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# CONTRIBUTIONS REGARDING THE INFLUENCE OF THE TEMPERATE-CONTINENTAL CLIMATE ON THE PERFORMANCE OF NEW WHEAT LINES

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**Abstract**

*The genetic diversity of wheat is high and continues to grow, which can contribute to the new challenges imposed by climate change. National Agricultural Research and Development Institute, Fundulea-Romania, using diverse genetic resources and biotechnological methods obtained a series of DH mutant/recombinant lines that can be used in the next years in many cropping zones because as a result of experimentation proved to adapt easily in moderate temperate continental conditions from south Romania. To evaluate the effect of this climate on their agronomic performance, 13 lines and the two forms from which they were extracted, were sowed in ARDS Caracal where average long-term climatic data indicate an increase in temperature with almost 2.50$^{0}$C and also the frequency of periods with drought and high temperatures, as well as extreme weather events. In this context, the new lines represent a superior genetic material that can be made available to farmers and has proven capable of giving high, stable, and quality yields corresponding to market requirements, under the increasingly frequent conditions of some higher temperatures and fluctuations in the pluviometric regime.*

**Keywords**: wheat, agronomic performance, temperate climate

## Introduction

Producing enough food to feed the increasing world population has become a major concern of modern society. Humanity's food is provided, mainly by four grains: wheat, rice, corn, and sorghum. In terms of wheat cultivation, in 2021 Romania occupied the fourth place in the European Union, after France, Germany, and Poland, with 2.175 million ha (INS) and a total wheat production harvested of 11.33 million tons. In the South-West Oltenia region, the wheat yield was 1.868 million tons, and in Olt county, where SCDA Caracal is located, production was 653.954 tons (5.044 kg/ha). (MADR).

Winter wheat is grown in almost all crop areas in the country, but the best results are obtained on fertile and permeable soils, in conditions of a good water supply, and in the absence of extreme temperatures of heat and drought. In a favorable environment from south Romania, wheat crop exploits the full potential of existing varieties. ARDS Caracal climate is temperate-continental with Mediterranean influences, characterized by alternative frosty and un-frosty winters and 2-6 dry months and maximum precipitations in July and minimum in August-September.

Current research to improve wheat yields includes mixing of germplasm through the crossing, interspecific and intergeneric hybridization, biotechnology techniques, and numerous other important research methods.

The realization of the production of haploids and double haploid lines (DH technology) in wheat, barley, triticale, and respectively of completely homozygous genotypes in a single generation, with favorable combinations of genes, either dominant or recessive, offers a real advantage in achieving progress genetically compared to classical breeding methods. The inclusion of the *Zea* biotechnological system in mutagenesis works is a safe and at the same time extremely useful way to homozygosity the material subjected to mutagenic treatments (Giura, A., 2011). Also, cultivars obtained using the DH system are expected to have better uniformity and stability (Săulescu et. all., 2012).

Climate change is putting pressure on wheat yields in South Romania in several ways: lower annual and autumn and spring rainfall, so later starts to the growing season, higher temperatures during the growing season. Most agriculture in this area is non-irrigated, based on annual rainfall. Common winter wheat lines possessing the *Gpc1* gene were obtained in a genetic background quite adapted to the conditions in Southern Romania (Săulescu, N.N. et all., 2010).

Crop yields are dependent on interactions of biological, technological, and ecological factors.

This study's objective was to analyze the performance of yield and its components under contrasting conditions of accumulation and distribution of precipitation and evapotranspiration, as a combined effect of temperature and air humidity to some modern DH mutant/recombinant wheat lines and to establish the gain of this wheat in stability and high productivity in a changing climate.

**Materials and methods**

The yield experiments were organized in South Romania (ARDS Caracal - 44°06' N; 24°21' E) in three successive crop seasons (2016-2019), on chernozem soil rich in humus ≥ 3 and with pH = 7.5-7.7, using randomized block design with 3 replications.

Biological material is represented by 15 DH mutant/recombinant lines obtained as a result of a protocol that included two genotypes, two gamma-ray (Gy) irradiation cycles, and DH technology, which made it possible to generate mutant DH lines of the wheat parents both after the first irradiation cycle and second irradiation cycle (Giura, 2013).

Crop management measures were performed according to the recommendations for winter wheat cultivation.

The area of the experimental plots for sowing was 9 $m^2$ and for harvest 7 $m^2$.

Measurements and determinations for this study included both morphological and quality issues and the obtained results were statistically evaluated by the variance analysis method (ANOVA). Differences between mean values were evaluated by Tukey's (LSD) test at the level of significance P=0.05 for every character.

## RESULTS AND DISCUSSION

A wheat genotype sown in the field must adapt as well as possible to the climatic conditions (to withstand drought and frost conditions) and the soil on which it is grown, acclimatizing even on soils with low fertility, so that the quality and production obtained to be as high as possible.

Temperature analysis in the 10 months of multi-annual vegetation indicates an average of 9.85$^0$C. The closest value is recorded in 2016-2017, with an average of 9.49$^0$C, with 0.36$^0$C below the multiannual value, while in the other two years of experimentation there were registered higher values of 10.7$^0$C in 2017-2018 and a positive deviation of 0.85$^0$C and 10.69$^0$C respectively in the year 2018-2019 and a positive deviation of 0.84$^0$C.

As concerns the analysis of the temperatures according to the vegetation phases of the plants, in the first part respectively from the sowing and until the exit of winter of the plants (the period of October-February), it should be noted that in comparison with the multiannual average, the first year of experimentation is noted through an extremely low period in January (average temperature -6.1$^0$C and a deviation of -7$^0$C), otherwise, the monthly deviations from the multiannual monthly averages have no exaggerated values (table 1).

The same situation is found in the interval in which the plants accumulate the thickness of vegetative mass (March-July), the monthly deviations from the multiannual monthly averages being rather within limits that can be considered normal.

Table 1

The variation of the temperatures recorded in the years of experimentation and the calculation of deviations from the multiannual values

| Year \ Month | | Oct. | Nov. | Dec. | Jan. | Feb. | March. | Apr. | May | June | July | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016-2017 | Value | 10.7 | 5.5 | 0.7 | -6.1 | 0.00 | 8.8 | 10.6 | 16.9 | 23.5 | 24.3 | 9.49 |
| | Deviation | **-0.5** | **0.2** | **0.5** | **-7** | **-1.4** | **2.8** | **-0.9** | **-0.6** | **2.2** | **1.1** | **-0.36** |
| 2017-2018 | Value | 12.1 | 6.5 | 3.1 | 0.8 | 1.00 | 3.8 | 16.1 | 19.6 | 22.1 | 21.9 | 10.70 |
| | Deviation | **0.9** | **1.2** | **2.9** | **-0.1** | **-0.4** | **-2.2** | **4.6** | **2.1** | **0.8** | **-1.3** | **0.85** |
| 2018-2019 | Value | 13.8 | 5.1 | 0.2 | 0.5 | 3.20 | 9.1 | 12 | 17.1 | 22.8 | 23.1 | 10.69 |
| | Deviation | **2.6** | **-0.2** | **0** | **-0.4** | **1.8** | **3.1** | **0.5** | **-0.4** | **1.5** | **-0.1** | **0.84** |
| Multi-annual | | 11.2 | 5.3 | 0.2 | 0.9 | 1.40 | 6 | 11.5 | 17.5 | 21.3 | 23.2 | 9.85 |

Precipitation analysis for the multiannual average indicates an amount of 429 mm, the highest value being recorded in 2016-2017 with an amount of 604.4 mm and a positive deviation of 175.1 mm. In the second year of experimentation, a precipitation amount of 448 mm was recorded, with a positive deviation from the average multiannual amount of 18 mm (table 2).

The lowest value is recorded in the case of 2018-2019 with a value of 387.5 mm/year and a negative deviation compared to the multiannual of 41.8 mm. In the analysis of the monthly values, in the first part of the vegetation period, the first year of experimentation is noted by higher levels of precipitation compared to the multiannual average, both at arise and at tiller formation, the winter period bringing in quantitative significant precipitations. In the period of intense growth in the spring (March-April) were also recorded higher values well above the multiannual average, which favored the intense development of the plants. The month was poorer in precipitation, but the negative deviation was reduced in value (-8.1 mm), being supplemented by the precipitations that occurred in March and April.

For the experimentation year 2017-2018, although at dawn there was sufficient rainfall to allow germination and planting, in winter the accumulated rainfall was modest in value, with negative deviations from the average multiannual values, as small quantities of water were accumulated, which did not allow good development of the plants in the first part of the spring. Only towards the end of March, when the plants had entered well into the vegetation and on a drought background in the soil, there were consistent precipitations. April came much closer to the normal values recorded, while the month of May came with consistent rainfall, but in this same period, the plants had finished their period of growth and accumulation of vegetative mass.

As concern the year 2018-2019, October was a very poor one in precipitation, only towards the end of November, significant quantities of precipitation were recorded, so the plants had major difficulties in the germination and sprouting process. Subsequently, during the winter, in the background of the drought in the autumn, the water supplies from the soil were not restored, which was accentuated in the first part of the spring, so the plants suffered from water stress. Only in May, it was recorded precipitations close to normal, but their development cycle had been seriously affected.

Table 2

The variation of precipitation recorded during the years of experimentation and the calculation of deviations from the multiannual values

| Year \ Month | | Oct. | Nov. | Dec. | Jan. | Feb. | March | Apr. | May | June | July | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016-2017 | Value | 46 | 63.8 | 103 | 38.8 | 56.4 | 86.4 | 104.6 | 55.6 | 10.2 | 39.6 | 604.40 |
| | Deviation | **5.6** | **11.4** | **56.3** | **0.7** | **18.5** | **45.6** | **52.7** | **-8.1** | **7.3** | **-14.9** | **175.10** |
| 2017-2018 | Value | 56 | 48 | 14 | 6.8 | 12.4 | 53 | 54 | 84.8 | 17.6 | 101.4 | 448.00 |
| | Deviation | **15.6** | **-4.4** | **-32.7** | **-31.3** | **-25.5** | **12.2** | **2.1** | **21.1** | **14.7** | **46.9** | **18.70** |
| 2018-2019 | Value | 7.4 | 46.8 | 53.4 | 38.6 | 14.2 | 25.2 | 44.4 | 69 | 28.5 | 60 | 387.50 |
| | Deviation | **-33** | **-5.6** | **6.7** | **0.5** | **-23.7** | **-15.6** | **-7.5** | **5.3** | **25.6** | **5.5** | **-41.80** |
| Multi-annual | | 40.4 | 52.4 | 46.7 | 38.1 | 37.9 | 40.8 | 51.9 | 63.7 | 2.9 | 54.5 | 429.30 |

From the following figures, it will be seen that in unfavorable environmental conditions, the level of production recorded by some lines is higher than the other genotypes, but in average climatic conditions, their production capacity is lower, while in favorable conditions all lines exceed the average.

In order to achieve the optimal density of the culture, the number of germinating grains that are sown per m$^2$ must be taken into account, a number that, taking into account the entire complex of phyto-technical factors and the particularities of the varieties, should ensure at least 600 productive spikes. The variation limits were between 504 pl./m$^2$ in 2017 (Line 4) and 621 pl./m$^2$ (Line 2) in 2016 (fig. 1).

Wheat has the ability, through tillering, to correct, within certain limits, its unfavorable densities. The number of harvestable spikes is influenced by the variety, each genotype constituting its own density. The potential of a variety to form a higher number of spikes per $m^2$ is strongly influenced by the emergence conditions and the level of cultivation technology. The limits of variation for this character are presented in figure 2. The average of the 3 years of experimentation was 683.76 spikes/$m^2$.

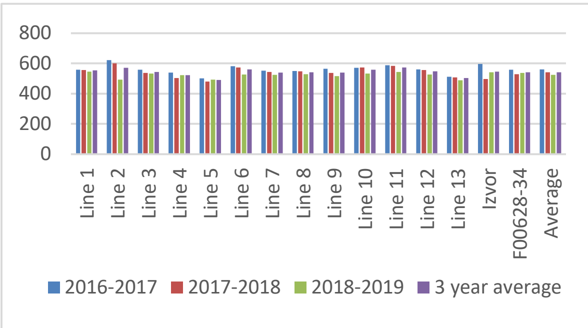


Fig. 1. Values for density to arise

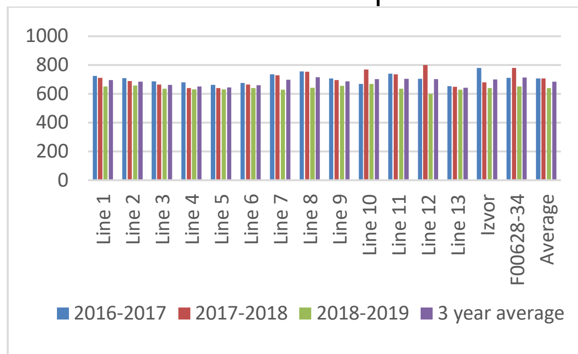


Fig. 2. Values for density to harvest

Plant height is a character that has a major influence on resistance to falling and indirectly on production capacity. The study of this character is an effective means of pre-estimating the fall resistance for the genetic material at the beginning of the breeding process. The mutant/recombinant lines tested alongside the Izvor variety and the improved Line F00628-34 revealed a rather small variability of this character (fig. 3).

Tillering capacity is expressed by the number of siblings, which is a variable hereditary property of the species, variety, variety. Environmental factors are superimposed on the hereditary property, which either limit or favor twinning, such as: nutrition space, temperatures, humidity, light, sowing time, sowing depth, etc. The number of tillers recorded by the experimental mutant/recombinant lines was quite variable depending on the climatic conditions (fig. 4).

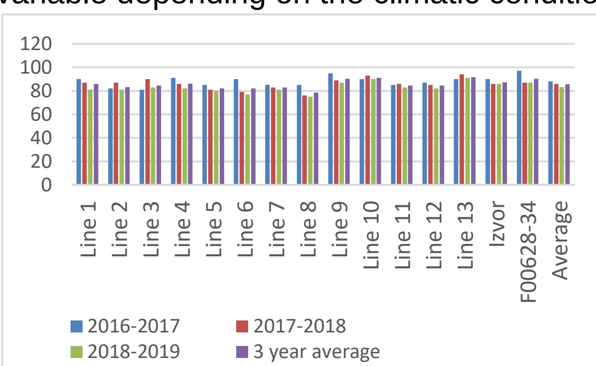


Fig. 3. Values for stem length (cm)

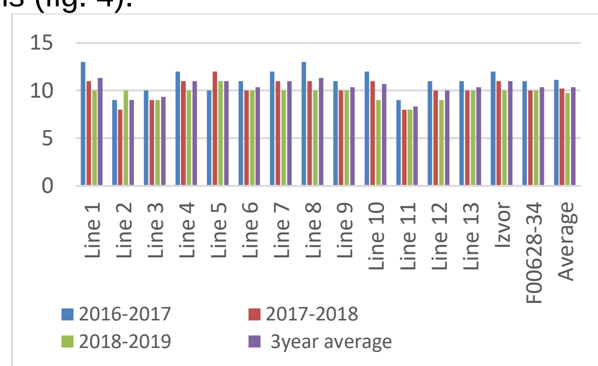


Fig. 4. Values for the number of tillers

The size of the spike is an element of productivity of great importance being determined by genes with additive action, located on almost all chromosomes (Ceapoiu, N. et al., 1984). The size of the ear is an element of productivity of great importance being determined by genes with additive action, located on almost all chromosomes (Ceapoiu, N. et al., 1984). The values recorded for this character are shown in figure 5.

The number of spikelets depends mostly on the compactness of the spike and to a lesser extent on its length. Figure 6 indicates that the mean values for this character were between 21.67 spikelets (Line 1) and 18.33 spikelets (Lines 2, 6, 9, 11, and 13). The average experience was 19.16 spikes.

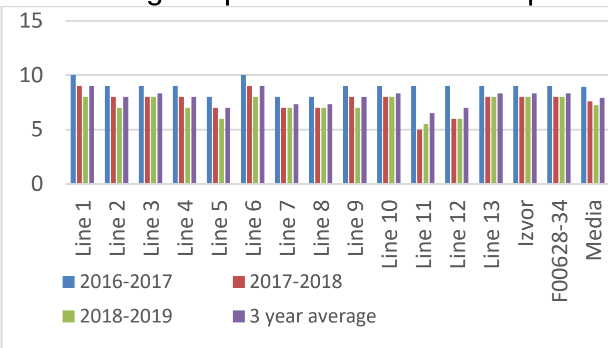


Fig. 5. Values for spike length (cm)

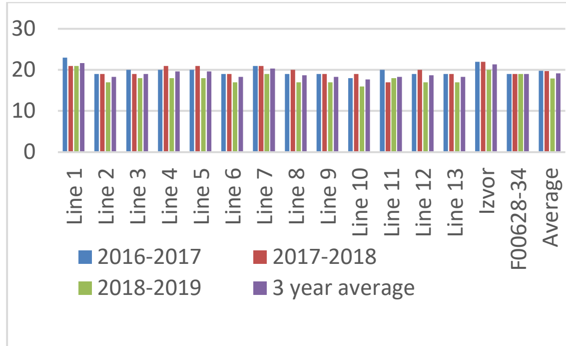


Fig. 6. Values for spikelets/spike

The number of grains in the spike is a variable character because, at the same sowing density, each variety has its own way of reacting to give a production as close as possible to the productivity ceiling. Thus, some lines have the ability to form more spikes/m$^2$ through productive tillering, while having the ability to form more grains in the ear, either by increasing the number of spikelets or the number of grains in each spikelet, which has the end result increased grain weight in the ear. This character is determined by several elements: the density of the spike, the number of grains in the spike, and the environmental conditions, each with a degree of variability (fig. 7, 8).

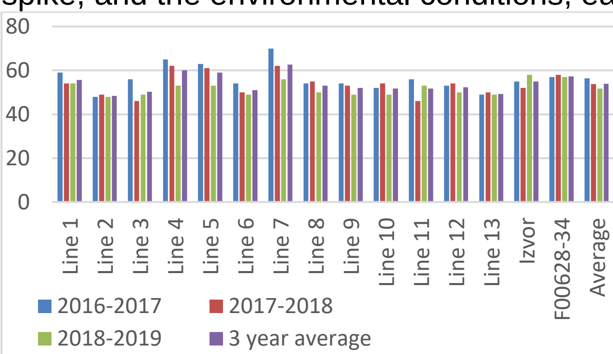


Fig. 7. Values for the number of grains/spike

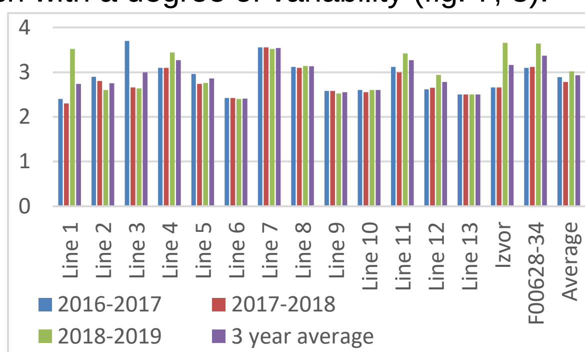


Fig. 8. Values for grain weight/spike

TGW is one of the most stable characters of the production, being an element that is easy to follow in the selection, especially in its first phases (Madoșa, E., 2000). Wheat grains are distinguished by their higher or lower 1000-grain weight, which, although largely influenced by environmental conditions, is primarily a varietal characteristic. The weight of 1000 grains depends on the size of the grain, as well as the state of compression or loosening of the constituent materials in the grain.

The biological material experienced indicates that climatic deviations influence this character quite a bit. The evaluation of the averages of the mutant/recombinant lines from the years of experimentation shows their instability from one year to another, the conclusion being that the selection must be continued to improve this trait (fig. 9).

The highest average production capacity was recorded by Line 5 (6578.67 Kg/ha), while Line 13 recorded the lowest production (5338 Kg/ha). The Izvor variety presented an average production of 6324.67 Kg/ha, and the F00628-34 line, a production of 6603 Kg/ha, against the average experience of 5853 Kg/ha.

It is also found that the experimental mutant/recombinant lines represent a material with a very good production capacity, especially in favorable agricultural years such as the one in the first year of experimentation where the productions were close to 8000 Kg/ha (figure 10).

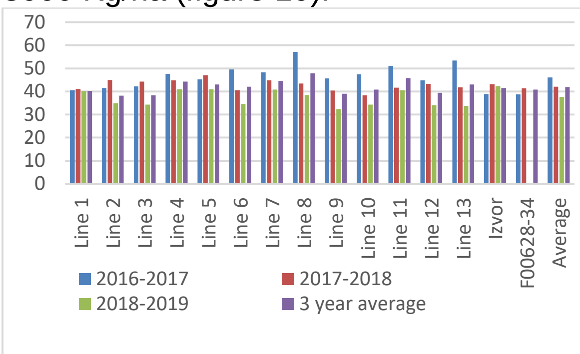


Fig. 9. Values for TKW (g)

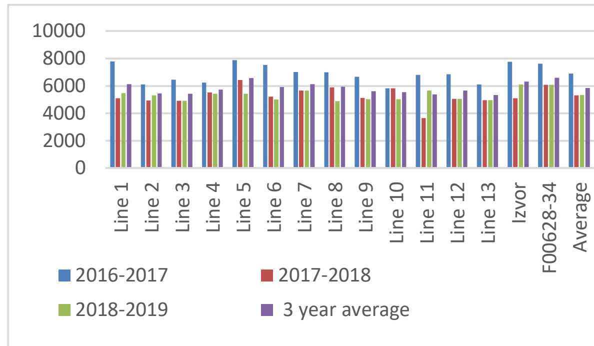


Fig. 10. Values for yield (Kg/ha)

The harvesting work must be finished when the grains have reached about 12-13% moisture, later the wheat goes into the overripe phase, and the losses by shaking increase (figure 11).

For the MH indicator, the Izvor variety ranks on average in the 1st place of the ranking both every year and on the 3-year average, with a value of 77.80 kg/hl, compared to 76.11 kg/hl. The HM recorded slightly fluctuating values between 72.2 kg/hl (Lines 2; 4; 5) and 78.8 kg/hl (Izvor variety) (figure 12).

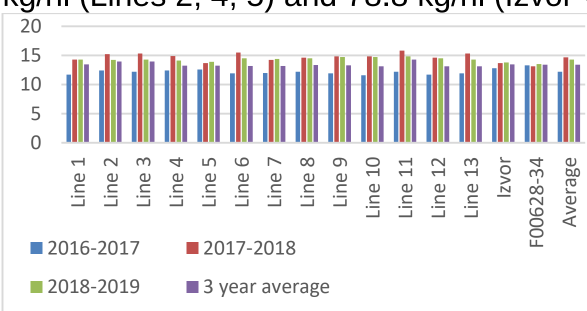


Fig. 11. Values for humidity to harvest (%)

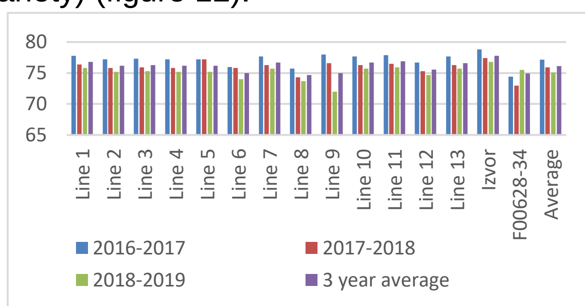


Fig. 12. Values for HM (kg/hl)

From the point of view of the ranking of qualitative characteristics for the protein content indicator, the limits of variation were between 12.2% (line F00628-34) and 14.6% (line 10), and an average of 13.63 % in 2017. From tables 3.1-3.4 and figure 3.13, it can be seen that this year all the mutant/recombinant lines showed higher values, both compared to the Izvor variety and the improved line F00628-34, and compared to the average, some of them registering values above 14% (fig. 13).

Wheat starch is considered to be a byproduct of wheat gluten. In the period 2016-2019, Line 13 presented the lowest starch content with limits between 69.7% and 72%, while lines 2 and 3, and F00628-34 line had the highest values, of 72.4% to 74.9%. The average of the 3 years of experimentation varied according to climatic conditions, and it varied from 70.97% in 2018 to 72.47% in 2019 and 73.46% in 2017 (figure 14).

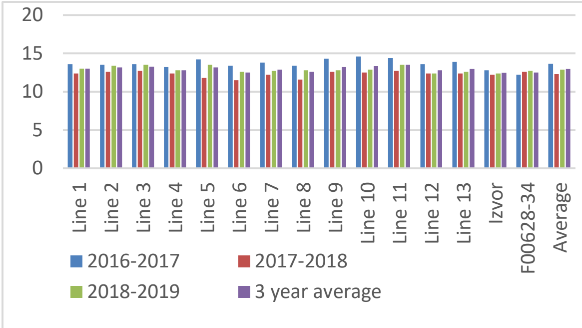


Fig. 13. Values for protein content (%)

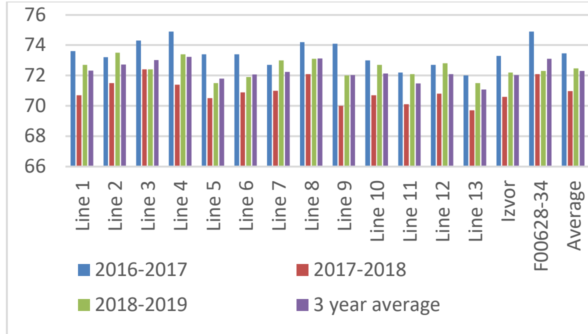


Fig. 14. Values for starch content (%)

Regarding the fiber content, higher values of this character are found in the first year of experimentation compared to the other two years, these being greatly influenced by the climatic conditions (figure 15).

In addition to establishing the variability of individual characters, the relationship between them was also monitored. This is represented by the correlation coefficient. The size of the correlation coefficient tells us the meaning and intensity of the correlation between the characters. Positive correlations are: a distinctly significant correlation between the number of spikelets/spike and number of tillers (r=0.523), yield and number of spikelets/spike (0.589), yield and number of grains/spike (0.695), moisture and weight grain/spike (0.426), moisture and yield (0.580), protein content and HM (0.506) and starch content and yield (0.363). Among the negative correlations, it can mention: the number of siblings and density at emergence (-0.475), MMB and plant height (-0.436), protein content and yield (-0.508), and protein content and moisture (-0.683) (table 3).

Table 3

Correlation coefficient values determined for the characters analyzed

| | Density to arise | Density to harvest | Stem length | No. of tillers | Spike length | No. of spikelets/ spike | No. of grains/ spikelet | Grains weight | TGW | Yield | HM | U% | Protein | Starch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Density to harvest | 0,622 | | | | | | | | | | | | | |
| Stem length | -0,129 | -0,030 | | | | | | | | | | | | |
| No. of tillers | -0,475$^{*}$ | -0,017 | -0,024 | | | | | | | | | | | |
| Spike length | 0,185 | -0,178 | 0,399$^{*}$ | 0,189 | | | | | | | | | | |
| No. of spikelets/spike | -0,161 | 0,059 | -0,126 | 0,523$^{**}$ | 0,170 | | | | | | | | | |
| No. of grains/spikelet | -0,394 | 0,026 | -0,137 | 0,585 | -0,241 | 0,606 | | | | | | | | |
| Grains weight/spike | -0,065 | 0,152 | -0,376 | -0,138 | -0,549$^{**}$ | 0,038 | 0,494$^{*}$ | | | | | | | |
| TGW | -0,022 | 0,006 | -0,436$^{*}$ | 0,057 | -0,413$^{*}$ | -0,442 | -0,060 | 0,212 | | | | | | |
| Yield | -0,305 | 0,461$^{*}$ | 0,630$^{**}$ | 0,602$^{**}$ | 0,312 | 0,947$^{***}$ | 0,793$^{***}$ | 0,132 | 0,314 | | | | | |
| HM | 0,050 | -0,133 | 0,154 | -0,028 | 0,020 | 0,358 | 0,012 | -0,113 | -0,130 | -0,249 | | | | |
| U% | -0,193 | 0,070 | -0,004 | -0,023 | -0,071 | 0,221 | 0,329 | 0,426$^{*}$ | -0,394* | 0,580$^{*}$ * | -0,288 | | | |
| Protein | -0,023 | -0,182 | 0,032 | -0,210 | -0,317 | -0,374 | -0,239 | -0,129 | 0,429$^{*}$ | -0,559$^{*}$ | 0,506$^{*}$ | -0,683$^{**}$ | | |
| Starch | -0,095 | 0,019 | -0,036 | 0,304 | 0,266 | 0,147 | 0,293 | 0,212 | -0,199 | 0,833$^{*}$ ** | -0,358 | 0,472$^{*}$ | -0,544$^{*}$ | |
| Fiber | -0,187 | -0,296 | 0,042 | -0,071 | 0,106 | -0,631$^{**}$ | -0,277 | -0,043 | 0,356$^{*}$ | -0,230 | -0,557$^{*}$ | -0,065 | 0,124 | 0,130 |

The quantitative ratio between two correlated characters is expressed with the help of regression. The regression analysis has important practical applications both as a quantitative ratio of correlation and in evaluating the effects of acting on characters with continuous variability. It is thus possible to predict the response that a characteristic of the organism gives to the stimulation by different means of another characteristic.

Regression, as a quantitative ratio of dependence, is expressed graphically by the regression line, and the analyzed characters, are presented in figures 16-21.

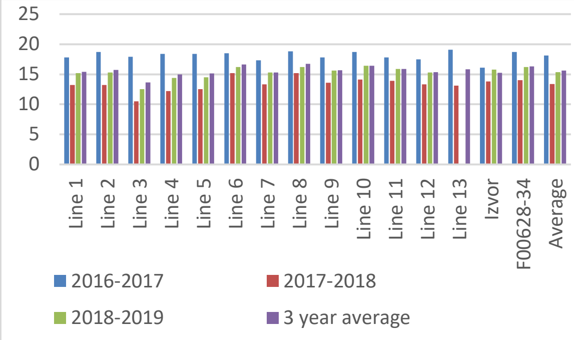


Fig. 15. Values for fiber content (%)

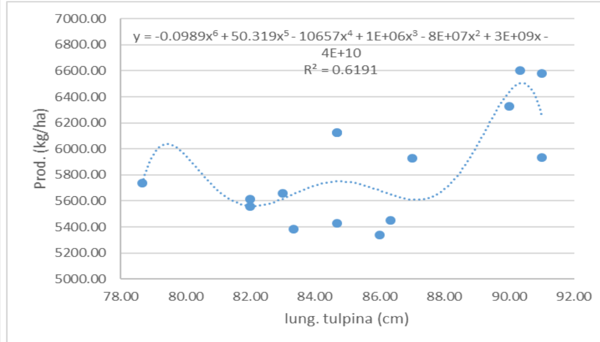


Fig. 16. Regression between yield and plant height

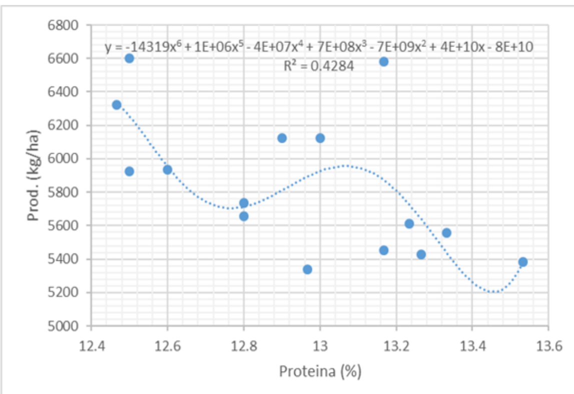


Fig. 17. Regression between yield and protein

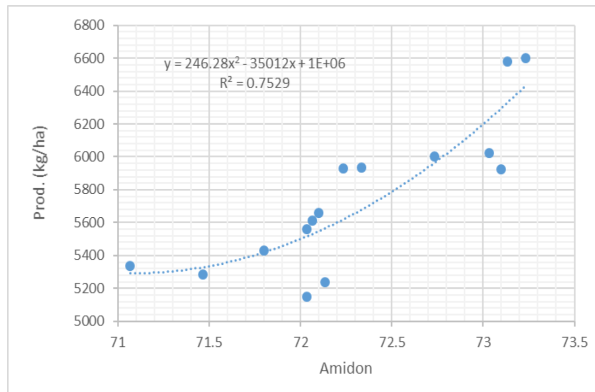


Fig. 18. Regression between yield and starch

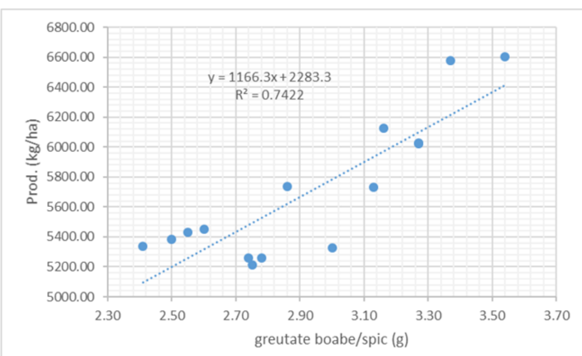


Fig. 19. Regression: yield and grains weight/spike

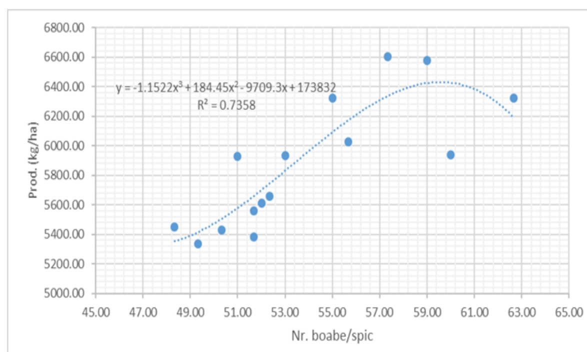


Fig. 20. Regression: yield and number of grains/spike

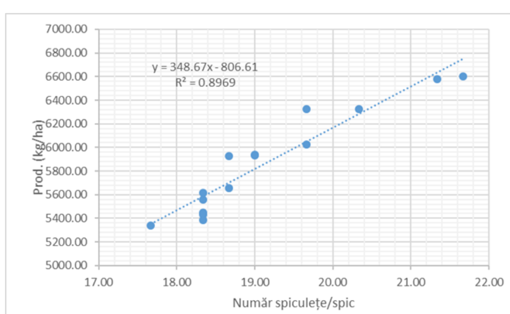


Fig. 21. Regression between yield and number of spikelets/spike

The variability of the existing growth and productivity characters within the wheat lines studied, in addition to the theoretical importance, can also have practical importance in the process of improving the genetic base, reaching the obtaining of varieties capable of capitalizing on the conditions in the southern area of Romania, as well as to actively participate in the use of intensive technical measures and therefore in increasing the profitability of production without additional investments.

Giura, A., et all., (2019) sustain that progress in breeding for heat tolerance could be enhanced by diversification of gene sources for tolerance to high temperatures and *Aegilops speltoides* can be used as a useful source.

Wheat represents an important crop generating a favorable economic aspect at the level of the local producers, especially in the conditions of favorable climatic and economic conjuncture (Medelete, D.M. et all., 2018).

## CONCLUSIONS

Contrasting climate patterns, particularly rainfall accumulation and distribution throughout the season, influenced the relative performance of the lines, affecting the duration of the wheat development stage and impacting productivity. Productivity indices and their performance under suboptimal conditions revealed four lines with a combination of relatively stable and high grain yields in the three seasons: Ai II 212, Bi II 40, Bi Ii 57, and Bi II 82.

## BIBLIOGRAPHY

Ceapoiu, N., 1984. Grâul. Editura Acad. R.S.R. București: 85-96.

Giura, A., Șerban Gabriela, Ciucă Matilda, Daniel Cristina, Turcu Alina Gabriela, Săulescu, N.N., 2019. Improved tolerance to increased temperatures during grain filling in a winter wheat (*Triticum aestivum* L.) line selected from a cross involving *Aegilops speltoides* Tausch. Romanian Agricultural Research, No. 36, pp. 21-26.

Giura, A., 2013. Wheat mutagenesis by combining recurrent irradiation, hybridization and DH technology. In: Journal of Horticulture, Forestry and Biotechnology, 17(4): 114-118.

Giura, A., 2011. Includerea tehnologiei DH într-un protocol de mutageneză la grâu – rezultate preliminare*. An. I.N.C.D.A. Fundulea, Vol. LXXIX, nr. I, pp. 1-10.

Madoșă, E., 2000. Ameliorarea plantelor agricole. Ed. Marineasa, Timișoara: 1-19.

Medelete, D.M., Pânzaru, R.L., Vladu, M., Matei, Gh., 2018. Some considerations regarding the primary wheat supply in Romania and its composition (2014 – 2016). Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development Vol. 18, Issue 1, pp. 245-252.

Săulescu, N.N., Ittu, Gh., Giura, A., Mustăţea, P., Ittu Mariana, 2012. Results of using *Zea* method for Doubled Haploid production in wheat breeding at Nardi Fundulea – Romania.

Săulescu, N.N., Ittu, Gh., Giura, A., Ciucă Matilda, Mustăţea, P., Ittu Mariana, Şerban Gabriela, Neacşu Florentina Amalia, 2010. Diversificarea bazei genetice ca fundament al progresului în ameliorarea grâului. An. I.N.C.D.A. Fundulea, Vol. LXXVIII, Nr. L, pp. 7-20.