EVALUATION OF THE PRODUCTIVITY OF DIFFERENT VARIETIES OF WINTER WHEAT IN THE CONDITIONS OF THE FUTURE CLIMATE UNTIL 2030 - 2050

V. Kazandjiev[1*], V. Georgieva[1], M. Ivanov[1],G. Mihova[2], Zl. Uhr[3]

[1]National Institute of Meteorology and Hydrology, 66 Tsarigradsko shausse blvd. 1784 Sofia, Bulgaria

[2]Dobrudja Agricultural Institute-G. Toshevo, DAI-AA, Bulgaria

[3]Institute for plant and genetic resources- Sadovo, IPGR-AA, Bulgaria

Abstract

In the agricultural practice of the country, more than 50 varieties of winter wheat - local and foreign - are currently used. The majority of them are the product of the Bulgarian selection in the DAI "G. Toshevo" and IPGR "K. Malkov" - Sadovo, but several foreign varieties are also used. All varieties have been created to achieve certain dominant qualities – high yields, resistance to drought, extreme low temperatures in winter and high temperatures in summer, resistance to diseases and pests.

The winter wheat varieties involved in our research are Kristalina, Nikodim, Bojana, Rada, Christi, Karina, Corona, Lazarka, Laska, Marilyn, Kalina, Katarzhina, Kiara, Enola, Dragana, Iveta, Pchelina, Anapurna, Avenue, Shibil, Chudomira, and Fedora.

The purpose of the research is to determine the productivity of some of the current varieties of winter wheat, which find the widest application in practice in recent years under the conditions of the future climate in our country.

Key words: *winter wheat, numerical modeling, agroclimatic conditions, development, yields, potential and real productivity*

INTRODUCTION

Forecasting the yields of the main agricultural crops is a matter of primary importance in the conditions of a market economy. The production of numerical predictions for a number of agricultural crops has been the subject of research interest by numerous scientists around the world. The topic is even more relevant when it comes to the zoning of agroclimatic resources or the forecasting of yields in a future period 2021-2050. The aim of the present study is by using the results of simulating the agrometeorological conditions by means of the numerical model ALADIN-Climate for the next 30 years day by day and putting them as input data to the WOFOST model for simulating the growth and development of the different varieties of winter wheat for 64 points of the agricultural territory of Bulgaria.

The WOFOST model has been adapted for the agrometeorological conditions of our country at NIMH and has been applied many times to forecast the yields of wheat, sunflower and soybean, and the results were published in 2005-2007 and 2018 by Kazandjiev et al. In these developments, the obtained yields are evaluated during the current growing season or a comparative analysis of the modeled and measured yields during a past period is carried out. At the moment, all of humanity is very concerned about the consequences of climate change and the continued deepening in this direction, the introduction of restrictions related to hydrocarbon pollution, the implementation of the green pact and the related livelihood of the population. From this point of view, the idea of simulating yields over the next 30 years using the growth characteristics of 60 of the current winter wheat varieties, for the weather conditions, the data obtained from the weather simulation with ALADIN-Climate for the next 30 years. We assume that the soils will have the same fertility and the same water-physical properties in the next three decades.

Similar studies have been conducted and are being conducted in many countries of Europe, America, Asia and Africa. Fayed T. et al. 2015 have conducted a two-year experiment at the experimental farm of the Faculty of Environmental and Agricultural Sciences of the University of the Suez Canal EL-Arish in order to determine the growth, development and productivity of 4 local varieties of bread wheat - Misr-1, Sakha-93, Giza- 168 and Gemmeiza-9, sown on three different dates 15th October, 15th November, 15th December under the metrological conditions of North Sinai. The results obtained from experimental field studies were used as indicators to test the performance of the DSSAT-Ceres numerical model. Albena Ivanova and Nikkolay Tsenov discuss the productivity of winter wheat cultivars grown under contrasting environments at two locations in Bulgaria. They were grown in two consecutive years: 2006 very favorable for growing wheat, but one of the worst, longest droughts in Bulgaria for the last 30 years was recorded in 2007. Drought resistance was determined by analyzing the correlations between grain yield and its components and by calculating well-known breeding indices. Nevertheless, a high positive correlation was found with grain yield and its environmental components.

Other authors, Kefei Chena et al., investigated the productivity of several modern winter wheat varieties under current agro-climatic conditions in Australia and under projected conditions 20-30 years from now. The aim of their research was to build a simple and parsimonious forecasting model of wheat yields, which can be implemented into a decision-making tool to be used by farmers.

The research of M. Iwanska et all in Poland aimed to estimate the average yield of winter wheat based on selected environmental factors in order to recommend cultivars depending on their performance in environments with different productivity. Mean expected yields in specific environments were calculated using an analysis of covariance-based model that describes the relationship between winter wheat yield and environmental factors such as soil suitability and pH, drought duration, and Selyaninov's hydrothermal coefficient (HTC) for 10 daily periods. The study confirmed the importance of soil suitability and HTC for winter wheat yield.

A. Esaulko et all studied the yields of soft winter wheat varieties are particularly affected by variations in hydrothermal conditions. This applies to the arid zone of the Central Transcaucasia, especially to direct seeding practices, for which the understanding of the relationships between the hydrothermal parameters of the soil and the environment, on the one hand, and the productivity of winter wheat, on the other, is one of the fundamental pillars of a stable agricultural systems. It was found that in 2019–2021, positive temperature changes and drought led to an increase in the length of the growing season of crop varieties, a thinned plant density and a reduced productivity of resistant to drought varieties. Evaluation of the parameters determining the ecological and genetic variability of varieties in the genotype-environment system led to the creation of models that describe the effect of drought on crop yields by type of manifestation and previous crops (sunflower, chickpea). These measures can increase or stabilize the productivity of winter wheat in dry environments. This will reduce the impact of changing climate conditions on winter wheat productivity in the region.

According to I. Ozturk at all grain-dressed, phenological development and evapotranspiration grain nitrogen (N) content of winter wheat depending on climate change was analyzed over a period of 80 years based on climate change projections of four models of the Regional Circulation Model (RCM) within the IPCC (International Panel on Climate Change) 21st century A1B emissions scenario using three process-based models; A 20-year set (1991–2010) of observed daily climate data from Aarslev, Denmark was used to form the baseline from which the RCM data were generated. Crop growth simulation was performed with increasing levels of carbon dioxide (CO2) and under a continuous monoculture system at different levels of N input. The results showed that grain yield and grain nitrogen would be reduced in the future despite increased concentration of CO2 in the atmosphere. Although increased N application may increase yield, it will not increase grain N. The present study suggests that alternative strategies for organic plant N acquisition should be developed in Denmark.

MATERIAL AND METHODS

In our country, within the framework of the National Scientific Programs - Healthy Foods for a Strong Bioeconomy and Quality of Life and Intelligent Plant Breeding, experimental field and laboratory studies on the productivity and sustainability of yields under various extreme manifestations of agrometeorological conditions for 69 varieties of winter wheat have been carried out for 5 years. 67 of which local and two French. The research was conducted in two locations – Dobrudja Agrarian Institute (DAI) - G. Toshevo and Institute for Plant and Genetics Resources (IPGR) K. Malkov in Sadovo.

With data on yield, dates of onset of the stages of grading and full maturity, gluten and protein content, productive brotherhood, plant height, weight of 1000 grains and hectoliter weight provided by DAI "G. Toshevo" for 69 varieties of winter wheat, 67 of which are local and two French varieties, numerical experiments were carried out to find suitable indicators for their classification. Of the local varieties, 26 were created and maintained by IPGR "K. Malkov", and the remaining 41 in DAI "G. Toshevo" as 20 of them are new and implemented in practice.

A statistical, cluster and regression analysis of the specified time series was carried out together with all available meteorological and agrometeorological information and, depending on the specific parameters, statistical, correlational and cluster characteristics of the latter were obtained. Similar information should have been submitted by the IPGR in Sadovo, which has not yet been received.

In order to be able to apply the simulation models to determine the most suitable varieties under the specific agro-climatic conditions, it is necessary to have the most complete set of experimental data possible in different regions of the agricultural zone of the country.

RESULTS AND DISCUSSION

With the data of DAI for 69 varieties of winter wheat, a cluster analysis was realized and determination of 2, 3 and 4 clusters, the idea of which is to separate the statistically significant parameters characterizing the biological characteristics of each variety of winter wheat.

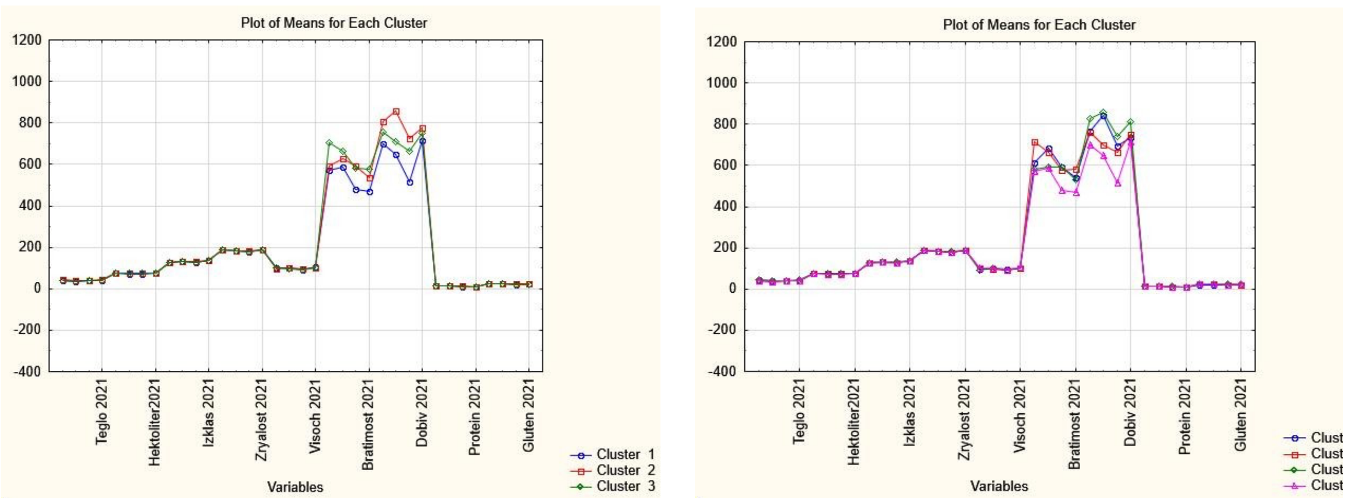


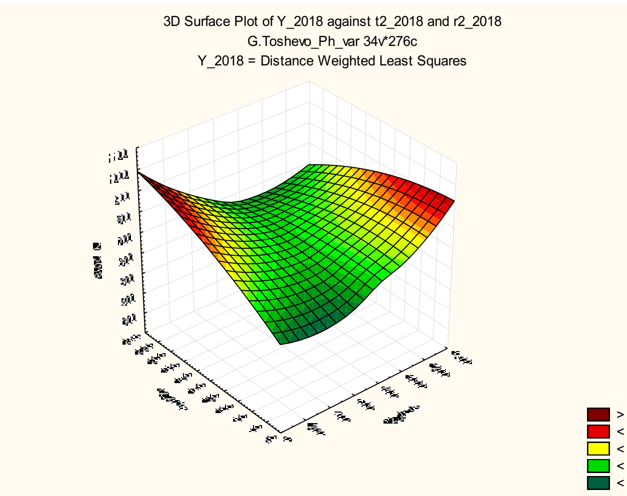
Fig. 1. Distribution of data for 69 cultivars in 3 and 4 clusters

The distribution of varieties in each cluster is given in Table 1. Since all field measurements in the DAI G. Toshevo were carried out in two replicates in the mass case and both replicates fall into the same cluster, but varieties such as Galatea and Albena fall into two adjacent clusters, and in the case of the Momchil variety, one replicate is in cluster A and the second in cluster C, t .is in this variety there is a more substantial difference. The parameter D indicates the distance to the center of each particular variety, i.e. the closeness or degree of relatedness to each of the classes. For the indicated case, we have chosen the indicated varieties to be in those classes in which the distance to the center of the class is the least. Clusters A, B and C correspond to yields of 570-670, 671-770 and 771-880 Kg/dka.

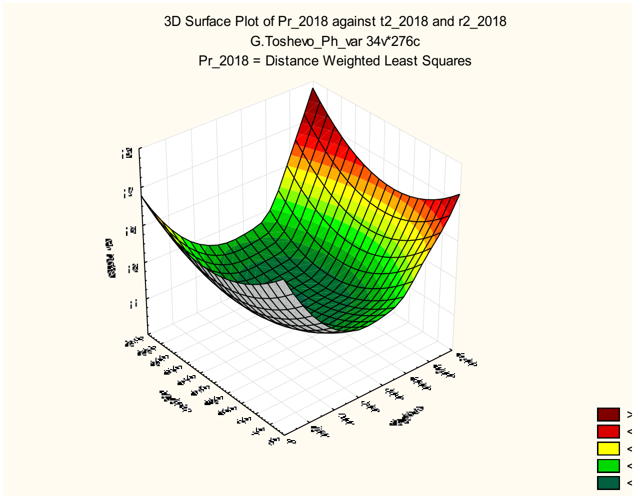
Table 1. Distribution of winter wheat varieties (69) from DAI G. Toshevo in three clusters according to their biometric characteristics for the period 2018-2021.

Cluster A		Cluster B		Cluster C	
Variety	**D**	**Variety**	**D**	**Variety**	**D**
Sadovo_552	18.2	Joana	29.3	Niki	14.1
Sadovska beliia	24.4	Nikolaj	35.0	Mustang	14.6
Katia	33.3	Zhana	29.3	Kosara	16.5
Murgavec	26.2	Fani	38.6	Ginra	17.1
Prelom	24.1	Kami	33.2	Bononiia	17.8
Sadovo_772	34.1	Priaspa	32.5	Diamant	19.2
Iunak	43.0	Kristalina	40.4	Boriana	19.8
Geia	34.9	Nikodim	30.5	Karat	19.9
Carevec	33.6	Todora	24.7	KM-135	19.9
		Bozhana	24.1	Niki BO	20.6
		Milena	35.6	Stoiana	20.6
		Rada	28.2	Gizda	22.5
		Tina	26.1	Liusil	23.6
		Kristi	26.4	Momchil	23.6
		Korona	27.4	Zlatica	24.9
		Neda	17.2	Avenue	25.3
		Boliarka	15.4	Karina	25.9
		Lazarka	11.5	Sadovo_1	26
		Demetra	28.5	Gines	26.3
		Gorica	22.6	Pobeda	27.1
		Laska	42.6	Aglika	27.8
		Merilin	41.7	Zdravko	29
		Galateia	23.0	Anapurna	30.5
		Kalina	25.0	Slavianka_1961	39.6
		Katarzhina	28.7	Fermer	43
		Kiara	26.3		
		Enola	37.4		
		Kristal	41.0		
		Albena	24.7		
		Dragana	21.3		
		Iveta	21.4		
		Pchelina	17.4		
		Shibil	23.4		
		Chudomira	20.8		
		Fedora	28.6		

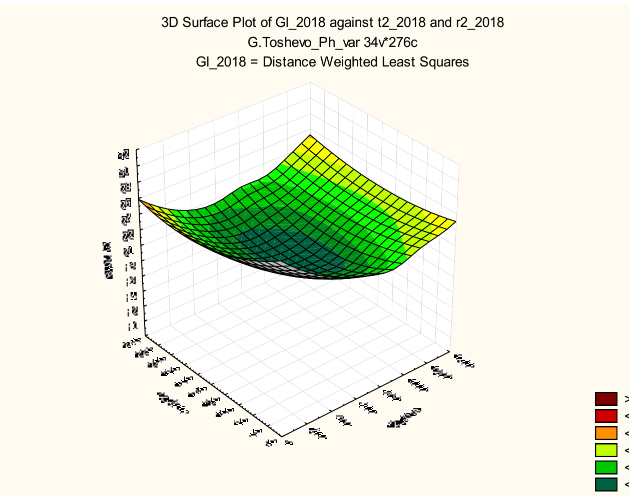
To the biometric measurements and yield structure - density, height, number of grains in the class, yield, grading date, amount of protein and gluten in the grain, we added several agrometeorological indices - sum of active temperatures from sowing to grading and from grading to full maturity - T1 and T2, respectively, and sum of precipitation for the same periods - r1 and r2. We conducted a statistical processing of the data and attempted to obtain information about the relationship between the individual factors as such was established for the extractions in G. Toshevo and T2 and r2. Similar relationships were also identified between the amount of protein and gluten in the grain and the values of the sum of the temperatures and the sum of the valves, fig. 2.



Total Production for the entire period 2018 – 2021.



Total Protein for the entire period 2018-2021.



Total Gluten for the entire period 2018 – 2021.

Fig. 2. Amount of winter wheat yields, the amount of protein and gluten depending on agrometeorological conditions during the period from grading to technical maturity 2018-2021 for winter wheat

By means of the determined statistically significant values of the sums of the active temperatures and the sum of precipitation for the period from grading to harvest maturity, yield values, the amount of gluten and protein are simulated, which are presented as 3D graphs in fig. 2. In addition to the graphic presentation, the graphs also have a physical meaning, which expresses the relationship between hydro-thermal conditions and the formation of yields, protein and gluten in winter wheat varieties.

Applying the method of principal component analysis allowed us to find the degree and sign of the relationship between yield and the sums of temperatures and precipitation from sowing to heading and from heading to full maturity of winter wheat crops. An interesting and very indicative fact of this dependence is observed for Northern (Toshevo) and Southern (Sadovo) Bulgaria, which adequately correlates with the agro-climatic features of these regions.

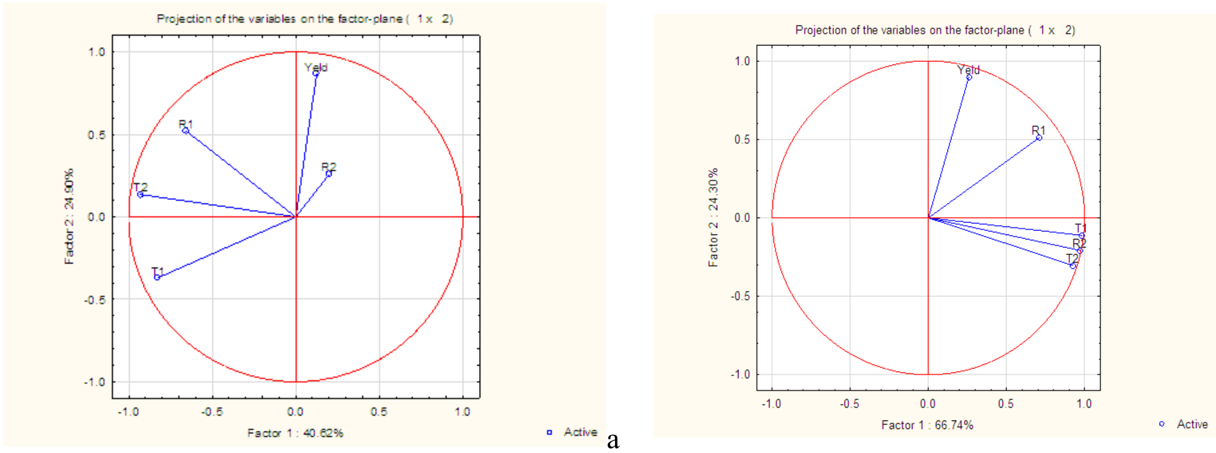
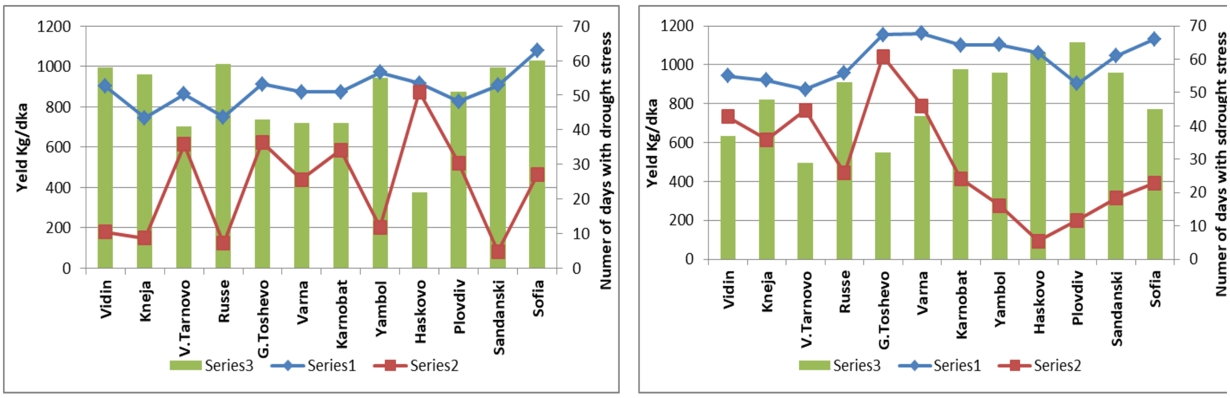


Fig. 3. Graphic representation of the relationship between yields (Y) agrometeorological indices T1, T2, r1 and r2 by applying Principle Components Analysis (PCA)

In the northern part of the country, yields are very closely correlated with the sum of precipitation from seeding to full maturity, this dependence is weaker with the sum of precipitation from sowing to seeding, and the sum of temperatures hardly affects the formation of yields. In the southern part of the country, the dependence between the yield and the amount of precipitation from sowing to grading is the strongest, the other components affect yields in a similar way as in the north, fig. 3.



2023 2030

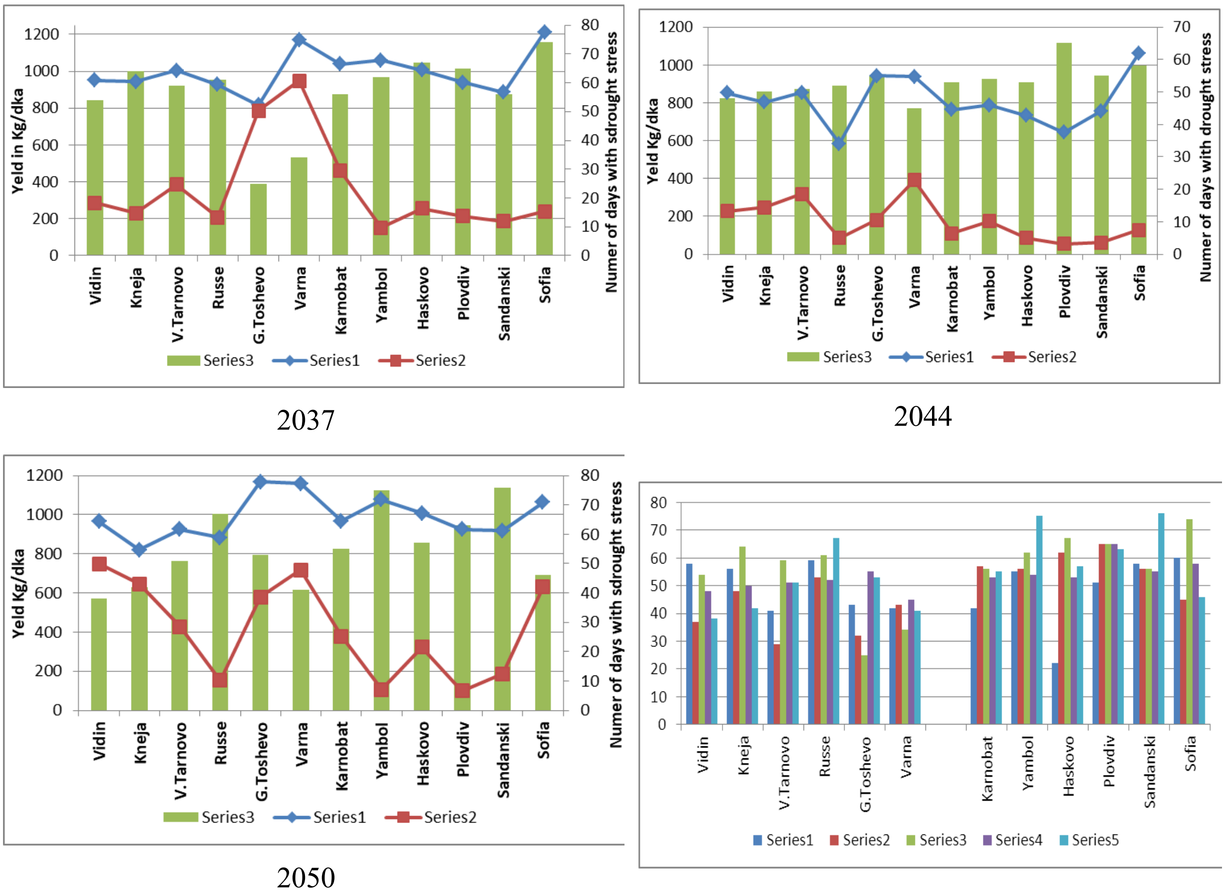


Fig. 4. Potential and real (limited by the water regime) productivity of modern wheat varieties for the period 2021-2050 (ser1 – potential yield in kg/ha; ser2 – real yield in kg/ha; ser3 – days with stress) and number of days with drought stress (ser1 –2023; ser2 – 2030; ser3 – 2037; ser4 – 2044; ser5 - 2050)

This study continued by modeling the productivity – potential and actual, limited by soil water availability, as well as the number of drought days during the growing season for the next 30 years, until 2050 by applying the WOFOST numerical model to 56 stations from NIMH network. As already stated, the data refer to the varieties of G. Toshevo and Sadovo and two French varieties - Avenue and Anapurna. In this publication, the data from 12 representative points for the production of winter wheat, 6 each in Northern and Southern Bulgaria - Vidin, Knezha, V. Tarnovo, Ruse, G. Toshevo, Varna, Karnobat, Yambol, Haskovo, Plovdiv, Sandanski and Sofia. For the same reasons, the simulation data for 2023, 2030, 2037, 2044 and 2050 are presented, fig. 4

CONCLUSIONS

After our conducted field and experiments - measurements and observations and laboratory analyzes and numerical modeling, the following more significant conclusions were established:

- Through climate modeling with ALADIN-Climate, data were obtained on the daily values of the minimum, maximum and average daily air temperature, 24-hour precipitation, relative air humidity, wind speed and duration of sunshine. And the next period will see intense drought, with the number of days with drought after 2037 increasing from 50-60 to 70-80 and more;
- Current winter wheat varieties will retain their potential productivity, but actual yields will be greatly affected by the length of drought periods;

- In years and in places where the drought lasts up to 20-30 days, the productivity of all varieties remains close to or equal to the potential, fig. 4 2023 – Haskovo; 2030 - V. Tarnovo; 2037 - Toshevo and Varna. In all investigated cases, when the duration of the period exceeds 40-50 days, yields are greatly reduced;
- The drought will be longer after 2037 in Southern Bulgaria, as the regions where it will manifest itself tangibly are Plovdiv, Yambol, Sandanski and Ruse.

ACKNOWLEDGMENT

This work was supported by the Bulgarian Ministry of Education and Science under the National Research Programme „Smart crop production" approved by Decision of the Ministry Council №866/26.11.2020 г. and by National Research Programme "Healthy Foods for a Strong Bio-Economy and Quality of Life" approved by DCM # 577 / 17.08.2018".

REFERENCES

1. Esaulko, Vl. Sitnikov, E. Pismennaya, O. Vlasova, E. Golosnoi, A. Ozherdova, A. Ivolga, and V. Erokhin - Productivity of Winter Wheat Cultivated by Direct Seeding: Measuring the Effect of Hydrothermal Coefficient in the Arid Zone of Central Fore-Caucasus, MDPI, agriculture, 2023, 13, 66 https://doi.org/10.3390/agriculture13010055
2. Ivanova A., N. Tsenov, D. Atanassova, V. Dochev - Evaluation of winter wheat productivity under contrasting environments in Climate Change: Challenges and Opportunities in Agriculture, Proceedings Agrisafe Final Conference, March 2011, Budapest Hungary.
3. Iwanska Marzena, Jakub Paderewski, Michai Stepien and Paulo Canas Rodrigues -Winter Wheat Cultivar Recommendation Based on Expected Environment Productivity in MDPI Agriculture 11(6) 522 https://doi.org/10.3390/Agriculture11060522
4. Taher Fayed, Eman El-Sarag, Mosaad Hassanein and Ahmed Magdy - Evaluation and prediction of some wheat cultivars productivity in relation to different sowing dates under North Sinai region conditions in Annals of Agricultural sciences v. 60 1/2015 p. 11-20.
5. Ozurk I., B. Sharif, S. Baby, M. Jabloun, and Olesen J. E. - The long-term effect of climate change on productivity of winter wheat in Denmark: a scenario analysis using three crop models, the Journal of Agricultural Science Vol. 155 , Issue 5 , July 2017 , pp. 733 – 750
6. Kazandzhiev V., V. Georgieva 2005. Calibration of the WOFOST model for predicting soybean yields (Glycine hispida (Moench) Maxim) for the conditions of Northern Bulgaria, report of a scientific conference on the occasion of 80 years Institute for Soy and Forage Crops 8 - September 9, 2005, Pavlikeni, Sb. Scientific Reports of the Jubilee Scientific Conference, 244-253.(in Bulgarian)
7. Kazandjiev V., V. Georgieva 2006. WOFOST Model Calibration for some Cereal Crops in Bulgaria, Proceedings of 8-th Conference on Meteorology – Climatology and Atmospheric Physics COMECAP 24-26 May 2006, Athens, volume C p. 97-102.
8. Kazandjiev V., V. Georgieva, M. Moteva 2007. Peculiarity of WOFOST model verification for maize (grain) under the soil and meteorological conditions of Bulgaria, paper on 7-th EMS and 8-th ECAM in El Escorial, Spain. http://www.cosis.net/abstracts/EMS2006/00561/EMS2006-A-00561.pdf
9. Chervenkov H., V. Kazandjiev, V. Gergieva. Application of the crop model WOFOST in grid using meteorological input data from reanalysis and objective analysis. IDOJARAS, 122, 3, Hungarian Meteorological Service, 2018, ISSN:03246329, DOI:10.28974/idojaras.2018.3.5, 305-320. SJR:0.36, ISI IF:0.66