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THE VARIATION OF A WHEAT QUALITY INDEX IN RELATION TO MINERAL FERTILIZATION; CASE STUDY ON STARCH

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Abstract

The study evaluated the variation of starch content (ST) in wheat grains, under the influence of mineral fertilization. The experimental were organized and carried out in the period 2020 - 2021, within the SCDA Lovrin, Romania. The Ciprian wheat variety was cultivated by appropriate culture technology, in non-irrigated system, on a chernozem type soil. Three doses for nitrogen was applied (0, 60 and 120 kg ha^{-1}), two doses for phosphorus (0 and 60 kg ha^{-1}), and four doses for potassium (0, 40, 80 and 120 kg ha^{-1}). The starch content (ST, %) was determined by the non-destructive method (NIR), PERTEN INFRAMATIC 9200 device. Values of the starch content were recorded between 68.60–72.17±0.30% in the conditions of 2020 year, 69.15–72.73±0.26% in the conditions of 2021 year, respectively 68.94–72.42±0.28% as average values, over the study period. The data series distribution, average values over study period, was as a normal type, and safety vas confirmed by correlation coefficient (values between r=0.829 in the case of V15, and r=0.985 in the case of V10). ST variation, depending to N and PK (as a direct and interaction effect of fertilizers), was evaluated by regression analysis (R^2=0.880, p<0.001). Based on the values of the coefficients of the obtained equation, the optimal values for N and PK were calculated and the values x_{opt}=75.10 kg N ha^{-1} active substance (a.s.), and y_{opt}=120.00 kg PK ha^{-1} a.s. were obtained. The Cluster analysis used, facilitated the grouping of the tested variants, based on the Euclidean distances, in relation to the starch content values recorded in the wheat grains.

Key words: *cluster analysis, mineral fertilization, optimal doses, starch, wheat*

INTRODUCTION

Wheat is one of the world's main agricultural crops, providing basic resources for human and animal nutrition, as well as for various economic sectors [2, 19]. Wheat production is characterized based on numerous indices, in relation to which it has different directions of use [11, 15]. The quality indices of wheat production are primarily a genetic attribute of the cultivated biological material [25].

The quality level of wheat grains was studied as a result of the interaction [genotype x environment], environmental factors having a variable influence on the cultivated genotypes [5, 20]. The quality level of wheat production is at the same time the result of the interaction [plants x culture technology], through which farmers ensure optimal conditions for growth and development of the wheat crop, and compensate as much as possible the unfavourable effect (sometimes) of environmental factors [27].

Wheat quality indices have been studied by appropriate methods, from different perspectives, genetic, molecular, chemical, biochemical, physical, etc. in order to characterize different genotypes of wheat of importance for food, or fodder for animals, to evaluate the “genotype × environment” interaction, and to control quality indices through crop technologies [13]. Certain wheat quality indices have been studied in relation to different genotypes and growing conditions [6], and with climatic conditions [14]. Wheat quality traits and indices were also studied in order to identify key influencing factors [10]. Within the crop technologies, fertilization has a particularly important role in relation to quality indices of wheat production [28]. The role and importance of nutritional elements (macro- and micronutrient) were evaluated in different cultivated wheat genotypes, in relation to soil and climate conditions, with

plant physiological indices, quality indices and the destination of wheat production [3, 16].
The present study evaluated the variation of starch content in wheat grains in relation to mineral fertilization with NPK, and calculated the optimal doses, in relation to starch content.

MATERIALS AND METHODS

The study was carried out in 2020 - 2021 period, within the SCDA Lovrin, Romania. The wheat crop (Ciprian variety) was placed on a cambic chernozem soil type (medium fertility level), in a non-irrigated cropping system, and an adequate culture technology was ensured.
Mineral fertilizers were applie in three doses in the case of nitrogen (0, 60 and 120 kg a.s. ha^{-1}), in two fertilization levels in the case of phosphorus (0 and 60 kg a.s. ha^{-1}) and in four fertilization levels in the case of potassium (0, 40, 80 and 120 kg a.s. ha^{-1}). Fertilizers with phosphorus and potassium fertilizers were applied in the fall and incorporated with the basic soil work. Nitrogen fertilizers were applied in spring, in two rounds. The variation of the starch content in the wheat grains was evaluated, in relation to the applied mineral fertilization. Starch was determined by the non-destructive method (NIR), PERTEN INFRAMATIC 9200 device.
The analysis of the results was done by appropriate statistical methods, related to established statistical safety parameters (p, r, R^2, Coph.corr.), and the PAST [4] and Wolfram Alpha [23] software were used.

RESULTS AND DISCUSSIONS

Fertilization with mineral fertilizers, applied to the soil, in different doses of nitrogen (N), phosphorus (P), and potassium (K) influenced the nutrition of wheat plants, the Ciprian variety, and determined the variation of the starch content (ST) in the grains of wheat. Also, differences were recorded during the two experimental years, 2020 and 2021, at the same doses of fertilizers. Values of the starch content were recorded between 68.60–72.17±0.30% in the conditions of 2020 year, 69.15–72.73±0.26% in the conditions of 2021 year, respectively 68.94–72.42±0.28% in the case of the average values over the two experimental years. The values of the starch content (ST, %) for the two experimental years, and the average value, are presented in Table 1. The analysis by the Anova test (Alpha=0.001), confirmed the statistical reliability for experimental data, and the presence of the variance in the data set (Table 2).

Table 1. The values of the starch content of wheat, the Ciprian variety, during the study period

Trial	Fertilizers			Experimental period		
	N	P	K	2020	2021	Average values
V1	0	0	0	71.93	72.25	72.09
V2	0	0	40	71.78	72.73	72.25
V3	0	0	80	72.17	72.68	72.42
V4	0	0	120	71.93	71.85	71.89
V5	60	0	0	70.33	70.75	70.54
V6	60	0	40	70.30	71.03	70.66
V7	60	0	80	70.43	71.05	70.74
V8	60	0	120	70.35	70.35	70.35
V9	60	80	0	70.60	70.95	70.78
V10	60	80	40	70.60	71.08	70.84
V11	60	80	80	69.93	71.20	70.56
V12	60	80	120	70.48	71.13	70.80
V13	120	80	0	68.73	69.15	68.94
V14	120	80	40	68.60	69.43	69.01
V15	120	80	80	68.60	70.28	69.44
V16	120	80	120	68.63	69.88	69.25
SE				±0.30	±0.26	±0.28

Source: original data recorded from the experiment.

Table 2. ANOVA test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	148.223	15	9.88157	17.2972	1.33E-22	2.8035
Within Groups	63.9834	112	0.57128			
Total	212.207	127				

Source: original data recorded from the calculation.

The distribution of the data series (average values), is presented graphically in Figure 1, as normal probability plot, under conditions of statistical safety, assessed on the basis of the correlation values (r), with values that fell between r=0.829 in the case V15, to r=0.985 in the case of V10. The graphic representation of the average values for the starch content (ST) on the experimental variants is presented in Figure 2, in the form of a radial plot, with the highlighting of the peaks of values on the directions of the variants' representation.

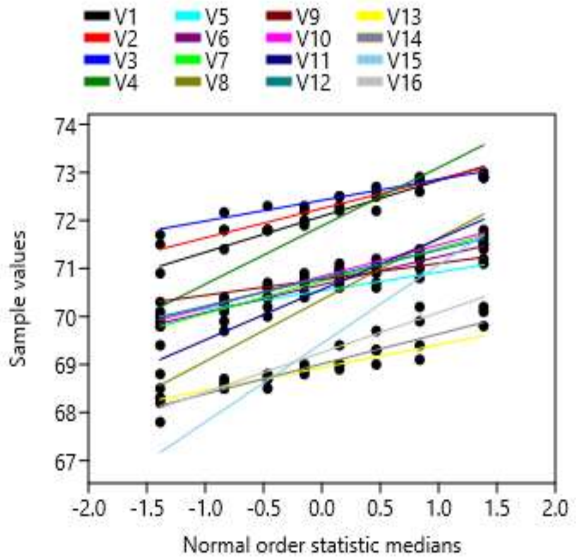

Fig. 1. The graphic distribution of the data series for starch content, as normal probability plot
Source: original graph based on experimental data.

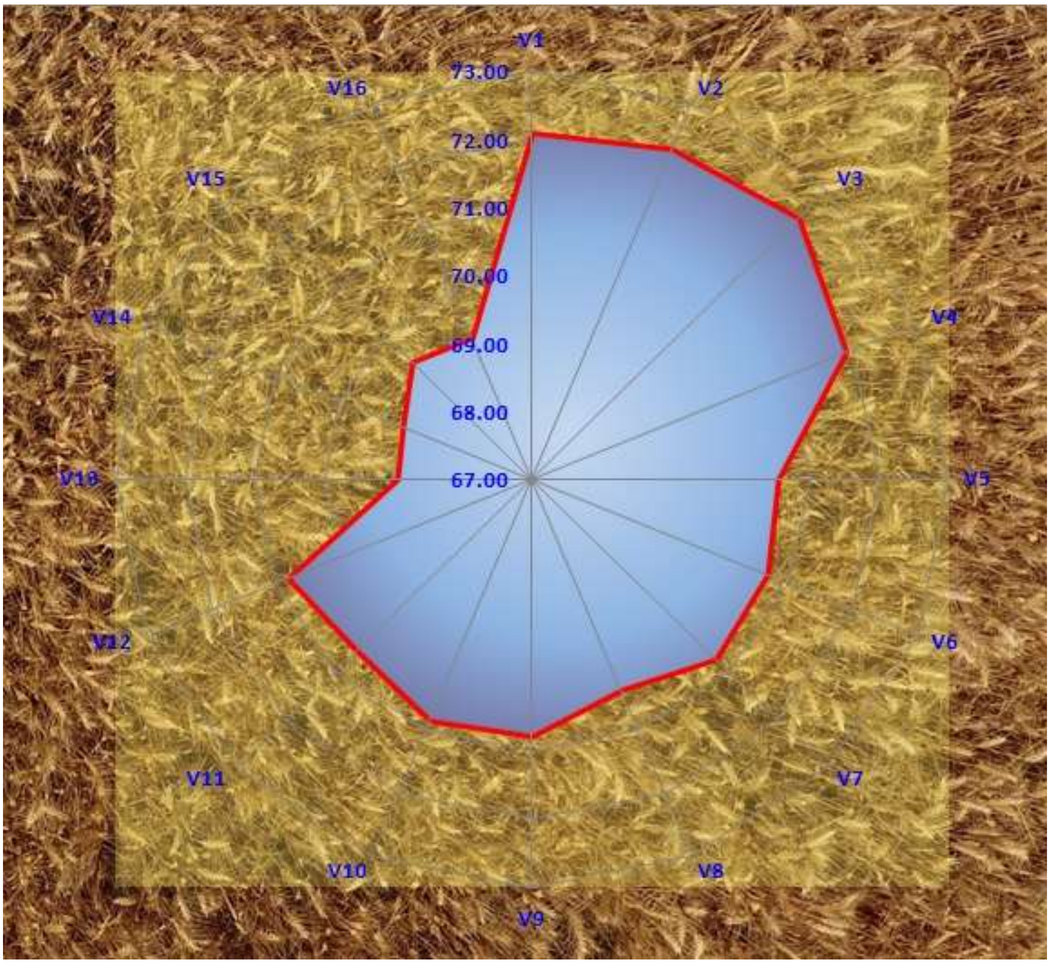

Fig. 2. The graphic representation of the starch content values in wheat, the Ciprian variety
Source: original graph based on experimental data.

The simple regression analysis facilitated the obtaining of equation (1), which described the variation of the starch content (ST) in the wheat grains, as direct relation with the applied fertilizers (NPK), under conditions of R^2=0.794, p<0.001.

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$$ST = 0.630 \cdot N - 0.271 \cdot P + 0.468 \cdot K \quad (1)$$

where: ST – starch content (%);
N – nitrogen fertilizer;
P – phosphorus fertilizer;
K – potassium fertilizer

Equation (2) was also obtained through regression analysis, which described starch content variation, in relation to N and PK fertilizers (as a direct, and as interaction effect), under safety conditions (R^2=0.880, p<0.001). The graphic distribution regarding starch content variation in relation to applied fertilizers is presented in figure 3 in the form of 3D model, and in figure 4, in the form of isoquants. Based on the values of the coefficients of equation (2), the optimal values for N and PK were calculated and the values x_{opt}=75.10 kg ha^{-1} a.s. were found. N, and y_{opt}=120.00 kg ha^{-1} a.s. PK.

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

where: ST – starch content (%);
x – nitrogen fertilizer (N, kg a.s. ha^{-1});
y – phosphorus and potassium fertilizer (PK, kg a.s. ha^{-1});
a, b, c, d, e, f – coefficients of the equation (2);
a= -0.00044939;
b= -0.00078700;
c= 0.92653190;
d= 0.72647611;
e= -0.00715836;
f= 0

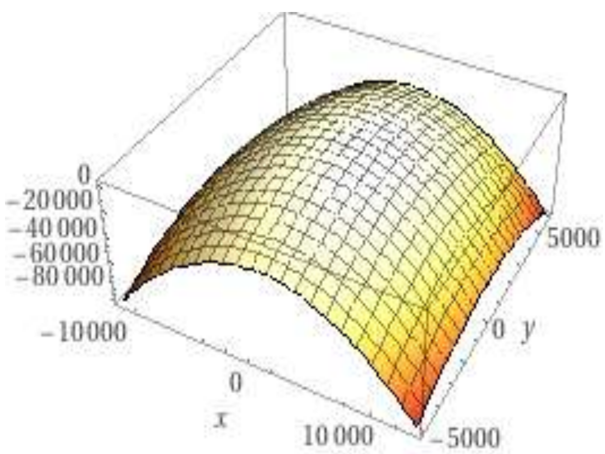

Fig. 3. 3D model of the variation of starch content (ST) in wheat depending on N (x-axis), and PK (y-axis)
Source: original graph.

The cluster analysis facilitated the obtaining of the dendrogram of of the variants association based on similarity, in relation to the values of starch content, depending on the applied mineral fertilization (Coph. corr.=0.842) (Figure 5).

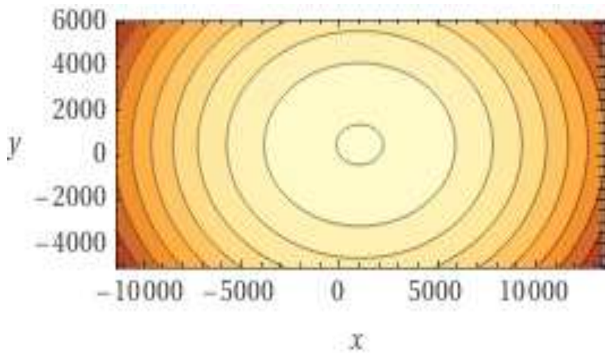

Fig. 4. Model in the form of isoquants, which represents starch content variation depending on N (x-axis), and PK (y-axis)
Source: original graph.

Two clusters resulted, each comprising several variants. The V1, V2, V3 and V4 variants within the C1 cluster were associated with the highest starch content. Variants V13, V14, V15 and V16 were associated within cluster C2, subcluster C2-1, with the lowest starch content.
The other variants were associated within cluster C2, subcluster C2-2, with intermediate values, regarding starch content. From the analysis of the dendrogram in figure 5, as well as the values of the SDI index (Table 3), the highest level of similarity was found between the V5 and V11 variants, respectively between the V9 and V12 variants, with the value SDI=0.02.
Based on the grouping of the variants, according to the similarity level for the starch content (expressed in Figure 5), and in relation to the average value for starch content (ST=70.66%), a graphic analysis was done additionally, in order to evaluate the position of each experimental variants in relation to the average starch content (Figure 6).
Starch is considered an important quality index for wheat grains, in relation to the use of wheat production for baking and pastry (bread, cookies, noodles, etc.).

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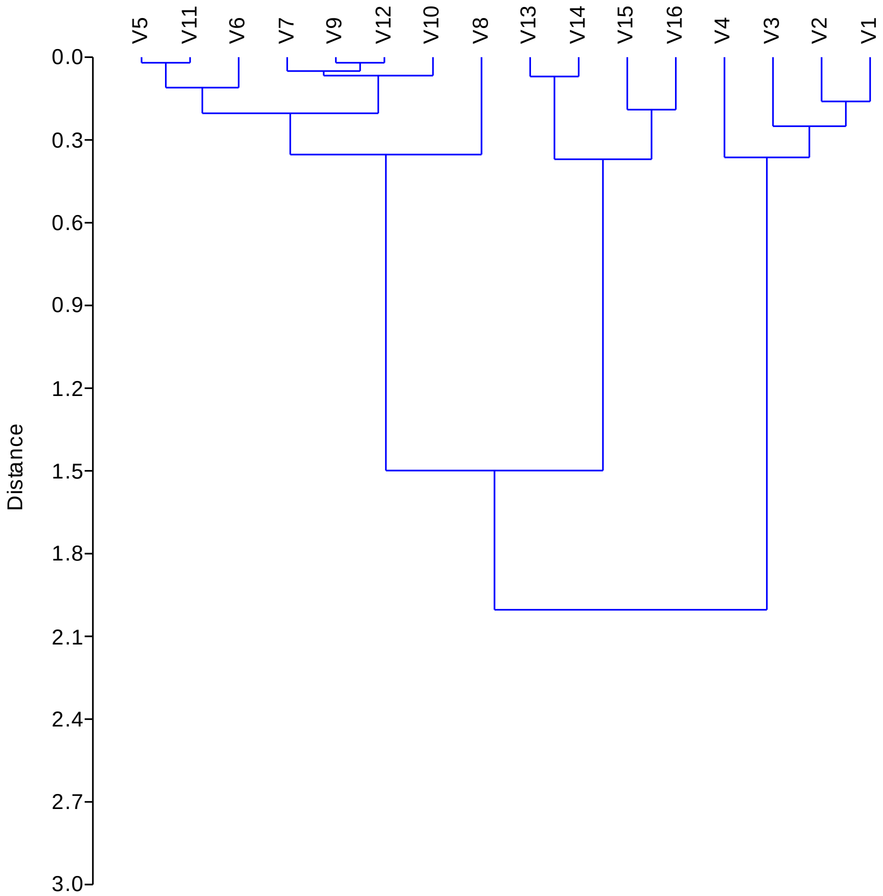

Fig. 5. Dendrogram of association of the variants according to the values of the starch content, the Ciprian wheat variety
Source: original dendrogram obtained on the basis of experimental data.

Table 3. SDI values for the variation of starch content in relation to mineral fertilization in wheat, the Ciprian variety

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16
V1		0.16	0.33	0.20	1.55	1.43	1.35	1.74	1.31	1.25	1.53	1.29	3.15	3.08	2.65	2.84
V2	0.16		0.17	0.36	1.71	1.59	1.51	1.90	1.47	1.41	1.69	1.45	3.31	3.24	2.81	3.00
V3	0.33	0.17		0.53	1.88	1.76	1.68	2.07	1.64	1.58	1.86	1.62	3.48	3.41	2.98	3.17
V4	0.20	0.36	0.53		1.35	1.23	1.15	1.54	1.11	1.05	1.33	1.09	2.95	2.88	2.45	2.64
V5	1.55	1.71	1.88	1.35		0.12	0.20	0.19	0.24	0.30	0.02	0.26	1.60	1.53	1.10	1.29
V6	1.43	1.59	1.76	1.23	0.12		0.08	0.31	0.12	0.18	0.10	0.14	1.72	1.65	1.22	1.41
V7	1.35	1.51	1.68	1.15	0.20	0.08		0.39	0.04	0.10	0.18	0.06	1.80	1.73	1.30	1.49
V8	1.74	1.90	2.07	1.54	0.19	0.31	0.39		0.43	0.49	0.21	0.45	1.41	1.34	0.91	1.10
V9	1.31	1.47	1.64	1.11	0.24	0.12	0.04	0.43		0.06	0.22	0.02	1.84	1.77	1.34	1.53
V10	1.25	1.41	1.58	1.05	0.30	0.18	0.10	0.49	0.06		0.28	0.04	1.90	1.83	1.40	1.59
V11	1.53	1.69	1.86	1.33	0.02	0.10	0.18	0.21	0.22	0.28		0.24	1.62	1.55	1.12	1.31
V12	1.29	1.45	1.62	1.09	0.26	0.14	0.06	0.45	0.02	0.04	0.24		1.86	1.79	1.36	1.55
V13	3.15	3.31	3.48	2.95	1.60	1.72	1.80	1.41	1.84	1.90	1.62	1.86		0.07	0.50	0.31
V14	3.08	3.24	3.41	2.88	1.53	1.65	1.73	1.34	1.77	1.83	1.55	1.79	0.07		0.43	0.24
V15	2.65	2.81	2.98	2.45	1.10	1.22	1.30	0.91	1.34	1.40	1.12	1.36	0.50	0.43		0.19
V16	2.84	3.00	3.17	2.64	1.29	1.41	1.49	1.10	1.53	1.59	1.31	1.55	0.31	0.24	0.19	

Source: original data obtained by calculation.

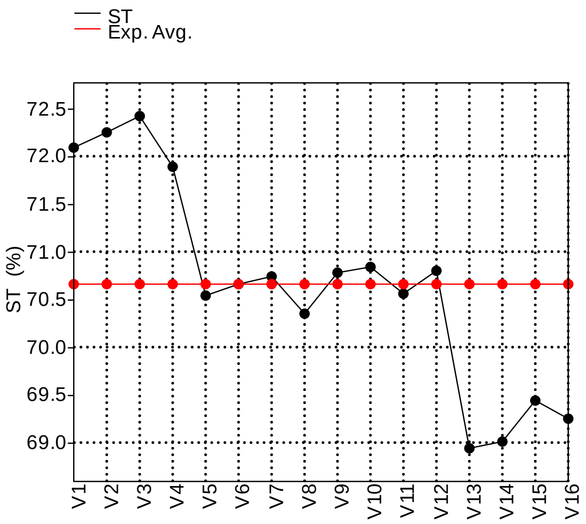

Fig. 6. The variants positioning based on starch content, in relation to average value (red line) on experiment
Source: original graph.

The synthesis and accumulation of starch, as well as the particularities related to the composition, structure, and transformations of starch have been studied in relation to genetic and environmental factors, and starch shows a greater sensitivity to thermal and water stress compared to other quality indices, such as be, for example, proteins [8].
Fertilization represents an important technological element for the variation of starch content in wheat. Xiong et al. (2014) [24] reported the variation in the distribution of starch granules in the grain endosperm, in relation to the level of nitrogen (0, and 240 kg ha^{-1} nitrogen), and the results suggested that high doses of nitrogen caused an increase in the number of small starch granules, and the decrease of large starch granules, variable but in different regions of the endosperm. Studying two different genotypes in relation to the water and nitrogen regime, Tong et al. (2021) [21] found the different response of the starch content in the two varieties, both in relation to water and nitrogen.
In relation to phosphorus, Zhang et al. (2018) [26] found changes in starch morphology, as well as in some genes expression, genes involved in wheat grains starch biosynthesis and degradation. The authors found and communicated that the 46 kg ha^{-1} phosphorus level, determined the increase in the genes expression associated to starch synthesis, the better accumulation of starch in wheat grains, and the starch granules formed at the respective phosphorus level released a much larger number of seeds reducing, compared to the starch formed at higher levels of phosphorus. The variation of the proportions of starch granules (surface area and volume) in grains of different wheat varieties, in relation to phosphorus fertilization, was also identified in other studies [9, 12].
In relation to potassium, some studies have confirmed the important role of potassium in improving photosynthesis, increasing stress tolerance of wheat plants, improving production, synthesis and translocation of starch in wheat grains, and ensuring optimal nutrition with potassium through fertilization is necessary [22].
Some studies evaluated the interaction of some microelements with basic macro-elements in wheat fertilization, in relation to plant nutrition status, productivity elements and wheat quality indices [1, 7].
The need to optimize wheat fertilization was also argued from the perspective of increasing the coefficient of utilization of nutritional elements, with a favourable impact on physical production, or on quality indices, as well as from considerations of the efficiency of the use of fertilizing resources, agricultural yields, and environmental protection [17, 18].
In relation to the present study conditions, the fertilizers optimal values, calculated according to the starch content values registered (x_{opt}=75.10 kg ha^{-1} a.s. N, and y_{opt}=120.00 kg ha^{-1} a.s. PK), can be taken into account, as guideline fertilization values for obtaining similar results for this quality index, of course in relation to the cultivated genotype, culture technology and environmental conditions.

CONCLUSIONS

Mineral fertilization tested in this study (doses and combinations), determined the differentiated accumulation of starch content in wheat grains, Ciprian cultivar, in relation to the three nutrients (NPK) administered.
A tendency to decrease the starch content, associated with the increase in the total level of fertilization, was found in the experimental

and study conditions.

The values of the starch content showed different levels during the two experimental years, under the same fertilization conditions, which shows the influence of the vegetation conditions in achieving the respective starch quality indices.

In relation to the applied fertilization doses, and the recorded starch content values, the optimal doses were calculated at the level of x_{opt}=75.10 kg ha^{-1} a.s. for N, and y_{opt}=120.00 kg ha^{-1} a.s. for PK, values that can be taken into account for other studies or agricultural practice.

The cluster analysis facilitated to obtain the grouping of the experimental variants, based on the similarity of the starch content, and makes it possible to choose the fertilization system (levels, combinations) in relation to the quality indices estimated for wheat (starch in this case) as well as the budget allocated for fertilization in framework of agricultural technology.

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