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OPTIMIZATION OF WHEAT FERTILIZATION IN RELATION TO CERTAIN QUALITY INDICES

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Abstract

The study evaluated the variation of some wheat quality indices in order to optimize the mineral fertilization with nitrogen and with the Super Fifty foliar biostimulator. Nitrogen (N) was applied in doses between 0 - 200 kg ha^{-1}, in five variants (N0, N50, N100, N150 and N200). Super Fifty foliar biostimulator (SF) was applied on each level of nitrogen fertilization in six concentrations, between 0 - 5 L ha^{-1} (SF0, SF1, SF2, SF3, SF4, SF5). The Alex wheat cultivar was cultivated under conditions of cambic chernozem soil, with medium fertility. The values of the quality indices of wheat grains, gluten (Glt), starch (ST) and Zeleny Index (Zel) were evaluated. Gluten content (Glt) ranged from 20.33 to 32.93 ± 0.78%. The starch (ST) content varied between 65.99 - 69.93 ± 0.21% and the Zeleny Index recorded values between 36.58 - 77.23 ± 2.56 units. Very strong positive correlations were recorded between the Super Fifty foliar biostimulator (SF) and gluten (Glt) on the N50 fertilization level (r = 0.964), on the N100 fertilization level (r = 0.909) and on the N150 fertilization level (r = 0.923). Strong positive correlations were recorded between the Super Fifty foliar biostimulator (SF) and the Zeleny index (Zel) on the N50 fertilization level (r = 0.893), and on the N100 fertilization level (r = 0.888). From the regression analysis were obtained equations that described the variation of quality indices in relation to N and SF, in conditions of statistical safety (R^2 = 0.963, p<0.001, F = 129.793 for Glt; R^2 = 0.918, p <0.001, F = 56.31099 for ST; R^2 = 0.975, p <0.001, F = 202.4062 for Zel). The optimal doses were calculated for N and SF in relation to the quality indices studied.

Key words: *foliar biostimulator, nitrogen, quality indices, optimization, wheat*

INTRODUCTION

The optimization of production and the market of cereal products are important and widely studied from socio-economic, ecological, production quality, food safety and security perspectives [5], [30], [22], [20], [23], [24], [18].
Fertilizer resources are an important factor in supporting grain production [44], [15].
Nitrogen is one of the elements of major interest from the perspective of agricultural sustainability, food security, in relation to agricultural systems, farm types, agricultural ecosystems and the natural environment, etc., so that many studies have addressed this nutrient [38], [29], [10], [19].
The efficiency of nitrogen use in agriculture has been studied in relation to different soil and climatic conditions, types of agricultural systems, N fertilizing resources, crop plants, yields, etc [35], [33], [13], [2].
Different methods and indicators have been used in relation to the efficient use of nitrogen, plant nutrition, production and quality of agricultural production [41], [8], [25], [43]. Imaging analysis on satellite, aerial or terrestrial images is very useful in evaluating wheat crop based on specific indices [6], [31], [3].
At the same time, various biofertilizing and biostimulating growth products, some with foliar application, have been used to plant nutrition management and plant metabolism control in wheat crops [32], [7].
The content of gluten, starch and the Zeleny Index are important indices for the quality of wheat production, in relation to the use for the food industry, especially for bakery [21], [4], [17], [40].
The elements of productivity and quality in wheat vary major and significant in relation to plant nutrition, fertilization, type and method of fertilizer application [27], [28], [9], [11],

[37], [46].
The present study evaluated the variation of gluten, starch and Zeleny Index in wheat grains, under the influence of nitrogen fertilization and foliar biostimulator Super Fifty, and found models of fertilization optimization in relation to the quality indices studied.

MATERIALS AND METHODS

The study aimed to analyze the variation of gluten content, starch and Zeleny Index, as quality indices in wheat, under the influence of nitrogen and a foliar biostimulator and doses optimization by mathematical analysis.
The Alex wheat cultivar was cultivated in the conditions of a cambic chernozem type soil, medium fertility, in Didactic and Experimental Resort Timisoara, BUASVM Timisoara, Romania. Nitrogen was applied as ammonium nitrate in five doses between 0 - 200 kg N a.s. ha^{-1} (active substance), and the following variants resulted: N0, N50, N100, N150, N200.
The Super Fifty (SF) biostimulator was applied foliar, in six concentrations between 0 - 5 L ha^{-1}, on each level of N (SF0, SF1, SF2, SF3, SF4, SF5). The combination of the two products (N and SF) resulted in 30 experimental variants, in three repetitions.
The content of gluten (Glt), starch (ST) and Zeleny Index (Zel) were evaluated. The determination of the quality indices values was made by the non-destructive NIR-FTIR method. The experimental data were analyzed by the ANOVA test. This analysis facilitated the evidenced of the variance in the data set, as well as the general statistical certainty of the data obtained.
Regression analysis was used to evaluate the interdependence between the quality indices values obtained, and the fertilizer resources used.
The regression analysis facilitated the obtaining of some equations that described the variation of the values of the quality indices in relation to N and SF, as a direct, and interaction influence.PCA was used to obtain the distribution of the experimental variants in relation to the quality indices (Glt, ST and Zel) studied. From the PCA analysis, the values of the variant explained by PC1 and PC2 were obtained.
The Cluster Analysis was used to group the variants based on similarity in generating the values of the studied quality indices.
The analysis and data processing was done with PAST software [12], and for the graphical representation of the quality index values according to N and SF, the Wolfram Alpha software (2020) [42] was used.

RESULTS AND DISCUSSIONS

Nitrogen fertilization, in the range of 0 - 200 kg ha^{-1}, in the five levels provided (N0, N50, N100, N150 and N200), and Super Fifty foliar biostimulator fertilization in 6 doses, on each nitrogen level, between 0 - 5 L ha^{-1} (SF0, SF1, SF2, SF3, SF4 and SF5), led to the variation of the quality indices of wheat grains production, Table 1. Gluten content (Glt) ranged from 20.33 to 32.93 ± 0.78%. The starch (ST) content varied between 65.99 - 69.93 ± 0.21% and the Zeleny Index recorded values between 36.58 - 77.23 ± 2.56 units. The ANOVA test (Alpha = 0.001) confirmed the statistical safety of the experimental data and evidenced the presence of the variant in the data set, Table 2.
The level of correlation between the values of the studied quality indices and the foliar biostimulator (SF), and nitrogen (N), respectively, was analyzed.
Very strong positive correlations were recorded between the Super Fifty foliar biostimulator (SF) and gluten (Glt) on the N50 fertilization level (r = 0.964), on the N100 fertilization level (r = 0.909), and on the N150 fertilization level (r = 0.923), respectively.Strong positive correlations were recorded between the Super Fifty foliar biostimulator (SF) and the Zeleny Index (Zel) on the N50 fertilization level (r = 0.893), and on the N100 fertilization level (r = 0.888).
Moderate, positive correlations were recorded between the Super Fifty foliar biostimulator (SF) and starch (ST) on the N50 fertilization level (r = 0.713), and between the SF and the Zeleny Index on the N150 fertilization level (r = 0.795).

Table 1. Wheat grains quality indices values, Alex cultivar, under the influence of nitrogen and Super Fifty foliar biostimulator

Trial	Independent variable (Nitrogen, Super Fifty)		Quality indices		
	N	SF	Glt	ST	Zel
V1	0	0	20.33	68.85	36.59
V2	0	1	20.53	69.43	36.88
V3	0	2	21.20	69.65	38.21
V4	0	3	22.73	69.68	44.24
V5	0	4	23.63	69.52	44.80
V6	0	5	21.53	69.13	38.97
V7	50	0	22.30	68.68	38.30
V8	50	1	22.87	69.05	40.49
V9	50	2	22.97	69.07	42.53
V10	50	3	25.10	69.74	48.06
V11	50	4	25.53	69.93	55.64
V12	50	5	27.30	68.26	50.01
V13	100	0	26.13	66.81	54.42
V14	100	1	27.63	67.27	59.53
V15	100	2	29.23	67.67	64.32
V16	100	3	30.60	68.25	69.56
V17	100	4	30.23	67.12	68.27
V18	100	5	30.43	66.95	67.81
V19	150	0	29.03	66.82	63.68
V20	150	1	30.17	67.51	65.00
V21	150	2	30.53	67.59	66.18
V22	150	3	31.63	67.44	72.36
V23	150	4	31.53	67.21	69.62
V24	150	5	31.60	67.16	69.47
V25	200	0	32.03	66.00	73.13
V26	200	1	32.17	66.69	73.45
V27	200	2	32.30	66.73	73.48
V28	200	3	32.47	66.76	77.23
V29	200	4	32.93	66.72	75.46
V30	200	5	32.27	66.57	73.28
SE			±0.78	±0.21	±2.56

SE – Standard Error
Source: Original data from the experimental field.

Table 2. ANOVA test, Two-factor

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	68633.36	15	4575.557	6.65801	2.25E-09	2.87868
Columns	28619.21	6	4769.868	6.9407	4.39E-06	4.14999
Error	61850.31	90	687.2257			
Total	159102.9	111				

Source: Data calculated based on experimental results.

Also, weaker intensity correlations were recorded between the Super Fifty foliar biostimulator (SF) and the quality indices studied, in some cases (eg. r = 0.698, between SF and Glt, on the N0 level).

Very strong positive correlations were recorded between nitrogen (N) and some studied indices (r = 0.933 between N and Glt; r = 0.926 between N and Zel Ind), and strong negative correlation was registered between N and ST (r = -0.895).

Starting from the recorded correlation levels, regression analysis was used to evaluate the influence of the two factors (N and SF) on the studied quality indices. For the high accuracy of the analysis, 16 decimals were used for the coefficients of the obtained equations (1), (2), and (3).

From the regression analysis, equation (1) was obtained, which described the variation of gluten content (Glt) in relation to N and SF, in statistical safety conditions, according to R^2 = 0.963, p <0.01, F = 129.793.

$$\text{Glt} = ax^2 + by^2 + cx + dy + exy + f \qquad (1)$$

where:
Glt - gluten content;
x – N doses;
y – Super Fifty (SF) foliar biostimulator;
a, b, c, d, e, f – coefficients of the equation (1);
a= -0.0005739;
b= -0.8988821;
c= 0.2705667;
d= 9.1827594;
e= -0.0281108;
f= 0.

The ANOVA test confirmed the statistical safety for the values of the equation (1) coefficients, as follows: p = 0.0259 for a; p = 0.03369 for b; p <0.001 for c; p <0.001 for d; p <0.001 for e.

The graphical distribution, in 3D form, of the Glt values according to N and SF, is shown in figure 1, and the graphical distribution in the form of isoquants, is shown in Figure 2.

Starting from equation (1), the optimal values for N and SF in relation to the gluten content

(Glt) were determined. The values x_{opt} = 179.28 kg N a.s. ha^{-1}, and y_{opt} = 2.30 L ha^{-1}, respectively, were obtained.

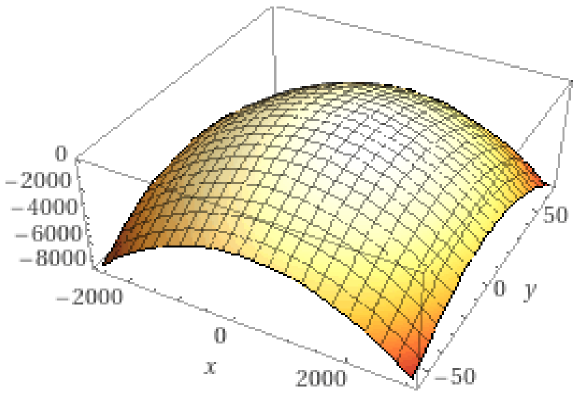

Fig. 1. 3D graphical distribution of Glt index values under the influence of N (x-axis) and SF (y-axis).
Source: Original graph, generated based on experimental data.

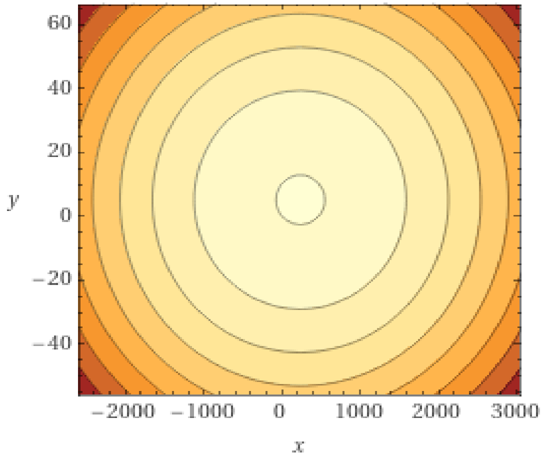

Fig. 2. Graphic distribution in the form of isoquants of Glt index values under the influence of N (x-axis) and SF (y-axis)
Source: Original graph, generated based on experimental data.

The regression analysis facilitated the evaluation of the starch content (ST) variation according to N and SF, as an independent action of the two factors, but also of the interaction. This variation was described by equation (2), in statistical safety conditions, according to R^2 = 0.918, p <0.001, F = 56.31099.

$$ST = ax^2 + by^2 + cx + dy + exy + f \qquad (2)$$

where:
ST - starch content;
x – N doses;
y – Super Fifty (SF) foliar biostimulator;
a, b, c, d, e, f – coefficients of the equation (2);
a= -0.0015411;
b= -3.0299650;
c= 0.6365794;
d= 29.2748572;
e= -0.0937512;
f= 0.

The ANOVA test confirmed the statistical safety of the coefficients of equation (2) values, as follows: p = 0.0901 for a; p = 0.04594 for b; p <0.001 for c; p <0.001 for d; p <0.001 for e.
The graphical representation of ST values according to N and SF is shown in Figure 3, in 3D form distribution, and the graphical distribution in the form of isoquants is shown in Figure 4.

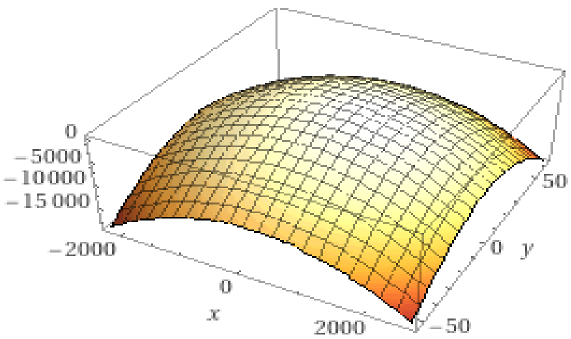

Fig 3. 3D graphical distribution of ST index values in relation to N (x-axis) and SF (y-axis).
Source: Original graph, generated based on experimental data.

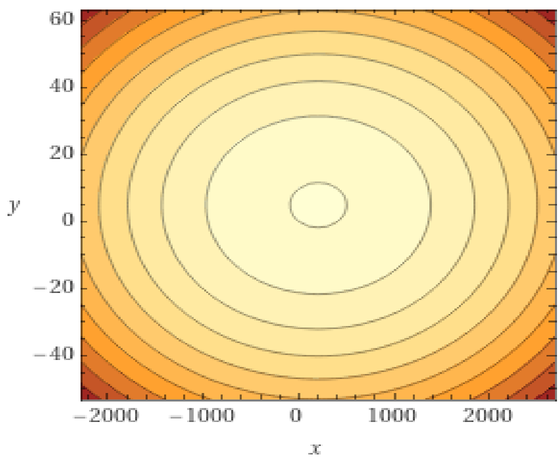

Fig. 4. Graphic distribution in the form of isoquants of ST index values in relation to N (x-axis) and SF (y-axis).
Source: Original graph, generated based on experimental data.

Starting from equation (2), the optimal values for N and SF in relation to the starch content (ST) were determined. The values x_{opt} = 112.56 kg N a.s. ha^{-1}, and y_{opt} = 3,089 L ha^{-1}, were obtained.

The regression analysis evaluated the variation of the Zeleny Index (Zel) values, as a function of N and SF, as an independent action and interaction of these factors. This variation was described by equation (3), in statistical safety conditions, according to R^2 = 0.975, p <0.001, F = 202.4062.

$$\text{Zel} = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

where:
Zel - Zeleny Index;
x – N doses;
y – Super Fifty (SF) foliar biostimulator;
a, b, c, d, e, f – coefficients of the equation (3);
a= -0.0010589;
b= -1.8111150;
c= 0.5621981;
d= 17.7242033;
e= -0.0483577;
f= 0.

According to the ANOVA test, the statistical certainty of the values of the coefficients of equation (3) was confirmed, as follows: p = 0.01828 for a; p = 0.01483 for b; p <0.001 for c; p <0.001 for d; p <0.001 for e.

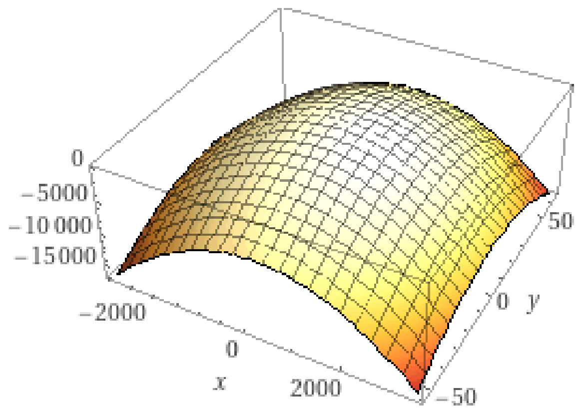

Fig. 5. 3D graphical distribution of Zel index values in relation to N (x-axis) and SF (y-axis)
Source: Original graph, generated based on experimental data.

The graphical distribution of the values of the Zeleny Index (Zel) according to N and SF is shown in Figure 5, in 3D form, and the graphical distribution in the form of isoquants is shown in Figure 6.

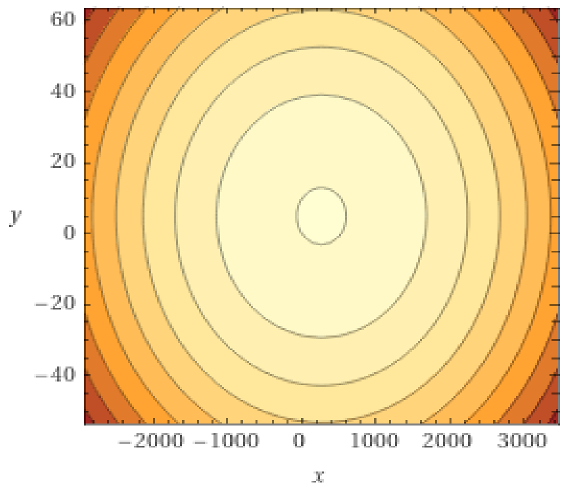

Fig. 6. Graphic distribution in the form of isoquants of Zel index values in relation to N (x-axis) and SF (y-axis)
Source: Original graph, generated based on experimental data.

Starting from equation (3), the optimal values for N and SF in relation to the Zeleny Index (Zel) were determined. Optimal values obtained were: x_{opt} = 221.14 kg N a.s. ha^{-1}, and y_{opt} = 1.941 L ha^{-1}.

Principal Component Analysis facilitated the distribution of the 30 variants according to the values of the studied quality indices. PC1 explained 99.635% of variance, and PC2 explained 0.19327% of variance, figure 7. A high affinity of the V13 - V30 variants with Glt and Zel indices (as biplot) was found, variants that were ensured by applying the Super Fifty biostimulator mainly on the high levels of nitrogen (N100, N150, N200).

The cluster analysis facilitated the grouping of variants based on Euclidean distances, on similarity levels in achieving the values of the studied quality indices (Glt, ST, Zel).

Two distinct clusters were recorded, in which the variants were grouped based on Euclidean distances, in statistical safety conditions, Coph. corr = 0.843, Figure 8.

A C1 cluster included the variants with lower values of the studied quality indices, registered at levels of N0 and N50 and the SF product. Within this cluster, two subclusters [(C1-1), (C1-2)] were formed, with several subclusters each. From the analysis of Similarity and Distance Indices (SDI), high levels of similarity were recorded for variants (V1-V2), SDI = 0.6786, for variants (V3-V5), SDI = 0.97821, and for variants (V4-V5), SDI = 1.072.

Cluster C2 included variants with high values of the studied quality indices, registered on levels of N100, N150 and N200 and the application of the SF product. Within this cluster, two subclusters [(C2-1 and C2-2)] were formed, with several subclusters each.

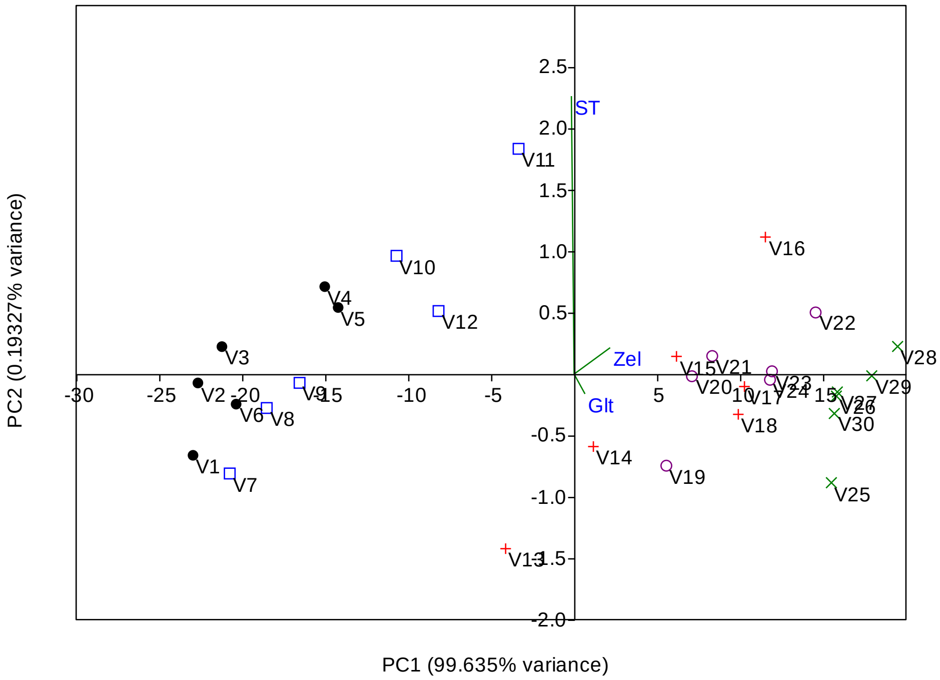

Fig. 7. PCA diagram regarding the distribution of experimental variants in relation to the analyzed quality indices (Glt, ST, Zel as biplot)
Source: Original graph, generated based on experimental data.

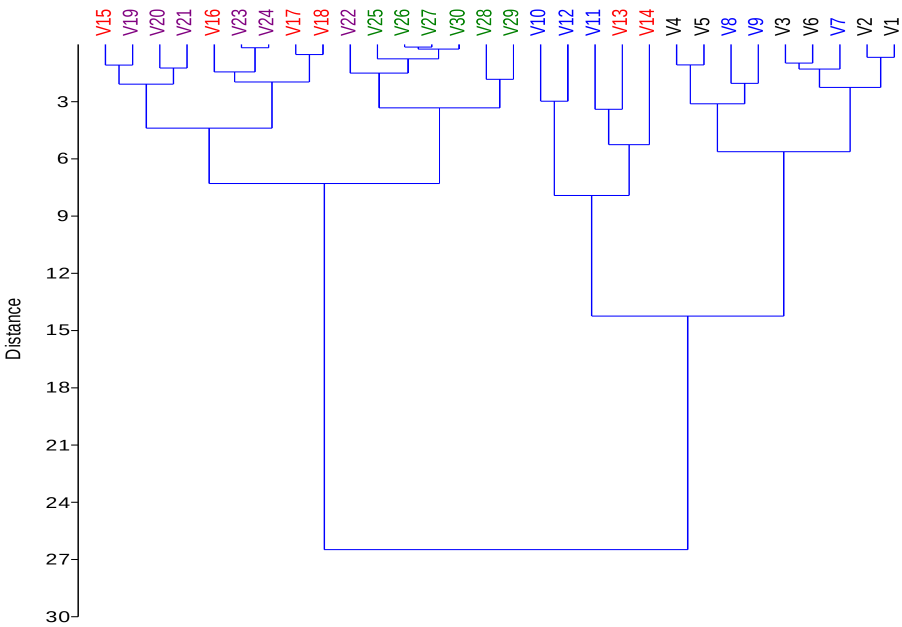

Fig. 8. Cluster grouping of variants based on Euclidean Distances, depending on the values of quality indices, Alex wheat cultivar
Source: Original graph, generated based on experimental data

High levels of similarity were recorded for variants (V26-V27), SDI = 0.13928, for variants (V23-V24), SDI = 0.17292, for variants (V30-V26), SDI = 0.23087, and for variants (V30-V27), SDI = 0.25788, respectively.

The analysis of the values of the quality indices studied, from the aspect of homogeneity, through the coefficient of variation (CV), showed a high degree of variation in the case of the Zeleny Index (CV_{Zel} = 24.1188), a moderate variation in the case of gluten content (CV_{Glt} = 15.5129), and a low degree of variation in starch content (CV_{ST} = 1.7897).

A similar assessment was obtained based on the diversity profile, figure 9, and from the distribution generated for each quality index, a high homogeneity of the data for starch (ST), moderate variation of gluten (Glt), and a high variation of the Zeleny Index (Zel) was found.

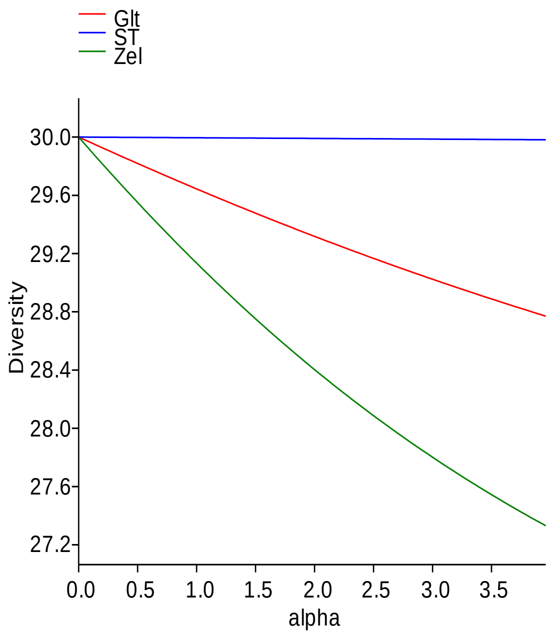

Fig. 9. Diversity profile quality indices in wheat grains, Alex cultivar, under the influence of nitrogen (N) and Super Fifty foliar biostimulator (SF)
Source: Original graph, generated based on experimental data.

From the analysis of the optimal doses for N and SF in relation to the studied quality indices, it can be appreciated that the two fertilizing resources need to be used differently in relation to the quality index which is a priority to be achieved in wheat production, Alex cultivar.

If the priority is the gluten content (Glt), the results obtained, in the conditions of the experiment, recommend that nitrogen (N) be applied at a dose of 179 kg N a.s. ha^{-1}, and the Super Fifty foliar biostimulator in a concentration of 2.30 L ha^{-1}. This combination of the two resources for wheat plants nutrition control, led to optimal values for gluten content (Glt).

In case of if it is desired to optimize the starch (ST) content in wheat grains, in accordance with the results obtained under presented experimental conditions, nitrogen (N) is recommended to be applied at a dose of 112.56 kg N a.s. ha^{-1}, and the foliar biostimulator Super Fifty (SF) to be applied in a concentration of 3.089 L ha^{-1}.

In the conditions in which the aim is to obtain high values for the Zeleny Index, in the wheat grains, according to the obtained results in the experimental conditions described, nitrogen (N) is recommended in higher doses, of 221.14 kg a.s. ha^{-1}, and the Super Fifty (SF) foliar biostimulator in a concentration of 1.94 L ha^{-1}.

The dose of N obtained from the calculations falls outside the experimental range studied (N0 - N200), but expresses the fact that nitrogen supplementation up to the value obtained from the calculation would have led to an increase in the values of the Zeleny Index.

The optimization of wheat production and quality through fertilization has been approached in numerous studies, in different soil and climatic conditions, technology, genotypes and varieties of fertilizer resources, due to the importance of wheat production for food and important sectors of the economy [16].

Zhang et al. (2020) [45] reported results on optimizing the application of nitrogen to wheat crops, in relation to photosynthetic processes, grain production and efficiency of nitrogen and water use in irrigation. Fertilization optimization in agricultural crops has been reported in other studies, and is a permanent concern in agricultural research and practice [34], [33], [36].

The efficiency of root and foliar fertilization in wheat culture has been studied and evaluated in relation to various nutrients, macro- and microelements, in order to ensure a quantitative and qualitative level of production [26], [1], [39].

At the same time, some studies have evaluated the possibility of reducing the dependence of wheat production on nitrogen fertilizers [14].

CONCLUSIONS

The quality indices, as gluten, starch and Zeleny Index, studied in wheat, Alex cultivar, recorded a specific variation, in close correlation with nitrogen (N0 - N200) and the foliar biostimulator Super Fifty (SF0 - SF5).

Regression analysis facilitated the obtaining of equations that described, in statistical safety conditions, the variation of quality indices, gluten (Glt), starch (ST) and Zeleny Index (Zel), in relation to nitrogen (N) and foliar biostimulator (SF), as influencing factors.

The optimal doses for nitrogen (N) and the Super Fifty foliar biostimulator (SF) were calculated in relation to the studied quality indices. Depending on the quality index with high interest, the optimal fertilization dose can be adopted.

PCA analysis and Cluster Analysis facilitated the grouping of variants in relation to the similarity of the response recorded by the quality indices studied, with the possibility to recommend different variants with similar response.

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