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Cumulative indicator of quality of grain for strong wheat for conditions of strongly continental climate

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Abstract. Durum wheat is second in importance after soft wheat for many countries of the world, its area is about 10% of common wheat sowing, and world grain production reaches 15-20 million tons. Identification of the role of climatic predictors in the formation of spring durum wheat on Based on the construction of computer models using the methods of mathematical modeling, it is of particular importance for agriculture.Earlier studies to identify the relationship between indicators of grain quality of durum wheat and weather predictors allowed us to establish that the formation of indicators of grain quality occurs under different weather conditions.In the work on the basis of a large experimental material on the quality of grain of two varieties of spring durum wheat, agrometeorological data of the Orenburg Regional Center on Hydrometeorology and environmental monitoring for May-August 1967-2017. Multiple regression models of the influence of weather predictors on the main indicators of the quality of hard wheat grain were built. Based on the solution of the system of regression equations, an integral indicator of the quality of spring hard wheat grain was developed for conditions of a sharply continental climate.

1. Introduction
Currently, in the field of agriculture, mathematical modeling is widely used to obtain predictive values of some key factors. And the problem of mathematical modeling is one of the most difficult not only in terms of creating models for all cultivated agricultural crops, but also in developing them for each territory, each agricultural landscape or field, taking into account the biological component of the crop, the characteristics of natural climatic, weather conditions and technological methods of cultivation.

A significant amount of work by domestic and foreign scientists is devoted to the issues of predicting the quality of wheat grain from climatic and agrometeorological conditions.

P. Toscanoa, L. Genesio, A. Crisci, F. P. Vaccari, E. Ferrari, P. La Cava, J.R. Porterde, B. Gioli created an empirical linear model for predicting the protein content of durum wheat from weather predictors in Italian regions in a changing climate [1].

P. D. Hollins, P. S. Kettlewell, P. Peltonen-Sainio, M. D. Atkinson developed a predictive regression model of winter wheat from weather predictors in Finland [2].

G. R. Brankovic, D. Dodig, M. Z. Zoric, G. G. Sultan-Momirovic, V. Dragicevic, N. Duric in their work use regression modeling to study the interaction of vitreous grain of durum wheat with suitable conditions in Serbia [3].

Various aspects of this problem are quite fully covered in literature. So, the numerous works of V.

V. Zhuravleva [4], D. A. Tursunov [5], G. Yu. Riznichen-ko, N. E. Belyaeva, I. B. Kovalenko, A. B. Rubin (14), A.S. Maslakova, T. K. Antala, G. Yu. Riznichenko, A. B. Rubin [6], D. Haboudane, JR Miller, N. Tremblay, PJ Zarco-Tejada, L. Dextraze [7].

Mathematical modeling of wheat grain quality using various methods was also considered in the works of P. Toscano, L. Genesio, A. Crisci, F.P Vaccari, B. Gioli, E. Ferrari, P.L. Cava, J.R. Porter [8] and S. Asseng, A. Bar-Tal, J.W. Bowden, B. A. Keating, A. Van Herwaarden, J. A. Palta, N. I. Huth, M. E. Probert [9].

All existing models are created in relation to local soil-climatic conditions. The work of G.N. is devoted to the problems of mathematical modeling of the quality of spring hard wheat grain using regression analysis in a sharply continental climate. Sandakova and A. G. Kryuchkov [10, 11].

Thus, the existing problem of mathematical modeling of key indicators from various predictors of agriculture is solved in many countries. But at the same time, it is necessary to constantly improve the modeling methodology, applying newer models.

2. Materials and methods

In this study, an experimental material was used to assess the quality of grain of two varieties of spring hard wheat, zoned under the conditions of a continental climate for the period 1967-2017. The experiments were carried out on the southern chernozem carbonate, medium-thickness, heavy loamy with the content of humus in a layer of 0-30 cm 3.5-4.2%, total nitrogen 0.22-0.32%, total phosphorus 1.6-2, 7 mg and exchangeable potassium 35-42 mg per 100 g of dry soil. The pH of the soil solution is 7.1-8.2, the amount of absorbed bases is not more than 40.2 mg / eq. per 100 g of dry soil.

During the growing season of spring hard wheat (May-August), there was a high variability of weather predictors over the years, so the coefficient of variation of precipitation was 38.8%, the hydrothermal coefficient was 43.7%.

The main indicators of the quality of spring hard wheat grain are:
- nature, gram/liter (Y1);
- glassiness,% (Y2);
- protein content,% (Y3);
- gluten content,% (Y4).
- As influencing predictors, indicators of agrometeorological conditions were selected during the growing season of spring durum wheat:
- -air temperature, ° C, average (X1),
- air temperature, ° C,minimum (X2),
- air temperature, ° C,maximum (X3),
- -precipitation, mm (X4),
- -relative humidity, %, average (X5)
- relative humidity, %,minimum (X6),
- -average deficit of air humidity (X7),
- -hydrothermal coefficient (GTK) G.T. Selyaninova (X8) [12].

For processing source data, searching for relationships between indicators of grain quality of spring hard wheat and weather predictors, calculating the integral index of grain quality of spring hard wheat using regression analysis, calculating the values of linear (R) correlation coefficients using Microsoft Exsel and Statistics 8.0 software packages.

To analyze the interrelation of predictors, the Spearman correlation index was used. The strength of the bond was rated on the Cheddock scale.

Exclusion of multicollinear predictors was performed by the method of principal components based on the performed correlation analysis.

Analysis to determine specific values of weather predictors to achieve the required level of grain quality parameters was carried out by identifying the maximum and minimum values for each of the weather predictors.

Analysis to determine specific values of weather predictors to achieve the required level of key

parameters was carried out by identifying the maximum and minimum values for each of the weather predictors in such a way that the quality parameters were not lower than the specified values for each specific parameter. Then, among the resulting values, the maxima and minima are again selected among all the quality parameters.

Obviously, it is impossible to simply summarize the quality parameters, since they are taken into account in different quantities.

To solve this problem of different dimensions of quality parameters, the scaling method was used. Reduction to a single scale is carried out according to the following formula:

$$y_k = \frac{y_i - y_{min}}{y_{max} - y_{min}} .$$

(1)

The values obtained as a result of such a transformation vary in the interval [0; 1], an increase in the quality parameter leads to an increase in its coefficient.

3. Results and discussion

At the first stage of the study, correlations between initial weather predictors and grain quality parameters were studied.

According to the results of the correlation analysis, the relationship of weather predictors with the main indicators of grain quality on the Cheddock scale in most cases is regarded as weak (0.1-0.3), in some cases as moderate (0.3-0.5), and in some cases cases not identified (<0.1). This circumstance complicates the analysis, since it is obvious that linear communication models give a low result.

In this regard, the method of nonlinear correlation (R) was applied for a more advanced analysis of the relationship of weather predictors with quality indicators.

To determine the nonlinear correlation coefficients (R), a regression model was constructed for each of the combinations "weather factor - quality score". For each of the above combinations, models of different types were selected, the preference being given to those whose determination coefficient (R2) turned out to be the greatest.

These models allowed us to calculate the nonlinear correlation coefficients (R) (Table 1).

Table 1. Nonlinear correlation coefficients (R) for each of the "weather predictor – quality indicator" combinations

Weather predictors	Nature, grams / liter (Y1)	Vitreousness ,% (Y2)	Protein content,% (Y3)	Gluten content,% (Y4)
Air temperature is average, °C (x1)	0,199	0,172	0,458	0,575
Minimum air temperature, °C (x2)	0,282	0,194	0,221	0,184
Maximum air temperature, °C (x3)	0,273	0,523	0,788	0,652
Precipitation, mm (x4)	0,335	0,381	0,262	0,213
Relative humidity, average,% (x5)	0,189	0,284	0,578	0,562
Relative humidity, minimum,% (x6)	0,264	0,459	0,416	0,473
The average deficit of air humidity, m / bar (x7)	0,225	0,247	0,436	0,449
Hydrothermal coefficient, units (x8)	0,323	0,285	0,265	0,198

The obtained nonlinear correlation coefficients are more significant in a sufficiently large number of cases. For eight paired coefficients, according to the Cheddock scale, the relationship is characterized as "noticeable."

These models allowed us to calculate nonlinear correlation coefficients.

The obtained nonlinear correlation coefficients are more significant in a sufficiently large number of cases. For eight paired coefficients, according to the Cheddock scale, the relationship is characterized as "noticeable."

The model includes only those weather predictors that had a correlation with grain quality indicators of 0.3 and above.

The resulting regression equations were combined into a system.

$$\begin{cases} y_1 = 0,114x_3 - 0,155x_4 + 0,189x_6 - 2,415x_7 + 811,8 \\ y_2 = 1,018x_3 + 0,02x_4 - 0,767x_6 - 1,636x_7 + 100,07 \\ y_3 = -0,055x_3 + 0,002x_5 + 0,350x_7 + 12,27 \\ y_4 = -0,114x_3 + 0,022x_5 + 0,675x_7 + 22,96 \end{cases} \quad . \tag{2}$$

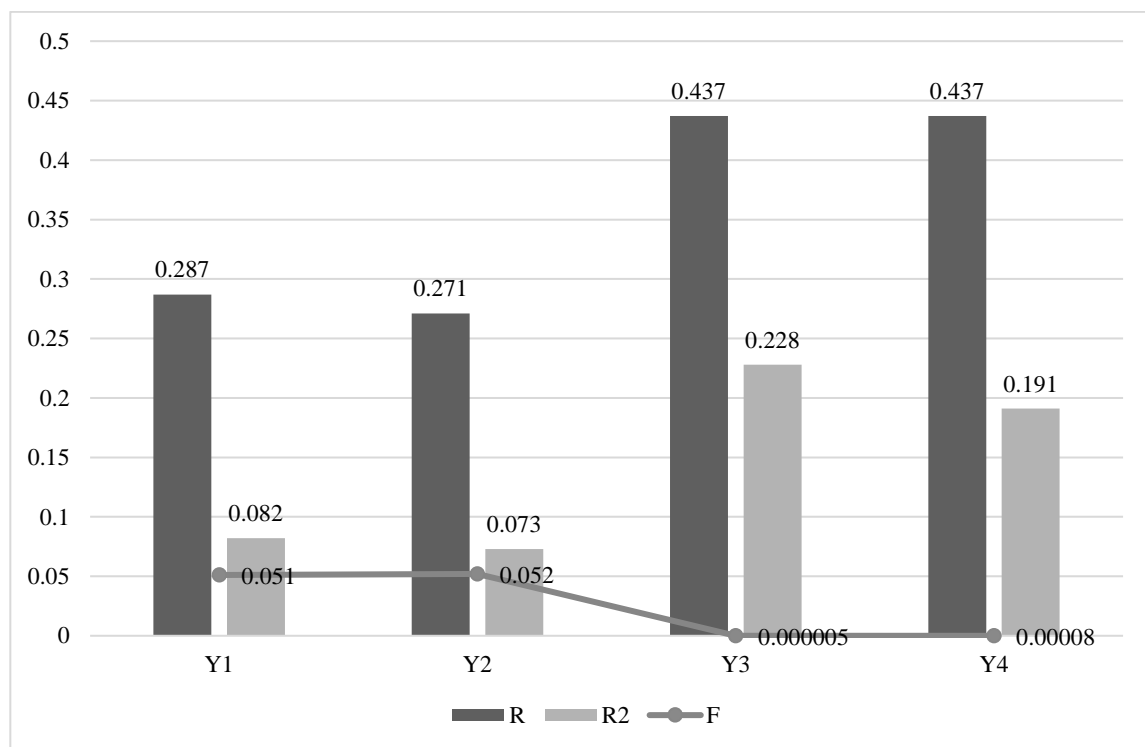We present the main parameters of this model in the figure.

Figure 1. Parameters of the nonlinear regression system

Analyzing Figure 1, we can conclude that for indicators Y1 and Y2, the models have low, although significant at the level of 0.1, reliability according to Fisher's criterion F, as well as low coefficients R and R2. This suggests a lack of data and the need to refine the models.

For indicators Y3 and Y4, the models have very high reliability with a low value of the coefficients R and R2, which indicates a number of unaccounted predictors that were not identified in this study.

For ease of use of the regression models obtained, an integral indicator of grain quality was developed.

The integral quality indicator should include all basic parameters corrected for the corresponding predictors. The integral quality indicator is reduced to the simplest form:

$$TQS = 0.23y_1 + 0.04y_2 + 0.42y_3 + 0.31y_4. \qquad (3)$$

For the convenience of presenting the results, the obtained coefficient is reduced to the scale [0; 1]. A unit can be achieved only if all the quality indicators are equal to the maximum values, zero - with the minimum values of the quality indicators.

In this paper, for the conditions of a sharply continental climate, an integral quality indicator of spring hard wheat (TQS) was calculated, in which 4 main quality indicators are displayed: glassiness, nature, protein and gluten content. Quality indicators are modeled by building regression equations that reflect the influence of weather predictors.

Acknowledgments

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