Agricultural Science; Vol. 2, No. 1; 2020
ISSN 2690-5396 E-ISSN 2690-4799
https://doi.org/10.30560/as.v2n1p252

Environmental Conditions and Genotype Influence Upon Some Correlations Value to Few Lines of Winter Wheat

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Received: March 26, 2020 Accepted: April 28, 2020 Online Published: May 25, 2020

Abstract

Twenty-five mutant/recombinant lines and the two parental forms of winter wheat were taken into study to assess the correlations between grain yield and some quality traits. This investigation was carried out at ARDS Caracal of University of Craiova, during 2015-2018 cropping seasons in randomized blocks design with 3 replications. It included two factors: A– influence of climatic conditions (2016-2017 favorable conditions (A_1); 2017-2018 less favorable (A_2) and 2018-2019 abnormal conditions (A_3) and b – genotype. Observations were recorded after harvest for grain yield and some quality traits every year after harvest. All the analyzed traits such as proteins, starch, TKW, seeds number/ear, seeds weight/100, seeds weight/ear indicate the experimented material combine well high level of yield and superior quality percent in the grains.

Keywords: winter wheat, PCA, correlation, yield, quality traits

1. Introduction

Globally, demand for wheat by 2050 is predicted to increase by 50 percent from present's levels, so identification of better genotypes with desirable traits is an important objective in every breeding programms.

Agriculture plays a central role in the economy of the southern region of Romania. Here, modern crop technologies have come to provide record harvests on some farms, but sometimes agricultural production is highly dependent on weather conditions.

In 2015, Romania was the 12th largest world grain exporter and ranked 3rd in the EU member states (28), and in 2017 it became the main cereal exporter in the European Union (https://uefiscdi.gov.ro).

Innovative plant improvement techniques respond in part to current challenges. So, improving the quality of the plants has been and is still a significant objective in the activity of breeders, who must create new varieties, which will yield higher yields of useful substances per hectare, with a better nutritional or commercial value.

A basic factor in improving the quality of cultivated plants is the value and diversity of biological material, which must be rich in quality genes or genotypes. The quality traits of the plants are genetic, determined monogenic or polygenic.

Wheat quality is as important as production capacity. The attention paid to improving the quality is highlighted by the numerous meetings and the large volume of research undertaken. They established that both protein and gluten content are heritable traits caused by quantitative physiological differences or as a result of processes of internal elements directed by a particular gene or combination of genes.

Considerable research in the past decade has been devoted to novel techniques and methodologies in wheat biotechnology. The integration of novel techniques and methods into wheat breeding programs is necessary to facilitate continued and accelerated progress in producing new wheat lines. In the past two decades, developments of *in vitro* culture techniques have enabled the production of large numbers of haploid plants, especially in cereals. Of these techniques, anthers culture and chromosome elimination in inter-generic crosses have been the most widely used. The production of DHs has been an important development in wheat breeding,
because, after chromosome doubling to recover fertility, the recovery of homozygous lines can be achieved in a single generation. This can significantly reduce the time taken before advanced comparative trials can be made and new commercial cultivars identified.

Induction of mutations is another possibility to improve quality traits and a useful method to generate new wheat lines. Mutation breeding induces mutations, usually in the seed and includes exposure of seeds to ionizing radiation, ultraviolet radiation or chemical mutagens. The yield and quality of a wheat crop is determined by the complex interaction of water availability, nutrition, environment, pest and disease and genetic make-up (Nuttall, J.G. et all., 2017).

The establishment of yield performance and their correlation with some quality characteristics in some mutant/recombinant wheat lines was the purpose of this study.

2. Material and Method

Field experiments were conducted in the ARDS Caracal (44"7' north latitude and 24"21' east longitude) placed in South Romania over three growing seasons (2016-2019) on a chernozem soil. 10 mutant/recombinant lines of wheat were sown in October at a seeding rate of 400 seeds m^2. Every year, before planting, phosphate was added into the soil at an amount of 70 kg P/ha and nitrogen fertilizer as ammonium nitrate was incorporated also at a rate of 65 kg N/ha. Most of the experimented lines are mutant/recombinant of Izvor variety which was created at NARDI Fundulea, through sexual hybridization, followed by repeated individual selection; it is precocious and has good resistance to fall and winter frost. It is resistant to drought (it has the ormo-regulatory gene) and is recommended for production expansion in the south and east areas of the country while other lines become from breeding line F00628-24 (http://www.madr.ro/docs/cercetare/Rezultate_activitate_de_cercetare/INCDA_Fundulea.pdf).

The analyzed characters were: yield, protein content, starch content, one thousand kernel weight (TKW), seeds no./ear, seeds weight/100 l, seeds weight/ear.

Protein and starch concentration was determined using a Perten Infrared Analyzer. TKW and seeds weight was measured by an electronic caliper (100 randomly grains of each wheat line).

Data were statistically analyzed and means were compared by least significant differences (LSD), P=0.05%. Correlation analysis and coefficients were compared after Pearson significance values and Principal Component Analysis (PCA) was performed based on the analyzed indices. Both correlation and PCA were performed by IBM SPSS Version 2011 and MS Office Excel 2016.

The experiment included two factors: A factor - the environment, with 3 graduations (A_1, A_2 and A_3) and B factor, genotype, with 10 genotypes (G_1-G_{10}).

The graduations of A factor, A_1 A_2, A_3, were considered the vegetation years 2016-2017, 2017-2018 and 2018-2019, the environment influencing decisively the crops behavior.

In the case of temperature analysis, in the 10 months of multi-annual vegetation the average is 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.

Regarding 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**
Multianual		11.2	5.3	0.2	0.9	1.40	6	11.5	17.5	21.3	23.2	9.85

In the case of precipitation analysis, the multiannual average amount was 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 vegetation period, the first year of experimentation is noted by higher levels of precipitation compared to the multiannual average, both at arise and tillering, 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.

Regarding 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 in small quantities of water were accumulated, which did not allow a 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.

Regarding 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 that 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 that 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**
Multianual		40.4	52.4	46.7	38.1	37.9	40.8	51.9	63.7	2.9	54.5	429.30

3. Results and Discussions

Quality characteristics (content of proteins and starch,) are strongly influenced by environment conditions and fertilization. Proteins are stable constituents in dry grains.

Proteins content from wheat grains may vary from less than 6 % to more than 20% and are distributed over the whole grain. The applying of fertilization during growing is essential for optimal plant development. Nitrogen (N) fertilization is, in particular, important for common wheat, because a high N supply provides high protein content.

It seems that for the experimented areal, the lines presented superior genetic potential, both for yield and some productivity elements and for quality.

3.1 Influence of A Factor

As concern yield analysis, TKW, no. of seeds/ear and seeds weight/ear, the highest value is registered at the A_1 graduation, which recorded significant differences compared to the values recorded by the other two graduations and between these there is a significant difference.

In the case of protein content, the highest value was registered at the A_3 graduation, which records significant differences compared to the values recorded by the other two graduations and between these, there is also a significant difference. Regarding the starch content, the highest value is registered at the A_2 graduation, with significant differences compared to the values recorded by the other two and between these, there is a significant difference.

In the case of seeds weight/100 l, the highest value was registered at the A_1 graduation with significant differences compared to the values recorded by the other two and between the latter not registering a significant difference (table 3).

Aslani, F. et all., 2013 stated that water stress and high temperature are the principle environmental parameters affecting wheat grain quality under Mediterranean conditions. Also, drought stress environments are generally in relation to a rise in protein content (Pompa, M. et al., 2009).

It can be seen from these results that abiotic stress influences yield and quality and it is difficult to calculate exactly how it will affect crops. In the future, the productivity of major crops is expected to decline in many countries of the world due to global warming, lack of water and other environmental impacts (Ali Raza et all., 2019).

Analysis of variance revealed significant differences among a category of amphidiploids and mutant/recombinant genotypes for many morphological characters of wheat, due mostly to the influence of the climatic conditions of the region (Iancu Paula et all., 2019 a).

Table 3. Influence of A factor upon studied characters' variability

Character / A graduations	Yield (kg/ha)	Protein (%)	Starch (%)	TKW (g)	Seeds no./ear	Seeds weight/100 l	Seeds weight/ear
A_1	6998.2^a	12.36^b	74^a	49.20^a	65.81^a	78.18^a	2.97^a
A_2	5467.6^b	11.69^c	72.32^b	45.39^b	49.86^c	77.73^{ab}	2.88^b
A_3	3846.9^c	12.92^a	71.33^c	43.48^c	58.23^b	76.81^b	2.74^c
Average	5437.5	12.32	72.55	46.02	57.97	77.57	2.86
LSD	109.38	0.321	0.379	1.056	1.248	1.014	0.107

3.2 Influence of B Factor

In the case of yield analysis the first five genotypes differ significantly from all the others and between them there are no statistical differences.

For protein content, the highest value was recorded by genotype B_8, this differing significantly compared to the last 5 classified genotypes.

In the case of starch content, the most productive genotype B_1 records the highest content, differing significantly from all other genotypes, except with the exception of the second classified genotype. As concern TKW analysis, the most valuable result was recorded by genotype B_2, which differs significantly from all other analyzed genotypes (table 4).

Regarding the seeds no./ear, the first classified genotype differs significantly compared to the last 7 classified, this being the most productive. For seeds weight/100 l, the best results are recorded by genotypes B_5 and B_6, which differ significantly compared to the last 4 classified genotypes. Concerning seeds weight/ear, the first 3 classified genotypes, which are also the most productive, register significant differences compared to all the other genotypes analyzed.

Table 4. Influence of B factor upon studied characters' variability

Character / B graduations	Yield (kg/ha)	Protein (%)	Starch (%)	TKW (g)	Seeds no./ear	Seeds weight/100 l	Seeds weight/ear
B_1	5945.00^{a}	11.67^{e}	74.07^{a}	45.47^{b-e}	62.07^{a}	78.30^{ab}	3.30^{a}
B_2	5958.33^{a}	11.97^{de}	73.40^{ab}	52.28^{a}	61.67^{ab}	78.12^{ab}	3.26^{a}
B_3	5858.67^{a}	12.07^{c-e}	73.13^{b}	46.64^{bc}	60.73^{ab}	77.73^{ab}	3.23^{a}
B_4	5773.33^{a}	12.27^{b-d}	73.03^{b}	45.53^{b-d}	59.53^{bc}	78.17^{ab}	2.92^{b}
B_5	5785.00^{a}	12.23^{b-e}	72.87^{bc}	44.96^{c-e}	58.20^{cd}	79.03^{a}	2.89^{b}
B_6	5156.33^{b}	12.47^{a-d}	72.27^{cd}	47.02^{b}	56.87^{d}	78.98^{a}	2.88^{b}
B_7	5253.33^{b}	12.37^{a-d}	72.20^{cd}	44.94^{c-e}	56.53^{d}	77.12^{b}	2.65^{c}
B_8	4934.00^{c}	12.90^{a}	71.97^{d}	43.67^{de}	56.27^{de}	76.93^{b}	2.59^{c}
B_9	4780.67^{c}	12.70^{ab}	71.70^{d}	46.18^{bc}	54.07^{ef}	76.60^{bc}	2.56^{c}
B_{10}	4930.33^{c}	12.60^{a-c}	70.87^{e}	43.55^{de}	53.73^{f}	74.73^{c}	2.34^{d}
Average	5437.50	12.32	72.55	46.02	57.97	77.57	2.86
LSD 5%	199.70	0.586	0.692	1.929	2.279	1.851	0.196

Literature ensures greater variation in protein content. It has been reported wider germplasm screens with the comparison of 212.600 lines in the World Wheat Collection showing a range from about 7 to 22% protein on a dry weight basis (Vogel, K.P. et all., 1976).

Lines with higher grain protein contents presented lower starch percent. Iancu Paula et all., 2018 a, also reported some amphidiploids lines which presented high quality characteristics in combination with other agronomic desirable characters and represent valuable genes sources which can be incorporated into future wheat breeding programs and other genetic studies.

As concern protein content of the whole grains flour of some mutant/recombinant lines, highly significant differences were detected and some of them could be grown as a new and suitable release for the experimented region (Iancu Paula et all., 2018 b).

Starch is the major storage carbohydrate of cereals and an important part of human
nutrition and lately became also an important feedstock for bioethanol or biogas production. The result for starch percent for the mutant/recombinant lines ranged from 70.87% (B_{10}) to 74.07% (B_1). Shewry, P.R., 2013 sustained that the increases in starch content are largely responsible for the increases in grain size achieved by breeding programs in order to produce high-yielding wheat varieties (table 5).

Table 5. Influence of A and B factors interaction upon studied characters' variability

Character / a_ib_i variant	Yield (kg/ha)	Protein (%)	Starch (%)	TKW (g)	Seeds no./ear	Seeds weight/ 100 l	Seeds weight/ear
a_1b_1	7900.00^{a}	12.00^{d-i}	75.30^{a}	48.55^{b-f}	70.20^{a}	79.10^{a-d}	3.47^{a}
a_1b_2	7840.00^{a}	12.10^{d-h}	74.90^{ab}	57.20^{a}	69.60^{a}	79.00^{a-d}	3.36^{ab}
a_1b_3	7827.00^{a}	12.40^{b-g}	74.30^{a-c}	49.50^{b-e}	67.60^{ab}	78.60^{a-d}	3.32^{a-c}

a_1b_4	7760.00^{a}	12.10^{d-h}	74.20^{a-d}	48.28^{b-f}	66.40^{a-c}	77.00^{a-e}	3.02^{c-h}
a_1b_5	7735.00^{a}	12.00^{d-i}	73.90^{b-e}	47.65^{c-g}	65.10^{b-d}	79.80^{a}	3.01^{c-h}
a_1b_6	6320.00^{b}	12.60^{b-f}	73.80^{b-e}	50.08^{bc}	64.80^{b-d}	79.75^{ab}	2.98^{d-h}
a_1b_7	6320.00^{b}	12.10^{d-h}	73.70^{b-f}	50.00^{b-d}	64.60^{b-d}	77.85^{a-e}	2.77^{g-k}
a_1b_8	6170.00^{bc}	12.60^{b-f}	73.50^{c-g}	46.67^{d-h}	64.00^{b-d}	77.65^{a-e}	2.70^{h-l}
a_1b_9	6092.00^{bc}	12.80^{b-e}	73.30^{c-h}	49.46^{b-e}	63.20^{cd}	77.00^{a-e}	2.69^{h-m}
a_1b_{10}	6016.00^{b-d}	12.90^{bd}	73.10^{d-h}	44.63^{g-k}	62.60^{c-e}	76.05^{d-f}	2.37^{m-o}
a_2b_1	5750.00^{de}	11.00^{i}	74.40^{ab}	46.44^{e-i}	53.60^{hi}	78.40^{a-d}	3.32^{a-c}
a_2b_2	5864.00^{c-e}	11.30^{hi}	72.90^{e-i}	51.09^{b}	53.40^{hi}	78.25^{a-e}	3.31^{a-d}
a_2b_3	5642.00^{d-f}	11.40^{gi}	72.80^{e-i}	42.98^{j-n}	53.00^{h-j}	77.50^{a-e}	3.30^{a-d}
a_2b_4	5635.00^{ef}	11.60^{f-i}	72.60^{f-i}	47.50^{c-g}	52.00^{i-k}	79.30^{a-c}	2.90^{e-i}
a_2b_5	5520.00^{ef}	11.70^{f-i}	72.40^{g-j}	44.16^{h-l}	50.40^{i-k}	79.20^{a-d}	2.87^{f-i}
a_2b_6	5312.00^{fg}	11.80^{e-i}	72.30^{h-j}	45.61^{f-j}	49.20^{jk}	79.20^{a-d}	2.87^{f-i}
a_2b_7	5628.00^{ef}	12.00^{d-i}	72.30^{h-j}	44.87^{g-j}	48.80^{kl}	77.00^{a-e}	2.68^{h-m}
a_2b_8	5075.00^{g}	12.00^{d-i}	71.80^{i-k}	43.21^{i-n}	48.60^{k-m}	76.80^{a-e}	2.60^{i-o}
a_2b_9	5125.00^{g}	12.00^{d-i}	71.30^{j-l}	44.50^{g-k}	45.00^{lm}	76.50^{b-e}	2.58^{i-o}
a_2b_{10}	5125.00^{g}	12.10^{c-h}	70.40^{mn}	43.57^{h-m}	44.60^{m}	75.10^{ef}	2.34^{no}
a_3b_1	4185.00^{h}	12.00^{d-i}	72.50^{g-i}	41.42^{k-n}	62.40^{c-e}	77.40^{a-e}	3.11^{b-f}
a_3b_2	4171.00^{h}	12.50^{b-f}	72.40^{g-j}	44.55^{g-k}	62.00^{de}	77.10^{a-e}	3.10^{b-g}
a_3b_3	4107.00^{hg}	12.40^{b-g}	72.30^{h-j}	43.44^{h-m}	61.60^{de}	77.10^{a-e}	3.07^{b-g}
a_3b_4	3925.00^{h-i}	13.10^{a-c}	72.30^{h-j}	40.80^{mn}	60.20^{d-f}	78.20^{a-e}	2.83^{f-j}
a_3b_5	4100.00^{hg}	13.00^{b-d}	72.30^{h-j}	43.08^{j-n}	59.10^{e-g}	78.10^{a-e}	2.78^{f-k}
a_3b_6	3837.00^{h-j}	13.00^{b-d}	70.70^{k-m}	45.38^{f-j}	56.60^{f-h}	78.00^{a-e}	2.78^{f-k}
a_3b_7	3812.00^{g-j}	13.00^{b-d}	70.60^{l-n}	39.96^{n}	56.20^{gh}	76.50^{b-e}	2.50^{j-o}
a_3b_8	3557.00^{j}	14.10^{a}	70.60^{l-n}	41.12^{l-n}	56.20^{gh}	76.35^{c-e}	2.47^{k-o}
a_3b_9	3125.00^{k}	13.30^{ab}	70.50^{mn}	44.57^{g-k}	54.00^{hi}	76.30^{c-e}	2.42^{l-o}
a_3b_{10}	3650.00^{ij}	12.80^{b-e}	69.10^{n}	42.44^{j-n}	54.00^{hi}	73.05^{f}	2.31^{o}
LSD	345.88	1.015	1.199	3.341	3.948	3.206	0.340

PCA analysis indicates that the first two components account for 78.78% of the total version, of which the first component registers 60.8% and the second component 17.93% (table 6).

Table 6. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1.	4.256	60.807	60.807	4.256	60.807	60.807
2.	1.255	17.932	78.739	1.255	17.932	78.739
3.	0.671	9.581	88.319			
4.	0.405	5.791	94.110			
5.	0.274	3.908	98.018			
6.	0.082	1.164	99.183			
7.	0.057	0.817	100.000			

Extraction Method: Principal Component Analysis.

In a similar experience, but in groundnuts, PCA analysis accounted 95.57% with the first PC of 74.38 % whereas the second PC of 21.19% (Iancu Paula et all., 2019 b).

Analysis of the first component indicate positive values for all analyzed characters except the protein content, so this component can be considered as an identifier for the variants with high production results, with good starch content and high value yield elements. For the second component, positive values for protein and seeds no./ear are recorded, so it is an identifier for high-protein variants with high values for TKW and seeds no./ear (table 7).

Table 7. Character Component score Method: Principal Component Analysis 2 components extracted

Character / Component	Yield (kg/ha)	Protein (%)	Starch (%)	TKW (g)	Seeds no./ear	Seeds weight/100 l	Seeds weight/ear
1	0.870	-0.542	0.954	0.803	0.607	0.765	0.836
2	0.028	0.798	0.100	0.112	0.744	-0.112	-0.170

The first group consists of 9 variants that have both positive components, these variants being: a_1b_1, a_1b_2, a_1b_3, a_1b_4, a_1b_5, a_1b_6, a_1b_7, a_1b_8 and a_1b_9. This group is characterized by the fact that almost all genotypes are present at A_1 graduation. In other words, A_1 graduation determines for all genotypes the highest production values, high protein and starch content and very high values of the production elements (chart 1).

The second group consists of 6 variants respectively a_2b_1, a_2b_2, a_2b_3, a_2b_4, a_2b_5, and a_2b_6, variants having the first positive and the second negative. Characteristic for this group is the fact that it was identify the first 6 genotypes as yield potential under the conditions offered by the A_2 graduation, this resulting in lower yields compared to the first graduation, the lowest protein content, high starch content and yield elements with highest values for seeds weight/100 l and respectively for seeds weight/ear.

The third group consists of 5 variants respectively a_2b_7, a_2b_8, a_2b_9, a_2b_{10} and respectively, a_3b_1, variants that have both negative components, being genotypes less productive under the conditions offered by A_2 graduation or B_1 genotype under A_3 graduation conditions. A_2 graduation provides for these genotypes poor production results and low protein and starch content, with low production elements.

The fourth group consists of 10 respective variants a_1b_{10}, a_3b_2 a_3b_3, a_3b_4, a_3b_5, a_3b_6, a_3b_7, a_3b_8, a_3b_9 and a_3b_{10}, variants having the first negative component and the second positive. Characteristic for these groups is the fact that it is represented by all genotypes in the conditions offered by the A_3 graduation, which determines the poorest production results, the highest content of protein, the lowest content of starch and production elements with modest values.

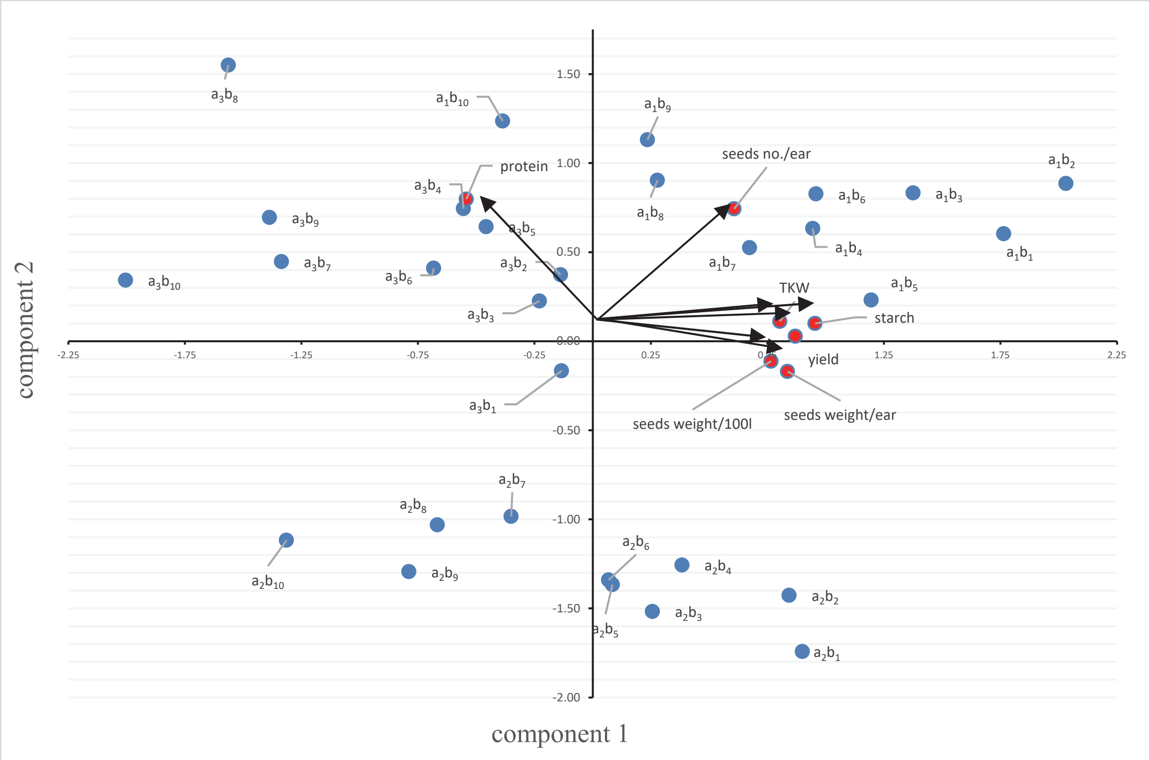

Chart 1. Distribution of the analyzed variants by groups according to PCA analysis

Analysis of cereal productivity data for the last few decades reveals considerable increase in yield, but it appears that negative impact of climate change have large influence in vegetation period. Drought conditions are a frequent impediment to maximized production. Plants are sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate. For every degree increase in mean temperature, grain yield decreased by 428 Kg/ha (Khan, S.A., et all., 2009). Climate change proved to have negative effect on yield and productivity of agricultural crops.

Genetic variability and character association is a pre-request for improvement of any crop and for selection of superior genotypes and improvement of any trait (Krishnaveni, B. et al., 2006).

In this study, the correlation coefficients between the studied characters were calculated according to each group resulting from the PCA analysis (table 6).

The correlation between yield and protein is very strong in productive genotypes both under favorable conditions (A_1) and less favorable (A_2) and weak at low productive genotypes or under abnormal conditions (A_3), irrespective of the biological production potential of genotypes.

The correlation between yield and starch is strong for all genotypes under favorable conditions (A_1) or abnormal conditions (A_3) and becomes insignificant for genotypes with lower biological potential under A_2 conditions. Also, the correlation between yield and TKW is very strong in genotypes with lower biological potential under A_2 conditions. Regardless of conditions or biological potential between yield and seeds no./ear there is a very strong correlation. Seeds weight/100 l influence production only on genotypes with high biological potential and under A_2 conditions.

Under favorable conditions (A_1) or less favorable (A_2), regardless of the biological potential seeds weight/ear strongly influences yield. The relationship between protein and starch is strong and indirect under favorable conditions (A_1) and normal conditions (A_2) regardless of biological potential. No relationship between protein and TKW was identified regardless of biological potential or experimental conditions. The relationship between protein and seeds no./ear is strong and inverse under normal conditions (A_2) to genotypes with high biological potential.

The correlation between protein and seeds weight/100 l is strong and inverse under normal conditions for genotypes with low biological potential. The relationship between protein and seeds weight/ear is strong and inverse, regardless of biological potential or experimental conditions. Only under favorable conditions (A_1) can a relationship between starch and TKW be identified.

The relationship correlation between starch and seeds no./ear is strong and inverse regardless of the biological potential or conditions of experimentation. There is a strong direct relationship between starch and seeds weight/100 l in abnormal conditions (A_3) regardless of biological potential. The correlation between starch and seeds weight/ear is strong and direct regardless of the biological potential. The relationship between TKW and seeds no./ear is strong and inverse under normal conditions (A_2) genotypes with low biological potential. The relationship between TKW and seeds weight/100 l was not identified, regardless of the biological potential and experimental conditions.

A strong inverse relationship between TKW and Seeds weight/ear normal conditions (A_2) can be identified in genotypes with low biological potential. The correlation between seeds no./ear and seeds weight/100 l is very strong under normal conditions regardless of the biological potential.

The correlation between seeds no./ear and seeds weight/ear is very strong and direct regardless of the biological potential and conditions of experimentation. The correlation between seeds weight/100 l and seeds weight/ear is very strong and direct, regardless of the biological potential under favorable conditions (A_1) or abnormal (A_3) and inverse less favorable conditions (A_2) (table 8).

Table 8. Variation of correlation coefficients between studied characters depending on variant groups resulted after PCA analysis

Crt. no.	Correlation relationship \ r values	PCA groups according to components: Comp. 1 + / Comp. 2 +	Comp. 1 + / Comp. 2 -	Comp. 1 - / Comp. 2 -	Comp. 1 - / Comp. 2 +
1.	yield/protein	-0.733***	-0.808***	0.104^{ns}	-0.324^{ns}
2.	yield/starch	0.807***	0.576*	-0.269	0.687***
3.	yield/TKW	0.235^{ns}	0.574*	0.945***	0.281^{ns}
4.	yield/seeds no./ear	0.815***	0.937***	-0.807***	0.733***
5.	yield/seeds weight/100 l	0.355^{ns}	-0.541*	-0.316^{ns}	0.043^{ns}
6.	yield/seeds weight/ear	0.853***	0.782***	-0.697**	-0.018^{ns}
7.	protein/starch	-0.660***	-0.927***	-0.834***	-0.342^{ns}
8.	protein/TKW	-0.170^{ns}	-0.289^{ns}	0.023^{ns}	-0.370^{ns}
9.	protein/seeds no./ear	-0.615^{ns}	-0.897***	-0.406^{ns}	-0.495**
10.	protein/seeds weight/100 l	-0.325^{ns}	0.624**	-0.928***	0.001^{ns}
11.	protein/seeds weight/ear	-0.551**	-0.885***	-0.641**	-0.522**
12.	starch/TKW	0.418*	0.152^{ns}	-0.298^{ns}	0.235^{ns}
13.	starch/seeds no./ear	0.989***	0.697**	0.736**	0.941***
14.	starch/seeds weight/100 l	0.409*	-0.384	0.971***	0.622***
15.	starch/seeds weight/ear	0.944***	0.682**	0.859***	0.555**
16.	TKW/seeds no./ear	0.483*	0.353^{ns}	-0.826***	0.219^{ns}
17.	TKW/seeds weight/100 l	0.218^{ns}	0.107^{ns}	-0.290^{ns}	0.093^{ns}
18.	TKW/seeds weight/ear	0.421*	0.234^{ns}	-0.656**	0.203^{ns}
19.	seeds no./ear/seeds weight/100 l	0.378^{ns}	-0.709***	0.694***	0.461*
20.	seeds no./ear/seeds weight/ear	0.958***	0.885***	0.952***	0.619***
21.	seeds weight/100 l/seeds weight/ear	0.533**	-0.891***	0.855***	0.668***
22.	r significance P 5%	0.380	0.468	0.514	0.361

23.	levels	P1%	0.486	0.589	0.641	0.462
24.		P 0.1%	0.597	0.708	0.760	0.570

Two tailed significance levels of the Pearson correlation coefficient

4. Conclusions

The first graduation of factor A is decisive regarding the expression of the yield potential for all genotypes, while the A_3 graduation is decisive regarding the protein content.

Concerning the B factor influence, the genotype, on yield potential, it is decisive in the A_1 graduation conditions, where even the least productive genotypes obtain superior results compared with the results obtained by the best genotypes under A_2 and A_3 graduations conditions.

Under the conditions offered by A_3 graduation, almost all genotypes obtain the highest protein content and record the lowest production results.

The first two graduations of factor A are decisive regarding the first two groups of variants. Thus, the variants in the first group are almost all genotypes on A_1 graduation, while the variants in the second group are the first 6 genotypes as biological potential under the conditions offered by the A_2 graduation.

In relation to the analysis of the correlations between the studied characters, certain correlations are universally valid regardless of the group of variables analyzed, among them we mention: yield and seeds no./ear, starch and seeds weight/ear, seeds no./ear and seeds weight/ear, seeds weight/100 l if seeds weight/ear.

Only one relationship was found to be insignificant regardless of the analyzed group, the one between TKW and seeds weight/100 l, otherwise said regardless of genotype and environment for the analyzed genotypes, there is no relationship between the two characters.

The relationship between yield and protein is strongly indirect only in favorable conditions that allow the expression of a high biological potential, in unfavorable conditions, the drastic decrease of the yield no longer allows the identification of a relationship between the two analyzed characteristics.

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