REVIEW

For PhD thesis elaborated in the higher education 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 at the Agricultural University – Plovdiv.

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. Boryana Georgieva Churkova, PhD; Research Institute of Mountain Stockbreeding and Agriculture - Troyan, direction of higher education 6. Agricultural Sciences and Veterinary Medicine, professional direction. 6.1. Crop production, scientific specialty "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.

1. Short introduction of the candidate.

Georgi Stoyanov Stoyanov was born on 08.01.1997. In the period 2016-2020 he studied at the Agricultural University - Plovdiv, where he received a Bachelor's degree in "Agronomy - Farming", and subsequently a Master's degree in "Mineral nutrition and fertilization of crops". In the period 2020-2022 he worked as a sales representative of ACM-Montana, and from 01.10.2022 he is an agronomist-consultant at Lebozol Bulgaria. He is enrolled in the doctoral part-time studies at the Department of Crop production at the Agrarian University by Order RD 05-26-71/23.12.2021 of the Rector of the University.

The doctoral student has passed the examination in forage production, crop production (Protocol № D-08/31.01.2024) and examinations in the following disciplines: maize cultivation technologies, scientific ethics, statistical data processing, after which he was discharged with the right to defend according to Order RD 26-51/20.06.2025. There are 3 published articles on the dissertation. Two of them are in the Proceedings of the Union of Scientists in Bulgaria-Plovdiv, one is independent and the other in co-authorship with the research supervisor. The third article was published in a scientific journal indexed in a world database web of science.

2. The reality of the problem.

Ever-changing climatic conditions have recently made upgrading crop production technologies necessary. Maize is a key crop for food and economic resources. High and sustainable yields depend on balanced and precise fertilisation that takes into account hybrid characteristics, developmental phenophases and the agrotechnics used. In this regard, the dissertation presents applied mathematical modelling of foliar fertilisation of maize, enabling the prediction, management and estimation of development and yield. The relevance of the thesis, which will benefit science and agricultural practice, is determined by the indication of adaptation measures integrated into models that reduce the negative effects of climate change on yields and thus on farmers' incomes. The introduction of modern data processing methods, such as the derivation of correlation dependencies, regression equations, coefficients of determination, the CART method, two-factor analysis of variance, the power of dependence and factor analysis, which prove the influence of individual factors both independently and in interaction, define the dissertation research as highly relevant in scientific terms.

3. Aim, objectives, hypotheses and research methods.

The aim of the scientific research is to develop mathematical (analytical) models for five maize hybrids with different origins and generations for silage and grain production.

This objective is realised by solving the following problems:

Study of the productive capabilities of the crop in the areas of silage and grain production; study of models for the influence of leaf products on yield; modeling of yield depending on structural elements; assessment of the optimal intervals of change in meteorological conditions and applied leaf products, as well as possible quality increases based on developed models; comparison of the results of the applied methods and the obtained models and their qualities for predicting the values of the dependent variable compared to real data; Statistical analysis with the application of the CART method for selecting adequate models; Diagnosis of errors, analysis and evaluation of the constructed models.

The goal and objectives are realised by setting up a field experiment involving a fertiliser trial under irrigated conditions at the Academic Technological Complex of the University of Trakia in Stara Zagora between 2022 and 2024. The experiment was conducted using the fractional plots method with four replications and an experimental area size of 15 m². Five maize hybrids and three foliar fertilisation treatments were studied (15 treatments in total). The following three factors were investigated:

1. **Factor A:** maize hybrids (A1 – DKC 4416; A2 – LG 31.390; A3 – PREMEO; A4 – PIONEER P9889; A5 – KNEJA-4).

2. **Factor B:** foliar nutrition products: B1 – control; B2 – nutrition with Aminosol + Lebozol B + Lebosol Zn + Nutriplant 36; B3 – nutrition with Kinsidro Grow + N-Lock.

3. Factor C: Weather conditions during the crop year (C1-2022; C2-2023; C3-2024). The independent action of the factors, as well as their interaction (between A and B), is investigated.

The following indicators were studied: *the Phenological development of maize hybrids*; crop height; the number of leaves per crop; and the *Structural elements of grain yield, including* ear length; the number of rows per ear; the number of kernels per row; the mass per 1000 kernels; and productive indicators, such as grain yield and green mass. Chemical analyses determining biomass quality included protein, crude ash, fat and grain, as well as total ash, protein and crude cellulose content. Based on these analyses, the nutritive value of the forage was calculated. The statistical treatment of the results obtained was presented using *two-factor dispersion analysis, as well as correlation and regression analysis.*

4. Illustration and presentation of the results.

The dissertation is structured in 175 pages, which are distributed as follows: title page-1 pag, Table of Contents – 2 pages, Introduction - 3 pages; Literature review - 24 pages; Aim and objectives of the study - 1 page; Material and methods - 30 pages; Results and discussion - 84 pages; Conclusions - 3 pages; Contributions - 2 pages, References - 25 pages. The literature review covers a total of 191 references, 24 in Cyrillic and 167 in Latin. The work includes 36 tables and 29 figures. The chosen structure is logically linked to the title and the stated aim of the study. The information presented is mostly from contemporary research and demonstrates a good literature awareness of the problem under development.

The "Literature Review'' section is divided into four subsections, organised according to the aims and objectives of the dissertation. It provides a thorough analysis of the origin, distribution and economic importance of maize (*Zea mays* L.). The second subsection presents the influence of diet on the development and productivity of maize for silage and grain production. The influence of climatic factors on maize's growth, development and

productivity is also discussed. The impact of mineral fertilisation involving nitrogen, phosphorus and potassium on maize's productive potential is also reported.

Data are presented on the impact of various foliar organic fertilisers on the chemical composition and nutritional value of maize intended for use as forage, as well as their influence on the structural elements of grain yield. The fourth subsection describes the CERES-Maize model, which simulates the growth of maize, as well as the dynamics of soil, water, temperature, and nitrogen in the field over a growing season. The impact of non-uniform irrigation and nitrogen fertiliser distribution on yields and the environment is established by applying the CERES-NC model using the DSSAT software application program.

5. Discussion of results and literature used.

The analyses of the in-depth studies conducted aimed to investigate the influence of organic fertilisation on five maize hybrids with different FAOs, with respect to indicators that determine the crop's productive capacity, in order to develop mathematical (analytical) models. The main section, **'Results and Discussion'**, consists of six subsections: phenological development; plant biometrics; structural elements of grain yield; productive indices; chemical analyses; and statistical treatment of the obtained data. The results are thoroughly organised and interpreted across 83 pages, and illustrated by 21 tables and 22 figures. Each indicator is presented in a subsection, including the experimental data of the maize hybrids that were studied and fertilised with biofertilisers. The results presented are consistent with the objectives and reflect the fertilisation method and rates using Aminosol + Lebozol B + Lebosol Zn and Nutriplant 36, as well as Kinsidro Grow and N-Lock.

The first subsection describes the phenological development of the five maize hybrids, providing dates for the occurrence of the following phases: emergence; 3rd leaf; spindling; bolting; emergence; milky; waxy; and full maturity. It also studies the influence of temperature and rainfall on the progress of the different phases after organic fertilisation. It was found that, under the conditions in B. Stara Zagora, the DKC 4416 maize hybrid was the earliest, with a vegetation period of 116.3 days; the Kneja-461 hybrid had a registered vegetation period of 124.7 days.

Studies have shown that foliar fertilisation can extend the length of the growing season. Biometric studies include maize crop height and the number of leaves per crop. The application of multi- and single-component fertilisers (Aminosol + Lebosol B + Lebosol Zn and Nutriplant 36) was found to increase the values of these parameters. Compared to the controls, crop height increased by between 8.3% (Kneja-461) and 119.7% (Premeo), and the LG 31.390 and Pioneer P9889 hybrids increased the number of leaves.

The structural elements of grain yield presented in the second subsection include data on ear length, number of rows per ear, number of kernels per row, and mass per 1000 kernels of the five maize hybrids after foliar fertilization applied by year and averaged over the period 2022-2024. A positive increasing trend in the parameters of cob length and number of rows per cob as a result of fertilization is presented. Longer cob length was found under the influence of complex treatment with Aminosol +Lebozol B + Lebosol Zn, Nutriplant 36 in Knezha-461 and Premeo hybrids. All hybrids studied increased the number of grains per row after foliar fertilization application, with the highest effect in terms of number of grains per row and weight per 1000 grains in the hybrid DKC 4416b (33.1%).

The third subsection provides information on the productive indicators of green matter and grain yield. The formation of green mass in the five hybrids is strongly influenced by the extra-root fertilisation applied. The combination of Aminosol, Lebosol B and Lebosol Zn with Nutriplant 36 was found to be the most effective in terms of both green mass and grain yield. During the study period, the hybrids with the highest green mass and grain yields were Kneja-

461 (87,816 kg/ha) and Pioneer P9889 (13,515 kg/ha), respectively. The analysis of variance presented shows that factor C, 'foliar treatment products', has the strongest influence on productivity, at 98% (2023) for green mass yield and 83% (2024) for grain yield.

The following subsection, 'Chemical analyses', presents data on indicators that characterise the quality of green matter and grain. Compared to the control, an increase of 15.2% in crude protein content in green mass was found in the Premeo hybrid (105.63 g/kg BW) after treatment with the foliar fertilisers Aminosol + Lebosol B + Lebosol Zn and Nutriplant 36. Off-root fertilisation using Kinsidro Grow and N-Lock increased crude protein levels from 4.8% (DKC 4416) to 13.8% (Premeo). Crude protein levels in grain increased from 4.5% to 19.0% for all hybrids compared to the controls, with the highest increase observed in DKC 4416 and Pioneer P9889. The effect of foliar fertilisation on the energy and protein content of forage crops was negligible.

Section six, 'Statistical analyses and models', presents the correlations between the quantitative and qualitative parameters relating to the application of fertiliser to five maize hybrids. Regression models are developed based on the obtained correlation values.

Strong correlations were found between the parameters 'number of leaves' and 'height' ($r = 0.866$), and between 'ear length' and 'mass per 1000 kernels'. Strong positive correlations were also found between the chemical parameters 'sulphur protein' and 'ash' ($r = 0.858$) in silage hybrids, and between 'crude protein' and 'crude fiber' ($r = 0.839$) in grain hybrids.

The theoretical regression line and regression equation for the fertilisation and silage yield parameters averaged over the study period are presented. On average over the study period, the high correlation coefficient of these two indicators allows a strong dependence to be expressed through the equation $y = 740.856x^2 - 3114.4x + 75023$, with a coefficient of determination $R^2 = 0.8554$. The dependence is even higher in grain production, as proven by the equation $y = -101.52856x^2 + 844.18x + 10,274$, with a very high $R^2 = 9.283$.

Hierarchical cluster analysis formed two clusters. The first cluster comprises the hybrids DKC 4416, LG 31.390 and Premeo, which have similar NFE content, ash content, FC, grain yield, number of leaves, length and number of rows. The second cluster comprises the hybrids Pioner and Kneja-461, which have a similar number of grains per row, ash content and silage yield. The decision tree obtained for the variables 'green mass yield' and 'grain yield' using the CART model is plotted.

The results are proven by properly derived research experiments, in-depth analyses and state-of-the-art statistical treatment of the data. The dissertation statement is clear and precise in style and language. The interpretation of the results is professional, and they are compared with those of other authors.

Based on the results obtained, **15 conclusions** have been formulated, which give a clear picture of the scope and content of the dissertation work. The conclusions are arranged in a logical sequence, following the course of the studied indicators.

6. Contributions of the dissertation.

As a result of the three-year research, the following results have been obtained and are distinguished as **contributions:**

Scientific and theoretical contributions:

1. For the first time, specific patterns in growth, development, and vegetation duration have been established for five early and mid-early maize hybrids under the agro-ecological conditions of Stara Zagora..

2. The quantitative influence of the factors 'foliar fertilisation' and 'hybrid' on grain and green mass yield was determined. The two-factor analysis of variance indicates that the

fertilization factor has a significantly greater influence than the genotype factor, accounting for 72.3% of the variation in grain yield and 81.3% in green mass.

3. Strong positive correlations were demonstrated between major yield structural elements and productivity indices. For example, there was a strong correlation between the number of leaves and height (r = 0.866), as well as between ear length, mass per 1000 grains, and grain yield.

4. The developed regression models ($y = 740.85x^2 - 3114.4x + 75{,}023$ with a coefficient of determination $R^2 = 0.8553$ for green mass, and $y = -101.52x^2 + 844.18x + 10{,}274$ with $R^2 = 0.9283$ for grain yield), along with a data mining model using CART machine learning, enable reliable prediction of the effect of foliar fertilizers.

5. Using hierarchical cluster analysis, the studied hybrids were grouped based on productivity and chemical composition, enabling targeted use in production.

Scientific and applied contributions:

1. The positive effect of foliar fertilization with the combination of Aminosol + Lebosol B + Lebosol Zn and Nutriplant 36 has been confirmed, resulting in increases of up to 49.6% in green mass yield and up to 31.8% in grain yield.

2. Hybrids (Premeo, Pioneer P9889 and DKC 4416) that demonstrate the greatest responsiveness to foliar fertilisation were identified, rendering them ideal for intensive production.

3. Based on the results obtained, specific combinations of foliar fertilisers have been proposed to optimise the technological parameters in maize cultivation, with the aim of increasing the crude protein content in green mass and grain.

4. A scientifically based technology for foliar fertilisation of maize has been developed and is applicable in Southeastern Bulgaria. It is supported by statistically proven results.

5. A practical basis for the precise management of fertilisation in maize has been established, including the possibility of adapting the model for different hybrids and production purposes (e.g. biomass or grain).

7. Critical comments and questions

I would like to make the following comments

1. There is probably in section "Purpose and objectives of the study" a technical error in Task 4 – instead of "increases," it says "decreases" in quality indicators.

2.When summarizing the contributions, the regression equations could be mentioned, not just the coefficients of determination, as they are the basis for forecasting productivity. It would be good to present the models that have been applied to correspond to the topic of the dissertation.

8. Published articles and citations.

The abstract accurately reflects the structure and content of the dissertation, presenting the scientific research, results, conclusions and contributions in a synthesised form.

Three articles based on the dissertation are presented in the abstract, including one independent article and two co-authored with the research supervisors. These articles meet the scientific-metric indicators for the Doctor of Education and Science degree, as set out in the Law on Research and Development and the Regulations on the Conditions and Procedure for the Acquisition of Scientific Degrees and Academic Positions at the Agrarian University.

CONCLUSION:

Based on the various research methods employed by the doctoral student, the correctly conducted experiments, and the resulting generalisations and conclusions, I conclude that the submitted dissertation aligns with the Agricultural University's regulations for its submission, leading me to evaluate it **POSITIVELY**.

I would like to propose to the esteemed Scientific Jury that they also vote in favour and award Georgi Stoyanov the degree of Doctor of Education and Science in the scientific specialty of 'Fodder Production, Meadow cultivation.

Date: 21.08.2025
Plovdiv