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THE VARIATION OF PROTEIN CONTENT IN MAIZE GRAINS IN RELATION TO THE FERTILIZATION LEVEL

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Abstract

The study analyzed the variation of protein content in maize grains under the influence of mineral fertilization. The experiment was organised at the Agricultural Research and Development Station Lovrin, Timis County, Romania. The study was carried out under the conditions of the 2019-2020 agricultural years, on a chernozem type soil with medium fertility. The corn hybrid DEKALB 4541, non-irrigated culture system, was cultivated. Fertilization was done with nitrogen (ammonium nitrate, doses between 0-200 kg ha^{-1} *N, active substance) and phosphorus (concentrated superphosphate, doses between 0-160 kg* ha^{-1} P_2O_5*, active substances). The combination of the two fertilizers resulted in 25 fertilization variants (V0 – control, to V25). The protein content (Pro, %) recorded values between 5.5±0.62% and 9.5±0.73%. The variation of the protein content under the influence of N, on each level of P, was described by polynomial equations of the 2nd degree, under statistical safety conditions (*R^2*=0.854 to *R^2*=0.975). The regression analysis facilitated the description of the protein content variation (Pro, %) in relation to N and P as a direct action and interaction, and the generation of 3D graphic models and in the form of isoquants, under statistical safety conditions. The cluster analysis facilitated the grouping of the variants based on the Euclidean distances, in relation to the similarity for the protein content values generated, in conditions of statistical safety condition (Coph. corr. =0.872).*

Key words**:** *3D model, cluster analysis, maize, mineral fertilizers, protein content, regression analysis*

INTRODUCTION

The consumption demand for vegetable protein resources in the human diet is high and will continue to grow in the coming decades, a number of factors being considered important in this regard [15]. Comparative analyzes highlighted the differences, advantages and benefits of the two categories of protein sources, vegetable and animal, in human nutrition [8, 28].
Studies of protein content from different sources have evaluated functional and nutritional properties for the human or animal body [33].
Maize is a cereal plant of high importance in the world, and the production of grains represents an important source of protein for human consumption, animal consumption, industrialization [13, 25, 38].
The quality of corn production, and especially in terms of protein content, depends on the cultivated genotype but also on the interaction between genotype and environmental conditions [1, 11, 19, 31].
The improvement of the protein content in corn has been addressed both through breeding programs [21, 34], and through culture technologies [2, 18].
The protein content, as an important quality index of agricultural production, has been studied in field crops in relation to productivity elements, and different quantitative and qualitative production elements and indices [16].
Maize is a plant with high ecological plasticity, and it is cultivated on extensive areas in the world and responds differently to the various pedoclimatic conditions [27, 30, 35].
Maize culture, production and quality indices were studied in relation to soil conditions [12, 26], climatic conditions [7, 20], irrigation conditions [9, 12, 24], fertilizers [5, 6, 10], stress factors [23, 36], and other influencing conditions.

The present study evaluated the influence of mineral fertilization with nitrogen (N) and phosphorus (P) on the protein content in corn grains, and found models to describing the variation of the protein content in relation to N and P, respectively calculated the optimal doses for fertilizers in relation to the protein content.

MATERIALS AND METHODS

The study was organised within SCDA Lovrin, Timis County, Romania. The location of the experimental field was made on a chernozem type soil with medium fertility, and the maize crop was in a non-irrigated system. The 2019 – 2020 agricultural years was taken into account. By fertilizing, nitrogen and phosphorus fertilizers were applied differently. Phosphorus fertilizers (concentrated superphosphate, 47% P_2O_5) were applied in doses between 0 - 160 kg P_2O_5 ha^{-1} active substance (a.s.). The phosphorus fertilizers were applied in the fall, and incorporated into the soil with the basic soil works. On each phosphorus level, nitrogen fertilizers (ammonium nitrate, 33.5% N) were applied in doses between 0 - 200 kg N ha^{-1} active substance. Nitrogen was applied twice, in the spring. The combination of the two factors (N and P) resulted in 25 experimental variants, in four repetitions. The size of a plot was 36 m^2. The corn hybrid DEKALB 4541 was cultivated in a non-irrigated system. At physiological maturity, production samples were collected for each experimental variant and repetition. The protein content was determined by NIR photometry, PERTEN INFRAMATIC 9200 apparatus. For the analysis and interpretation of the experimental data, the standard error (SE) was calculated, and the analysis of variance, regression analysis and cluster analysis were used [14, 37].

RESULTS AND DISCUSSIONS

Under the influence of the fertilization options, maize crop, the DEKALB 4541 hybrid, made different use of the nutritional conditions provided, and the qualitative level of grain production, in terms of protein content (Pro, %), recorded different values. Protein content values were recorded between 5.93±0.23% in the case of the V11 variant and 8.75±0.23% in the case of the V20 variant. The values of the protein content obtained under the experimental conditions are presented in Table 1, where the values for the standard error (SE) were calculated, in the case of each variant. The graphic distribution of the protein content variation in relation to the fertilization variants is shown in figure 1.

Table 1. Values of protein content in corn grains, the DEKALB 4541 hybrid, under the influence of mineral fertilization

Experimental variants	N	P	Protein content (Pro) and Standard Error (SE)
	(kg a.s. ha^{-1})	(kg a.s. ha^{-1})	(%)
V1	0	0	6.18±0.22
V2	50	0	7.30±0.63
V3	100	0	7.55±0.46
V4	150	0	7.98±0.29
V5	200	0	7.98±0.27
V6	0	40	6.15±0.15
V7	50	40	6.93±0.60
V8	100	40	7.28±0.27
V9	150	40	8.03±0.31
V10	200	40	8.05±0.30
V11	0	80	5.93±0.23
V12	50	80	7.48±0.49
V13	100	80	7.58±0.14
V14	150	80	8.50±0.29
V15	200	80	8.03±0.22
V16	0	120	6.18±0.19
V17	50	120	6.33±0.16
V18	100	120	7.73±0.14
V19	150	120	8.28±0.21
V20	200	120	8.75±0.23
V21	0	160	6.23±0.24
V22	50	160	7.68±0.73
V23	100	160	7.48±0.46
V24	150	160	7.98±0.33
V25	200	160	8.30±0.25

Source: original data recorded from the experiment.

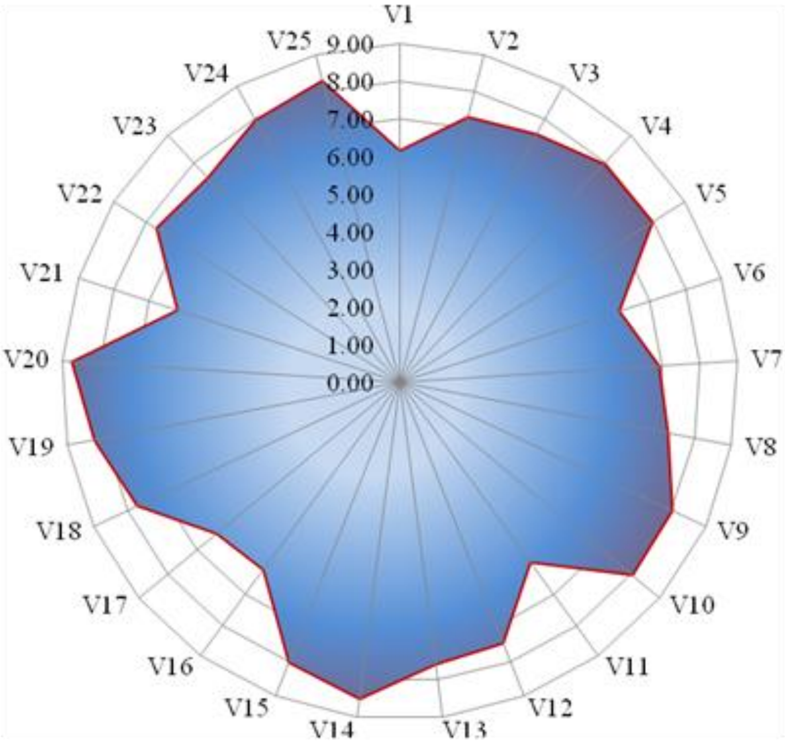

Fig. 1. The graphic distribution of the protein content (Pro, %) in corn grains in relation to mineral fertilization
Source: original graph based on experimental data.

The variation of the protein content in relation to the doses of nitrogen (N) on each level of phosphorus (P) was described by polynomial equations, under conditions of statistical safety; equation (1) described the protein variation in relation to N on the P0 fertilization level, under conditions of R^2=0.973, p=0.0267, F=36.355; equation (2) described the protein variation in relation to N on the P40 fertilization level, under conditions of R^2=0.975, p=0.025, F=38.989; equation (3) described the protein variation in relation to N on the P80 fertilization level, under conditions of R^2=0.924, p=0.0765, F=12.071; equation (4) described the protein variation in relation to N on the P120 fertilization level, under conditions of R^2=0.945, p=0.053, F=17.076; equation (5) described the protein variation in relation to N on the P160 fertilization level under conditions of R^2=0.854, p=0.145, F=5.8751.

$$\text{Pro}_{(\text{N,P0})} = -5.886E-05x^2 + 0.02033x + 6.248 \quad (1)$$

$$\text{Pro}_{(\text{N,P40})} = -3.2E-05x^2 + 0.0162x + 6.148 \quad (2)$$

$$\text{Pro}_{(\text{N,P80})} = -9.2E-05x^2 + 0.02884x + 6 \quad (3)$$

$$\text{Pro}_{(\text{N,P120})} = -6E-06x^2 + 0.01538x + 6.006 \quad (4)$$

$$\text{Pro}_{(\text{N,P160})} = -4.457E-05x^2 + 0.01779x + 6.423 \quad (5)$$

where: x – nitrogen doses, kg a.s. ha^{-1}.

The regression analysis led to obtaining the equation (6) which described the variation of the protein content in the corn grains, in relation to N and P, as a direct and interaction effect, under statistical safety conditions, R^2=0.941, p<0.001, F=63.4889. The graphic representation of the protein content variation in corn grains, under the experimental conditions, is represented in the form of a 3D model in Figure 2, and in the form of isoquants in Figure 3. Based on the values of the coefficients of equation (6), the optimal values for N and P were calculated in relation to the protein content (Pro, %), and x_{opt}=151.20 kg ha^{-1} (N), respectively y_{opt}=83.13 kg ha^{-1} (P) were found in the experimental conditions. For high calculation accuracy, the values of the coefficients of equation (6) had values up to 16 decimal places.

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$$\text{Pro} = ax^2 + by^2 + cx + dy + exy + f \qquad (6)$$

where: Pro – protein content (%);
x – nitrogen dozes (N, kg ha^{-1});
y – phosphorus doses (P, kg ha^{-1});
a, b, c, d, e, f – coefficients of the equation (6);
a= -0.00019579;
b= -0.00022802;
c= 0.07985390;
d= 0.07546559;
e= -0.00024838;
f= 0

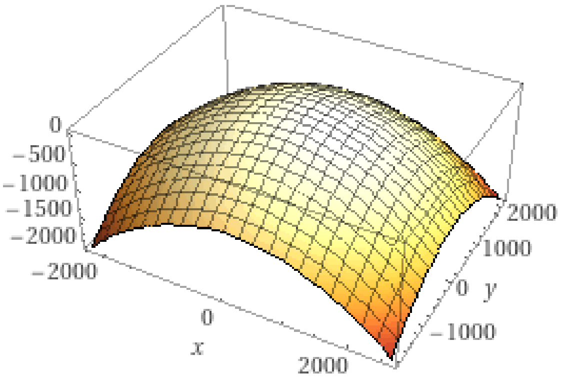

Fig. 2. 3D model of protein variation (Pro) in corn grains in relation to the doses of nitrogen N (x-axis) and phosphorus P (y-axis)
Source: original graph based on experimental data

The increase in protein content in relation to the level of nitrogen was calculated for each level of phosphorus, and the results are presented in Figure 4.

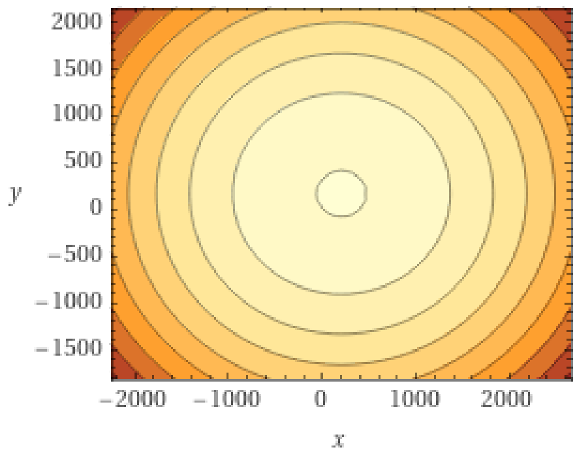

Fig. 3. Graphical representation in the form of isoquants of the variation of protein (Pro) in corn grains in relation to the doses of nitrogen N (x-axis) and phosphorus P (y-axis)
Source: original graph based on experimental data

On the P0 level, nitrogen generated an increase in the protein content between 1.13 - 1.80%, associated with nitrogen doses between 50 - 200 kg ha^{-1}.

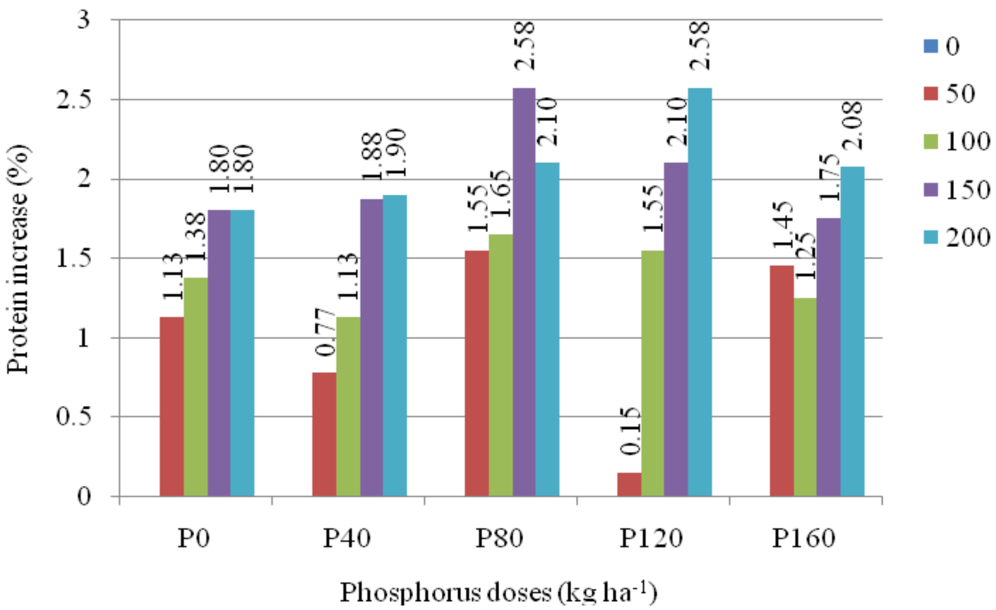

Fig. 4. The increase in protein content generated by N on each level of P, the maize DEKALB 4541 hybrid
Source: Original graph, based on calculated data.

On the P40 level, nitrogen generated an increase in the protein content between 0.77 - 1.90%, in relation to the doses of N applied (50 - 200 kg ha^{-1}).

On the P80 level, nitrogen applied in doses between 50 - 200 kg ha^{-1} generated increases

in the protein content between 1.55 - 2.58 %.
On the P120 level, the increase in protein content generated by nitrogen, in the administered doses, was between 0.15 - 2.58%.
On the P160 level, the increase in protein content determined by nitrogen, in the administered doses, was between 1.25 - 2.08%.
High values of the protein increase, obtained by calculations on the experimental variants, (Pro=2.58%) were recorded in the conditions of P80 and N150, but also in the conditions of P120, N200, Figure 4. In the version of fertilization with N200 on the level of P120, the costs are already higher with the related doses of fertilizers, so that, in terms of protein content, lower doses of fertilization, with similar results, are justified.
The cluster analysis facilitated obtaining the diagram represented in Figure 5, under conditions of statistical safety (Coph. corr=0.872). The association of variants based on Euclidean distances led to the formation of two distinct clusters (C1 and C2) with several sub-clusters within each.

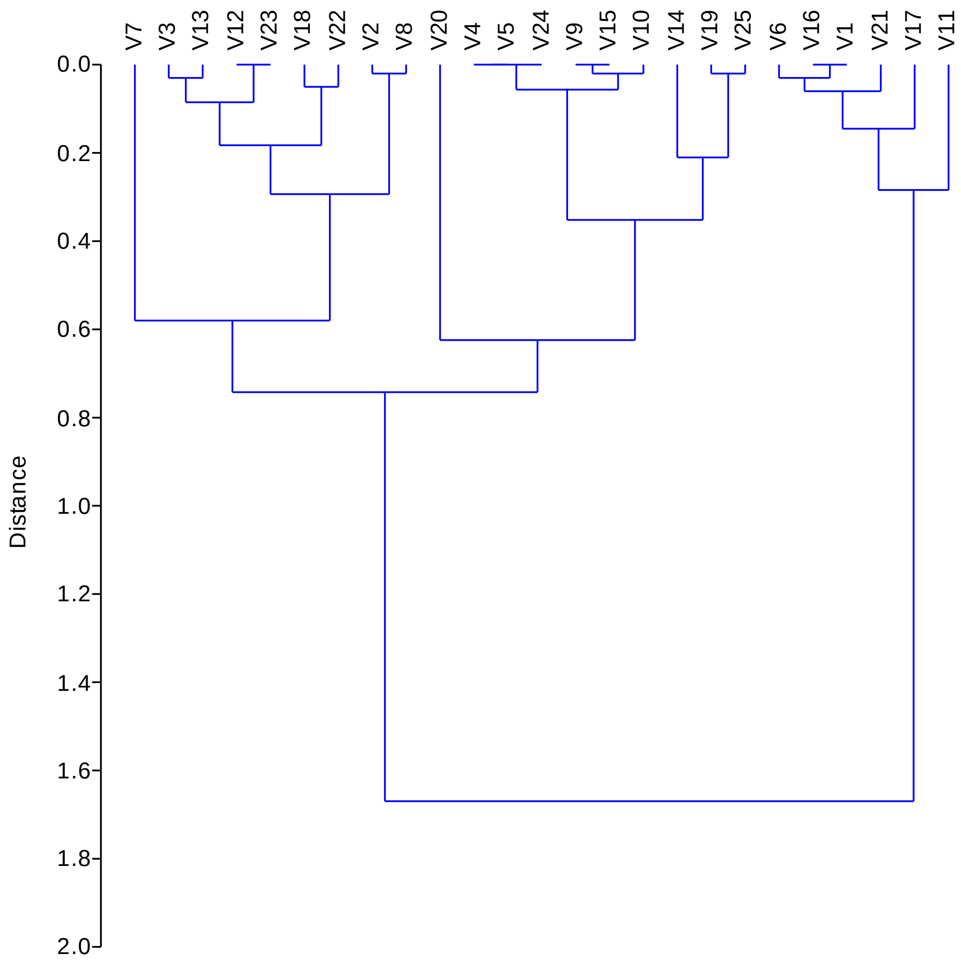

Fig. 5. Cluster diagram of variants grouping based on Euclidean distances in relation to protein content in corn grains, the DEKALB 4541 hybrid
Source: original figure based on experimental data.

Cluster C1 included variants with low protein content (V1, V6, V11, V16, V17 and V21). Within the C1 cluster, a high level of similarity was found in relation to ensuring the protein content between the V1 and V16 variants.
Cluster C2 includes variants grouped in two distinct sub-clusters (C2-A and C2-B), each with several sub-clusters.
Sub-cluster C2-A includes variants with high protein content (V4, V5, V9, V10, V14, V15, V19, V20, V24 and V25). Within this sub-

cluster, a high level of similarity was found in the case of variants V4, V5, V24 and respectively in the case of variants V9 and V15. The V20 variant with the highest protein content was positioned independently within the C2-A sub-cluster.

The sub-cluster C2-B includes the variants (V2, V3, V7, V8, V12, V13, V18, V22 and V23), with intermediate values of the protein content. Within this sub-cluster, a high level of similarity was found between the V12 and V13 variants.

The variation of the quality indices, including the protein content in the corn kernels, was analyzed and evaluated in relation to N as a single fertilization, but especially N associated with macro and microelements.

Different techniques, methods and models have been used to describe and predict the variation in production, some quality indices and economic elements in corn crop, in relation to mineral fertilization or technology factors [4, 22, 29].

Căbăroiu et al., (2019) [6] communicated the variation of quality indices in corn grains under the influence of nitrogen (as mineral fertilization on the soil) associated with different doses of silicon (Si) applied foliarly, and highlighted the increase in N efficiency associated with Si, under statistical safety conditions.

The management of fertilizers (especially N) related to corn hybrids was evaluated in order to improve the protein content of corn grains [39], and the importance of fertilization in accordance with the ability of the hybrid to capitalize on fertilizing resources was highlighted.

The significant variation of protein content in corn, along with other qualitative indices, as a genotype x fertilization interaction, was communicated by Illés et al. (2020) [17], based on the use of different statistical analysis methods.

Shynkaruk and Lykhochvor (2021) [32] reported the maximum protein content (11.10%) in corn under the influence of N160P80K140, while for other quality indices (starch 74.20%, fat 4.33%), high values were recorded at lower fertilization rates (N80P40K60) under the experimental conditions.

Based on a study on quality indices in three maize hybrids (FAO middle group) under the influence of mineral fertilization, Bojtor et al (2022) [3] found that the maximum value for protein content was recorded at 120 kg N ha^{-1}, and higher nitrogen values did not lead to an increase in protein content under the study conditions.

Under the conditions of the present study, the applied mineral fertilization, with N and P mineral elements, generated a range of protein content values, as an interaction [genotype x fertilization].

The recorded values, associated with the fertilization variants that generated the nutritional status of the plants and the afferent protein content, grouped in the dendrogram based on the Euclidean distances, constitute an indicative basis for the selection of the different fertilization variants to obtain comparable results, in relation with the technology adopted for grain corn crop.

CONCLUSIONS

Under the study conditions, NP mineral fertilization of the corn crop, the DEKALB 4541 hybrid, led to a set of protein content values, as an effect of the genotype x fertilization interaction, and which can constitute a reference base for research and agricultural practice.

The way of analyzing the experimental data facilitated the grouping of the variants into clusters (fertilization variant groups), with practical importance in the choice of fertilization variants in relation to the budget allocated to the corn cultivation technology, respectively in relation to the production destination and the protein level expected.

The regression analysis facilitated the obtaining of mathematical and graphical models in the form of 3D and isoquants, to describe the variation of the protein content (Pro) in relation to the two nutrition factors N and P, under conditions of statistical safety.

The calculated optimal doses (x_{opt}=151.20 kg ha^{-1} N, respectively y_{opt}=83.13 kg ha^{-1} P) facilitate practical recommendations to optimize the fertilization of the corn crop in relation to the expected protein content.

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