation field 6. Agricultural Sciences and Veterinary Medicine, research supervisors: Assoc. Prof. Atanas Sevov, PhD and Assoc. Prof. Velika Kuneva, PhD.

Topic of the dissertation: "Study of the possibilities of using mathematical models for managing the yield of maize (*Zea mays* L.), grown in different directions".

Reviewer: Prof. Tatyana Ivanova Bozhanska, PhD, Research Institute of Mountain Stockbreeding and Agriculture - Troyan, higher aducation field 6. Agricultural Sciences and Veterinary Medicine, professional direction 6.1. Crop production, scientific speciality "Fodder production, meadow cultivation", appointed as a member of the scientific jury by Order № RD-16-823/04.07.2025 of the Rector of the University of Agriculture.

I. Short presentation of the candidate

Georgi Stoyanov Stoyanov was born on 08.01.1997 in the town of Stara Zagora. In 2016 he graduated completed his secondary education in from the Professional High School of Civil Engineering, Architecture and Geodesy "Lubor Bayer" - Stara Zagora, and in 2021 he obtained a diploma of higher education series AU - 2020, № 319433, reg. № 27604/2020 issued by the Agricultural University - Plovdiv for the educational qualification degree of Bachelor in the specialty "Agronomy - Farming", professional qualification "Agronomist" and Master's degree in the specialty "Mineral Nutrition and Fertilization of Crops".

Since November 2022, Georgi Stoyanov Stoyanov is a part-time doctoral student at the Department of Crop production at the University of Plovdiv. In the meantime, in the period 2018-2022, he worked as an agronomist-consultant at Lebozol® Bulgaria Ltd, representative of ACM Ltd and logistics organizer at the trade cooperative "G-8" - Stara Zagora. He is fluent in written and oral English and German, which is an advantage in future scientific activity. He works in the Internet environment, has computer skills for working with Microsoft Office (Word, Exsel, PowerPoint) and excellent training in the disciplines of "Maize Cultivation Technology", "Statistical Data Processing" and "Scientific Ethics".

By Order № RD 26-71/23.12.2021 of the Rector of the Agricultural University -

Plovdiv, Georgi Stoyanov Stoyanov was enrolled in the Department of Crop production, doctoral program "Fodder production, meadow cultivation", professional direction 6.1. Crop production, higher education field 6. Agricultural Sciences and Veterinary Medicine.

On the basis of Article 40 of the Regulations for the implementation of the Law on the development of academic staff (Official Gazette №75 of 24.09.2010, 15 of 19.02.2019) at the Agricultural University - Plovdiv, the decision of the Faculty Council of Agronomy (Protocol № 2/06.02.2025) and the Order № RD 26-51/20.06.2025 of the Rector of the Agricultural University - Plovdiv, Georgi Stoyanov Stoyanov is dismissed with the right to defend his dissertation.

II. The Actuality of the Problem

Maize (*Zea mays* L.) is a major cereal crop in Bulgaria with high, genetically determined productivity. To realize this potential, it is necessary to optimize basic agronomic factors. Genetic and breeding issues in maize are related to increasing crop productivity by improving quantitative and qualitative grain and green mass indicators, as well as some morphological and economic traits.

The results in the present dissertation illustrate the capabilities of statistical mathematical modelling in predicting the yield of maize (*Zea mays* L.) grown in different directions. Precise and accurate mathematical methods are a common approach to describe and model data from scientific experiments. They are a priority in modern agricultural science to carry out a multifaceted and in-depth analysis of the relationships between the traits under study (meteorological indicators, phenological development, biometric indicators, yield structural elements, productivity, quality indicators). Data mining methods allow to obtain or extract useful knowledge from the data, to develop and propose models from the data, to support decision making on the development, productivity and quality of the crop under study.

The mathematical models proposed for predicting and managing grain and green mass yield in maize hybrids treated with micro- and macronutrient-enriched preparations are highly significant for the advancement of scientific research and agricultural practice.

III. Aim, objectives, hypotheses and research methods

This dissertation aims to develop mathematical (analytical) models for yield management of maize (*Zea mays* L.) grown in various conditions. The experimental work is organised into seven scientific tasks, namely:

- Investigating the productive potential of maize grown for grain and silage.
- Construction and investigation of models to determine the effect of leaf products on maize hybrid yield.
- Modelling crop yield in relation to structural elements.
- Using mathematical models to illustrate the influence of weather conditions and imported leaf products, evaluate the optimal variation intervals and possible changes in quality indicator values.
- Compare the results of the applied methods, the obtained models and their qualities for predicting the values of the dependent variable against real data.
- Statistical analysis using the CART method to select suitable models.
- Error diagnosis, analysis and evaluation of the constructed models.

The research methodology is subordinate to the main objective of applying data mining with machine learning methods to statistical modelling and investigating dependencies

in the values of meteorological, biological and chemical parameters, as well as changes in yield, grain quality and green mass in maize. Five maize hybrids ('DKC4416', 'LG 31.390', 'Premeo', 'Pioneer P9889' and 'Kneja-461') were grown in the Academic Technological Complex (ATC) of Trakia University in Stara Zagora in two directions (grain and silage) and treated with organic products (Aminosol), inorganic products (Lebosol B, Lebosol Zn and Nutriplant 36) and organomineral products (Kinsidro Grow).

The indicators tracked are correctly sequenced according to the study's purpose and reporting requirements. Agroclimatic and soil characteristics for the study period are presented. Average monthly air temperatures and rainfall totals during the crop's growing season are compared with those of a thirty-year period.

In the data processing, mathematical and statistical approaches: variance, correlation, regression, factorial and cluster analysis were applied to evaluate the influence of applied foliar products on maize yield and to construct appropriate models considering the structural and chemical parameters of grain and green matter. Statistically significant differences in the values of some quantitative and qualitative parameters of maize fertilized with organic and inorganic products were determined through correlations calculated and regression equations derived.

From the modern data mining methods for statistical modeling and multivariate data analysis, classification and regression trees (CART) method was applied in the conducted research experiment to process, and analyze real empirical data in crop production. Calculations and data processing were performed using Microsoft Excel and SPSS 26 software products.

IV. Illustration and presentation of the obtained results

The dissertation thesis is developed in a form and volume corresponding to the requirements of the Law on Higher Education in the Republic of Bulgaria and the Regulations for the Implementation of the Law on the Development of the Academic Staff at the Agrarian University - Plovdiv. It consists of 175 pages and the main sections required for such a thesis: title page (1 page), contents (2 pages), introduction (3 pages), literature review (24 pages), aim and objectives (1 page), material and methods (30 pages), results and discussion (84 pages), conclusions (3 pages), contributions (2 pages) and references (25 pages). The sections are developed consistently and thoroughly.

The introduction focuses on introducing the topic and objects of study, as well as the aim of the dissertation thesis. The data illustration includes 36 Tables and 29 Figures, consistent with the methods applied in the study to generate and process information, supporting the systematisation of primary data and derived statistical analyses.

V. Discussion of Results and Literature Used

The Results and Discussion section constitutes the largest part of the dissertation (51.7%). It consists of six subsections:

i) Phenological development;
ii) Crop biometrics;
iii) Structural elements of grain yield;
iv) Productivity;
v) Chemical analyses;
vi) Statistical analyses and models.

The discussion of the obtained results is detailed and follows the tasks set in a logical sequence. This discussion is supported by a comparative analysis of the work of other authors cited in the literature review.

The phenological development of five maize hybrids is studied, as well as the changes in the values of the structural elements of yield and crop quality following the application of foliar fertilisation. Subsections i–v conclude with preliminary findings on the influence of factors on the studied quantitative and qualitative parameters of maize.

The mathematical models presented in Subsection VI describe important linear traits and enable predictions to be made about the degree to which fertilizer inputs influence grain productivity, quality and green mass.

In the study of five maize hybrids from the early and medium-early groups, the results are summarised and synthesised into 15 conclusions related to the influence of meteorological conditions, and the positive effects of applying multi- and single-component fertilisers on the length of the growing season, morphological traits, yield, and the chemical composition of the grain and silage crops.

A reliable pattern of increased trait parameters was observed: crop height (up to 119.7%), number of leaves per crop (up to 13.7%), cob length (up to 12.9%), number of rows per cob (up to 5.8%), number of grains per row (up to 33.1%), mass per 1000 seeds (up to 28.5%), green mass yield (up to 41.4%), and grain yield (up to 23.6%). A two-factor analysis of variance was used to determine the percentage effect of each predictor (hybrid and fertiliser) and their interaction on these indices. It was found that, of the maize hybrids studied, the applied fertiliser had the most significant effect on grain yield (72.3%) and green mass yield (81.3%).

Foliar treatment with the combination: Aminosol + Lebosol B + Lebosol Zn and Nutriplant 36, increased crude protein content in dry matter of green matter and grain by 15.2 and 19.0%, respectively.

There was a proven, positive correlation between the height of the treated crops with the number of leaves ($r = 0.866$); the mass per 1000 grains with the length of the cob ($r = 0.806$) and the number of grains per row ($r = 0.815$); the green mass yield with the length of the cob ($r = 0.830$) and the mass per 1000 grains ($r = 0.953$), and the grain yield with the number of grains per row ($r = 0.866$).

Regression models were developed to determine the influence of foliar fertilisers on the productivity of maize hybrids for grain and silage production. These models had high coefficients of determination ($R^2 = 0.9283$ and $R^2 = 0.8553$, respectively).

Hierarchical cluster analysis identified the clustering sequence of the study sites. Based on 18 tracked metrics, the hybrids were evaluated and grouped into two clusters of varying proximity. The hybrids DKC 4416, LG 31.390 and Premeo showed similar economic traits in terms of grain yield, number of leaves per crop, cob length, number of rows per cob, nitrogen-free extract content, ash content and crude fat content. Meanwhile, the hybrids Pioneer P9889 and Kneja-461 showed similar traits in terms of silage yield, number of grains per row and ash content.

Given the volume of data and the data mining analysis, the classification and regression trees (CART) method is proposed for the decision variables 'green mass yield' and 'grain yield'. The strength of the influence of the individual variables on the main structural elements of yield in the studied maize hybrids was determined.

Of the 191 literature sources used, 24 (12.6%) were in Cyrillic and 167 (87.4%) in Latin. This is undeniable evidence of the doctoral student's excellent knowledge of the literature and theoretical background. Furthermore, the doctoral student demonstrates an ability to logically interpret the emphases in the relevant literature.

VI. Contributions to the dissertation thesis

Contributions of a scientific-theoretical (5 items) and scientific-applied (5 items) nature have been formulated. The author considers these to be well-founded and of value for both theoretical research and practical applications. The most significant of these can be summarised as follows:

Scientific and theoretical contributions: highlight specific regularities in the growth, development, and vegetation duration of five maize hybrids ('DKC4416', 'LG 31. 390, Premeo, Pioneer P9889 and Kneja-461) from the early and medium-early group according to the FAO. The influence of organic-mineral fertilisation on grain yield and green mass was also investigated in Southeastern Bulgaria. Regression models have been developed, and a CART-type machine learning data mining model presented. These allow the influence of foliar fertilisers on the productivity of the studied maize hybrids to be predicted with a high degree of reliability. A positive correlation has been found between the number of leaves and crop height ($r = 0.866$), grain yield and ear length ($r = 0.596$) and mass per 1000 kernels ($r = 0.758$).

Scientific and applied contributions: the most suitable maize hybrids for intensive production (Premeo, Pioneer P9889 and DKC 4416) have been identified; a scientifically based foliar fertilisation technology has been developed, proposing specific combinations of the tested preparations to optimise technological parameters such as yield and crude protein content in green mass and grain; and a practical basis for precise fertiliser management has been established, including the possibility of adapting the model to different maize hybrids and production types (e.g. biomass or grain).

VII. Critical remarks and questions

I have no questions for the doctoral student. However, from a technical point of view, I would like to make the following comments:

Citation Format: The citation of literary sources within the text should be standardized. For example, references currently at the end of the sentence written as: "Koteva et al. (2014)" (page 12); "Damian et al. (2017)" (page 13), etc., should follow the standardized format: (Koteva et al., 2014); (Damian et al., 2017). Similar inconsistencies appear throughout the manuscript and should be corrected.

Reference List Formatting: Some entries in the "References" section are missing page numbers, contain unnecessary commas and periods, or have formatting inconsistencies. These should be carefully reviewed and revised according to the appropriate citation style.

Clarification in Aims and Objectives: In the "Aims and Objectives" section, objective 4 currently reads: "... to assess the optimal intervals of their change and the possible decreases in quality indicators." This should be corrected to: "... to assess the optimal intervals of their change and the possible increases/changes in quality indicators."

Standardization of Variety Names: In the "Materials and Methods" section, the names of the studied varieties are presented in Latin, but Cyrillic versions appear in the text (e.g., on page 76: "... Premeo and LG 31.390 have 1.2 units") this should be standardized throughout the dissertation to ensure consistency.

VIII. Published articles and citations

The three scientific publications related to the dissertation are as follows: one in the *Scientific Papers journal. Series A: Agronomy*; and two presented at the 10th International Conference of Young Scientists in Plovdiv and published in the Scientific Proceedings of the Union of Scientists in Bulgaria, Series B: Natural Sciences and Humanities. The doctoral

student is the sole author of one of the articles and a co-author of the others with the scientific advisors. The number and quality of the publications fully meet the minimum national requirements for the educational and scientific degree of 'Doctor'.

I note that one of the publications has been cited in a refereed journal indexed in the *Web of Science* global scientific information database with a Q4 rating.

The abstract provides an objective reflection of the structure and content of the thesis. It includes the main sections, as well as the results, conclusions and contributions. It also contains a list of scientific publications and a short summary in English. The 36-page document contains 15 tables and 16 figures.

CONCLUSION:

Based on the various research methods employed by the doctoral student, the correctly conducted experiments, and the generalisations and conclusions drawn, I deem the submitted dissertation to align with the stipulations of the Law on the Development of Academic Staff in the Republic of Bulgaria and the Agrarian University's regulations for its implementation. This leads me to evaluate it **POSITIVELY**.

I would like to propose to the esteemed Scientific Jury that they also vote positively and award **Georgi Stoyanov Stoyanov** the educational and scientific degree of "Doctor" of Science in the specialty of "Fodder production, meadow cultivation".

29.08.2025

Plovdiv

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