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RESPONSE OF SOME NEW WHEAT GENOTYPES TO NITROGEN FERTILIZATION AND PROSPECTS OF YIELD BREEDING BASED ON YIELD ELEMENTS

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ABSTRACT

Fertilizing wheat with nitrogen plays an important role in obtaining high yield and quality. In Romania's environmental conditions, data regarding nitrogen fertilization are reported in various studies at different N levels.

The aim of this research was to study the effect of different nitrogen doses on yield and quality of several new mutant/recombinant lines of winter wheat. Field trials were carried out in south of Romania during 2015-2017 in a rape-wheat rotation. The design of the yield trial was as complete randomised blocks with four replications and included two factors: A – three variants of fertilization (N_0, N_{50} and N_{100}) and B – genotype (line). At harvest, the number of grains per spike, grain weight/spike, thousand grain weight, grain yield and hectolitre weight were analysed. In variants fertilized with N_{100} the highest values for all studied parameters (yield – 5104.55 kg/ha; grains weight/spike – 3.35 g; TGW – 48.31g; HW – 78.76; number of grains/spike – 58.35) were registered. These results confirm good efficiency of N application.

Principal component analysis revealed that seven variants, which had both positive components were fertilized with N_{100} and were all ranked in firsts seven position in the yield classification.

Keywords: wheat, grain yield, nitrogen, yield elements.

INTRODUCTION

The cereals represent the group of plants with the largest cultivation area, both at world level and for Romania, due to the special importance and multiple uses. Wheat belongs to the category of species with thermal needs of temperate climate and the most favourable soils are chernozems.

Nitrogen is the main factor in growth and development of plants, with positive influence on rooting, tillering, leaf system development and photosynthesis process, the elements of productivity and also quality (Matei, 2014).

Although it has a relatively low consumption of nutrients, wheat is particularly demanding of fertilizer, due to the fact that the root system explores a small amount of soil and has low power of solubilization and absorption of nutrients.

Wheat has long growing season, but most of the nutrients are absorbed in a relatively short time. To obtain high yields, plants can not meet nutritional requirements however rich the soil may be. Thus, early spring application of fertilizers, especially those with nitrogen for replenishing the soil becomes necessary and appropriate for the culture of wheat. Also, wheat nutrition in the cold season, from sprouting until the early formation straw must not be neglected.

With the transition to the intensive agriculture and the use of higher doses of fertilizers it became necessary to create new varieties able to use superior quantities of nutrients. The investigations conducted until today in Romania have shown that nitrogen is the main factor in increasing winter wheat yield (Mihăilă et al., 1980; Hera et al., 1984). The introduction into cultivation of new wheat varieties, with high production capacity, with higher protein content and enhanced resistance to unfavourable factors, has led to an increase of their requirements to fertilization.

In a research paper in which the evolution of wheat yield was presented when was cultivated after maize and after pulses, depending on fertilization with nitrogen and

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phosphorus, from the establishment of trial (1966, for wheat cultivated after maize and 1976, for wheat cultivated after beans), Ţinţişan (2015) concluded, that the economic optimum dose maintains soil fertility, genetic progress manifestation of genotypes grown and produce high yields in sustainable agriculture.

Period of application, efficacy and dose of fertilizer have been the subject of much research at NARDI Fundulea. Fractional autumn and spring fertilization achieved a growth factor for use of fertilizers by 8-9% (Burlacu et al., 2007). Also, in a three year study with 4 different tillage treatments and 3 nitrogen fertilization levels for winter wheat, Stošić et al. (2017) mentioned that, excluding the weather conditions, the strongest influence on the investigated parameters had tillage treatments, and much less Nitrogen fertiliser and at the end tillage treatment × Nitrogen fertilise interaction.

In Romania, the optimum N fertilization rate of wheat is locally regarded as 120 Kg N ha^{-1} or 80 kg N ha^{-1} when is cultivated after pea. Also, yield benefits are greater when N is applied at tillering than when it is applied at planting; higher values of N fertilizer recovery can be obtained after application at tillering. N fertilizer use efficiency ranging from 25-35%, the highest value being obtained with N applied at 54 kg ha^{-1} at tillering after pea crop (https://www-pub.iaea.org/MTCD/publications/PDF/te_1164_prn.pdf).

Wheat grain yield is highly dependent on genetic and environmental factors: nitrogen availability, water, temperature and management practices. The objective of this study was to make an evaluation of the influence of the interaction of nitrogen doses and genotype.

MATERIAL AND METHODS

The yield trial was organized in South Romania (ARDS Caracal - 44°06' N; 24°21' E) in two successive crop seasons, on chernozem soil rich in humus ≥ 3 and with pH = 7.5-7.7, using randomised block design with 4 replications. Biological material consisted of 11 mutant/recombinant lines of wheat obtained by NARDI Fundulea using a specific mutagenesis protocol including two modern wheat genotypes by applying two irradiation cycles, hybridisation and DH technology (Giura, 2013).

Crop management measures were performed according to the recommendations for winter wheat cultivation. The previous crop was winter oilseed rape. The area of experimental plots for sowing was 9 m^2 and for harvest 7 m^2. Two factors: nitrogen doses (N_0, N_{50}, N_{100}) applied in two fractions (half at the time of sowing and the other half at stem elongation) and genotype (11 mutant/recombinant lines) were tested during 2015-2017. Measurements and determinations for this study included: yield, grain weight/spike, thousand grains weight (TGW), hectolitre weight of grains (HW) and number of grains/spike.

Grain yield obtained from the plots was calculated per 1 ha, considering 14% humidity, grains weight/spike and TKW were determined by weighing with high precision balances. The obtained results were statistically evaluated by the method of analysis of variance (ANOVA). Differences between mean values were evaluated by Tukey's (LSD) test at the level of significance P=0.05 for every character. The computations were done using the Statistica 8.0 programme (StatSoft, Tulsa, USA) and also included Pearson correlations for every pair of characters, regressions model for correlations with R^2 higher than 0.7, PCA analysis and correlation between nitrogen doses and characters.

RESULTS AND DISCUSSION

Southern Romania is an important agricultural region, which is increasingly affected by drought and the distribution of rainfall became very un-uniform.

Climatic conditions of the experimentation years showed favourable conditions for winter wheat crop. First experimentation year presented warmer winter comparative with the second and both years registered consistent quantity of rainfall (Figures 1 and 2).

As consequence, the incidence of diseases was strong, with large effects on yield. January was the coolest month with temperatures of -3.7°C, respectively -6,1°C, as compared with -1.3°C average of 30 years. Highest temperatures were registered in July, when few days were very hot.

Quantity of rainfall varied from 3.6 mm (December) to 110.8 mm (November) in the first year and from 6.8 mm (January) to 101.4 mm (July) in the second year. There were few months when the quantity of rainfall was excessive, favouring N levigation.

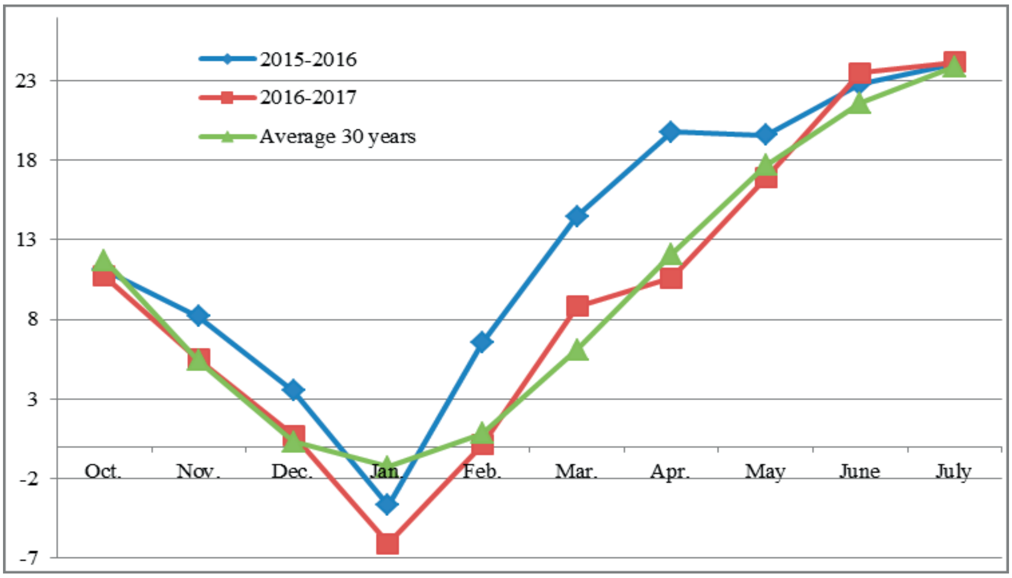

Figure 1. Average monthly temperature (°C)

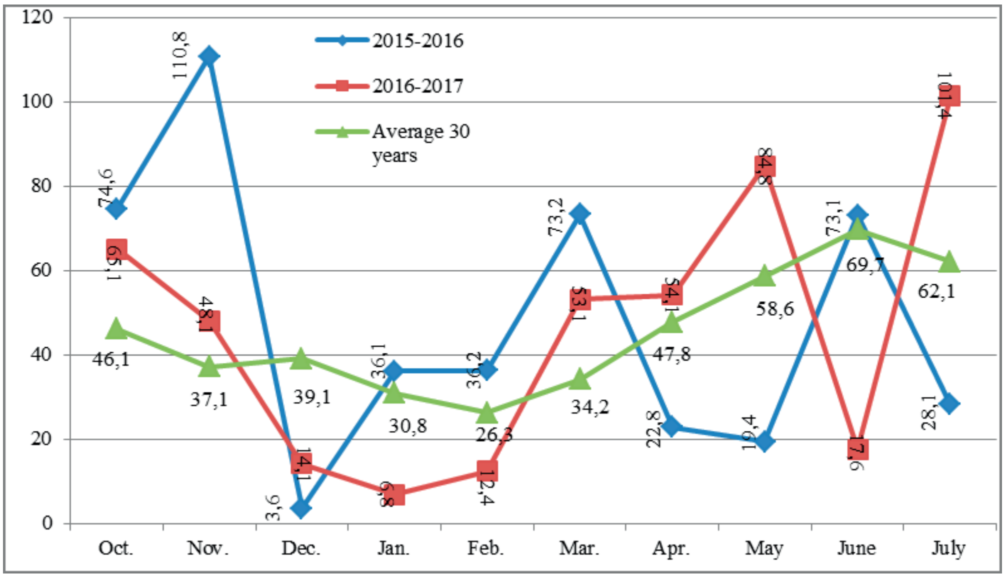

Figure 2. Monthly sum of rainfall (mm)

Grain yield and the N demand to maximize yield evolve simultaneously (Guarda et al., 2004) and N application is most effective for increasing wheat grain yield. Application of inadequate and unbalanced quantity of fertilizers to rice and wheat crops leads to low crop yield as well as unsustainable productivity (Gupta and Sharma, 2013).

The investigation of direct and indirect effects of various characters on yield has major importance to increase the yielding capacity of bread wheat (Mohammadi et al., 2012).

The values recorded on the third A level (N_{100}) showed significant differences compared with the values recorded on the other two A levels (N_{50}, N_0) for yield and respectively grain weight/spike, HW, HW and grain weight/spike (Table 1).

In many studies, it has been reported that grain number per spike had a positive effect on yield (Dogan, 2009). Also, TGW and biological yield are assumed to be the main yield components (Khan et al., 2003).

Table 1. The analysis of the A factor (N doses) influence on the studied characters

Character / A level	Yield (kg ha^{-1})	Grain weight/spike (g)	TGW (g)	HW (kg/100 l)	No. of grains/spike
N_0	3140.91^{c}	2.10^{c}	39.53^{c}	71.87^{c}	57.28^{ab}
N_{50}	3986.36^{b}	2.67^{b}	45.08^{b}	75.01^{b}	56.28^{b}
N_{100}	5104.55^{a}	3.35^{a}	48.31^{a}	78.76^{a}	58.35^{a}
LSD 5%	273.39	0.11	0.154	0.518	1.75

The gradual increase in wheat yield with increasing rates of nitrogen fertilization is reflected by the increases in almost all other grain yield components. This can be explained, based on the role of productive lines to benefit more of the nitrogen. The obtained results indicated the role of nitrogen fertilizer in the improvement of wheat plants growth under the conditions of the present study.

In an experiment from ARDS Turda, as concern fertilization of winter wheat, Urdă et al. (2015) reported a winter wheat yield increase with 28.1% on variant with additional fertilization (50 kg ha^{-1} N active substance applied in the stage of straw elongation, comparatively with basic fertilization (NPK, 50:50:0, applied after emergence of plants).

Data from a long term experience with chemical fertilizers for wheat, located at ARDS Secuieni showed that through the application of fertilizers with nitrogen and phosphorus, yield increases between 12-58% compared to the control variant N_0P_0 (Lupu et al., 2016).

Correlation analysis is used to define the significant relationship between traits. In this case, correlation analysis between N doses and the studied characters (Table 2) shows a very strong correlation between N doses and yield, grain weight/spike, HW and TGW. There was only one exception in the case of no. of grains/spike, where there was no correlation.

In a research made in Didactic Station of the B.U.A.S.V.M. in Timişoara during 2005-2007 for establishing the reaction to fertilization on mass of 1000 grains in two winter wheat cultivars, the authors concluded that there is a correlation between mass of 1000 grains and fertilizer doses and recommended $N_{100}P_{45}K_{45}$ as being optimal for the studied varieties (Alda et al., 2010).

Marinciu et al. (2018) studying seventeen winter wheat cultivars under reduced N fertilization for 4 years in three locations, identified low correlations between the experimented cultivar performances under adequate and reduced Nitrogen. Mandic et al. (2015) reported that the grain yield had very strong positive correlation with TGW in a study with three N fertilization levels (0.75 and 150 kg N ha^{-1}) from Serbia.

In this experiment, for the correlations with R^2 higher than 0.7, the regression models are shown in Figures 3, 4 and 5.

Table 2. The correlation coefficients variability between N doses and the studied character

Character	Yield	Grain weight/spike	TGW	HW	No. of grains/spike
N doses	0.863**	0.801**	0.933**	0.931**	0.163

P 5% = 0.31; P1% = 0.40

Correlations can be a reliable element only if reveal relationships that can be utilised in making a selection programme more effective. A correlation coefficient between two attributes that is unusually high, suggests a strong heritable association and possibly a narrow gene base.

Regression techniques proved to be very useful to predict crops yield. Regression is a data mining function that predicts a number (Shastry et al., 2017). In this study, in the case of regression model between N doses and yield, a regression coefficient of 19.63 was calculated, which means that for each kg of nitrogen used for fertilizing, the yield increases with 19.63 kg/ha (Figure 3).

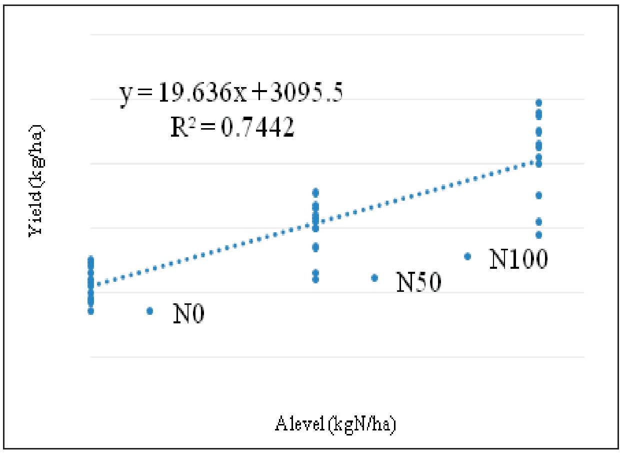

*Figure 3.*The regression model between the N doses and the yield

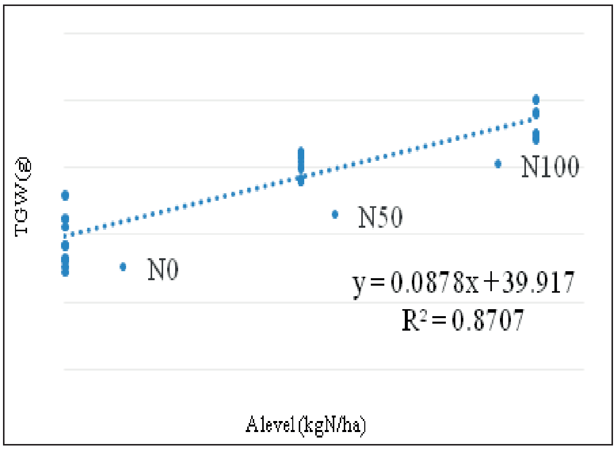

*Figure 4.*The regression model between the N doses and the TGW

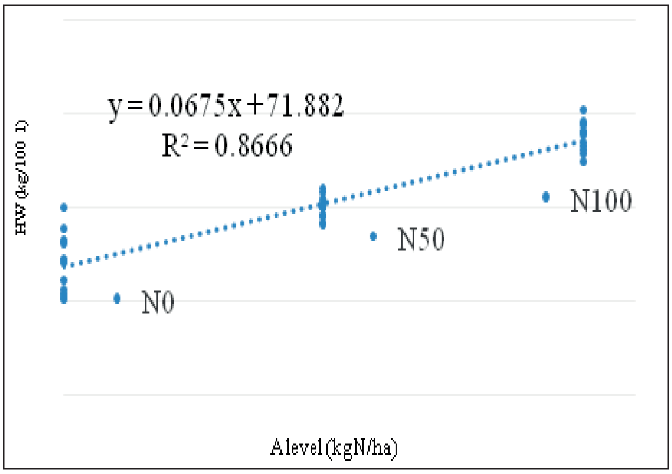

*Figure 5.*The regression model between the N doses and the HW

Concerning the influence of the B factor (genotype) on yield variability the first classified genotype, A i- II 126, recorded significant differences compared with the last 5 ranked genotypes. The last genotype, A i- I 18, registered negative significant differences compared with first 8 genotypes. In the case of the grain weight/spike, HW and no. of grains/spike, the most productive lines obtained the highest values for those characters. The highest value of TGW was noticed in the A i- I 18 genotype, which was significantly differentiated from all others genotypes (Table 3).

Table 3. The B factor (Genotypes) influence on the studied characters variability

B level \ Character	Yield (kg ha^{-1})	Grain weight/spike (g)	TGW (g)	HW (kg/100 l)	No. of grains/spike
A i- I 18	3266.67^{d}	2.17^{e}	46.45^{a}	74.04^{g}	54.06^{fg}
A i- I 27	3416.67^{d}	2.30^{de}	45.81^{b}	74.08^{g}	53.90^{g}
A i- I 69	3700.00^{cd}	2.31^{de}	45.43^{c}	74.32^{fg}	55.61^{d-g}
A i- I 75	4000.00^{bc}	2.38^{d}	45.13^{d}	74.56^{e-g}	55.78^{d-g}
A i- I 77	4166.67^{a-c}	2.73^{bc}	44.57^{e}	75.23^{c-f}	56.75^{c-g}
A i- II 27-A	4150.00^{a-c}	2.64^{c}	43.98^{f}	75.45^{b-e}	56.94^{b-g}
A i- II 47	4133.33^{bc}	2.86^{b}	43.88^{f}	75.67^{a-d}	57.77^{a-d}
A i- II 55	4366.67^{ab}	2.85^{b}	43.25^{g}	74.94^{d-g}	58.95^{a-d}
A i- II 107	4466.67^{ab}	3.11^{a}	43.17^{gh}	76.27^{ab}	61.09^{a}
A i- II 123	4516.67^{ab}	3.18^{a}	42.94^{hi}	76.21^{a-c}	59.47^{a-c}
A i- II 126	4666.67^{a}	3.26^{a}	42.79^{i}	76.57^{a}	60.02^{ab}
LSD 5%	523.50	0.21	0.30	0.99	3.35

Table 4 shows that nitrogen and genotype had significant effects on all analized characters. So, AxB interaction and its influence on yield variability, from first 10 ranked positions, 8 are variants fertilized with N_{100}, those ones being in the first 7 positions.

Grain weight/spike (g), HW and no. of grains/spike had a similar ranking like in the case of the yield, while TGW, had an opposite dynamic compared with the yield.

Results obtained in yield trials made by Săulescu et al. (2005) under a wide range of environmental conditions, with and without supplementary N fertilization, indicated variation among modern Romanian cultivars in nitrogen acquisition, nitrogen use and nitrogen storage efficiency is small, but usable in a breeding program.

Table 4. The AxB interaction influence on the characters variability

AxB levels \ Character		Yield (kg ha^{-1})	Grain weight/spike (g)	TGW (g)	HW (kg/100 l)	No. of grains/spike
A_1	b_1	2700^{o}	1.59^{v}	42.95^{k}	70.11^{n}	52.11^{l}
	b_2	2850no	1.68^{uv}	41.32^{l}	70.59^{m}	52.14^{kl}
	b_3	2900no	1.78^{suv}	41.11^{l}	70.27^{n}	53.47^{i-l}
	b_4	3000^{m-o}	2.01^{r-u}	40.55^{l}	70.44^{m}	55.55^{c-l}
	b_5	3100^{l-o}	2.12^{o-s}	39.27^{m}	72.22^{k-m}	57.22^{a-l}
	b_6	3150^{l-o}	2.01^{r-u}	39.25^{mn}	72.10^{lm}	57.56^{a-k}
	b_7	3200^{k-o}	2.05^{q-s}	39.18^{mn}	73.12^{j-l}	59.22^{a-g}
	b_8	3300j^{k-o}	2.27^{n-r}	38.24^{m-o}	71.15^{mn}	59.35^{a-f}
	b_9	3400^{i-o}	2.55^{k-n}	38.11^{no}	73.89^{g-k}	62.45^{a}
	b_{10}	3450^{h-o}	2.47^{l-o}	37.58^{o}	73.22^{i-l}	60.27^{a-d}
	b_{11}	3500^{h-o}	2.55^{k-n}	37.28^{o}	73.47^{h-l}	60.76^{a-c}
A_2	b_1	3200^{k-o}	2.18^{o-r}	46.28^{c-f}	74.11^{g-j}	53.22^{j-l}
	b_2	3300j^{k-o}	2.38^{m-q}	46.11^{d-g}	74.21^{f-j}	53.55^{h-l}
	b_3	3700^{g-n}	2.45^{l-p}	45.92^{e-h}	74.57^{e-j}	56.24^{c-l}
	b_4	4000^{g-l}	2.11^{p-s}	45.74^{f-h}	74.99^{e-i}	54.57^{f-l}
	b_5	4150^{f-j}	2.78^{h-l}	45.45^{f-h}	75.01^{e-h}	54.55^{g-l}
	b_6	4000^{g-l}	2.56^{k-n}	45.12^{g-i}	75.27^{e-g}	54.78^{e-l}
	b_7	4100^{f-k}	2.98^{g-j}	44.91^{h-j}	74.99^{e-j}	55.11^{d-l}
	b_8	4300^{e-i}	2.78^{h-l}	44.25^{ij}	74.56^{e-j}	59.25^{a-g}
	b_9	4200^{e-j}	2.99^{g-j}	44.13^{i-k}	75.48^{e-g}	59.26^{a-g}
	b_{10}	4350^{d-h}	3.08^{f-i}	44.01^{i-k}	75.86^{d-f}	59.26^{a-g}
	b_{11}	4550^{c-g}	3.11^{d-h}	43.98^{jk}	76.01^{d-e}	59.27^{a-g}

A_3	b_1	3900^{g-m}	2.75^{i-l}	50.11^{a}	77.89^{bc}	56.85^{b-l}
	b_2	4100^{f-k}	2.85^{h-k}	50.01^{a}	77.45^{cd}	56.01^{c-l}
	b_3	4500^{c-g}	2.69^{j-m}	49.27^{a}	78.11^{bc}	57.12^{a-l}
	b_4	$5000b^{c-f}$	3.01^{f-j}	49.11^{a}	78.26^{bc}	57.22^{a-l}
	b_5	5250^{a-d}	3.28^{c-g}	49.00^{a}	78.45^{bc}	58.48^{a-j}
	b_6	5300^{a-c}	3.35^{c-e}	47.56^{b}	78.99^{a-c}	58.49^{a-j}
	b_7	5100^{a-e}	3.56^{b-c}	47.55^{b}	78.89^{a-c}	58.99^{a-h}
	b_8	5500^{ab}	3.49^{b-c}	47.26^{bc}	79.11^{a-c}	58.25^{b-j}
	b_9	5800^{ab}	3.78^{a-b}	47.26^{bc}	79.45^{ab}	61.55^{ab}
	b_{10}	5750^{ab}	3.99^{a}	47.22^{b-d}	79.56^{ab}	58.88^{a-i}
	b_{11}	5950^{a}	4.11^{a}	47.11^{b-e}	80.22^{a}	60.02^{a-e}
LSD 5%		906.74	0.36	1.13	1.72	5.45

The highest positive correlations were established between yield and grain weight/spike, while correlations between yield and HW, and HW and grain weight/spike, were the next correlation coefficients (Table 5):

- yield and grain weight/spike, the coefficient value being of 0.954;
- yield and HW, the coefficient value being of 0.930;
- grain weight/spike and HW, the coefficient value being of 0.910.

Positive relationships between the mentioned characters indicate that these had major contribution in final wheat grain yield and its improvement.

Table 5.The correlation coefficients between the studied characters

Character	Yield	Grain weight/spike	TGW	HW	No. of grains/spike
Grain weight/spike	0.954**	-	-	-	-
TGW	0.665	0.573	-	-	-
HW	0.930**	0.910**	0.759**	-	-
No. of grains/spike	0.477	0.574	-0.164	0.442*	-

P 5% = 0.31; P1% = 0.40

Different statistical techniques can be applied in modelling wheat crop yield. The principal component analysis (PCA) is concerned with explaining the variance-covariance structure through a few linear combinations of the original variables. The most important objectives of PCA are data reduction and interpretation (Rameeh, 2016). Mohammadjani Asrami et al. (2014) applied PCA analysis to determine the diversity and grouping the experimented rapeseed genotypes based on the quantitative characteristics.

Principal component analysis indicated that first two components explained 96.063% from the variance (Table 6). This means that experimented lines presented limited variation in the response to reduced N fertilization and vice versa.

Table 6. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.617	72.337	72.337	3.617	72.337	72.337	3.217	64.331	64.331
2	1.186	23.726	96.063	1.186	23.726	96.063	1.587	31.732	96.063
3	0.132	2.641	98.704						
4	0.038	0.762	99.466						
5	0.027	0.534	100.000						

Extraction Method: Principal Component Analysis

Concerning the four groups, those were:

- The group with both positive components was formed by the next variants: a_2b_9, a_2b_{10}, a_2b_{11}, a_3b_7, a_3b_6, a_3b_5, a_3b_9, a_3b_8, a_3b_{10} and a_3b_{11}.
- The group with first component positive and the second component negative was formed by the next variants: a_3b_4, a_3b_3, a_2b_7, a_3b_1, a_2b_6, a_2b_5, a_3b_2, a_2b_4 and a_2b_2.
- The group with both negative components was formed by the next variants: a_1b_4, a_2b_3, a_1b_3, a_1b_2, a_2b_1 and a_1b_1.
- The group with first component negative and the second component positive was formed by the next variants: a_1b_9, a_1b_{11}, a_1b_{10}, a_1b_8, a_1b_7, a_2b_8, a_1b_6 and a_1b_5.

From the figure 6 it can see that seven variants which had both positive components were fertilised with N_{100} and are all ranked in firsts seven position in the yield classification (Figure 6).

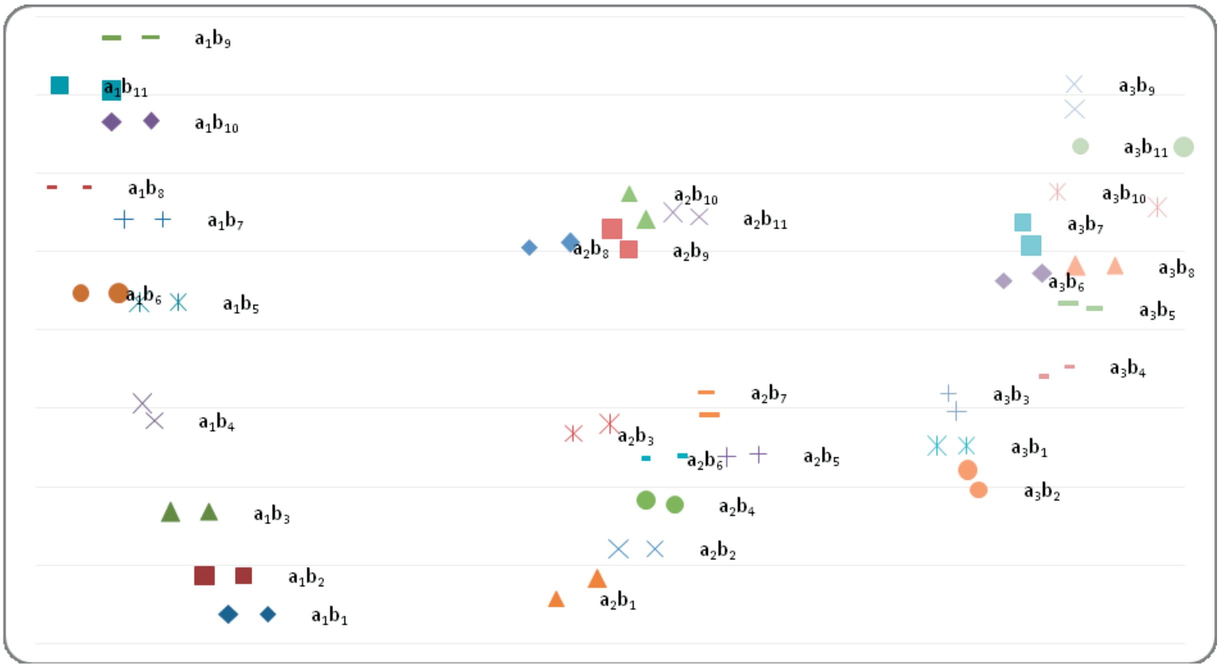

Figure 6. PCA analysis for the studied variants

CONCLUSIONS

1. Concerning the influence of the A factor (N doses), the registered values on the third A level realised significant differences compare with the values recorded on the other two A levels for the yield and grain weight/spike, yield and HW and HW and grain weight/spike characters.

2. Concerning the influence of the B factor, genotype, on the yield variability study, the first classified genotype, A i- II 126, recorded significant differences compare with the last 5 ranked genotypes. The last genotype, A i- I 18, recorded negative significant differences compare with first 8 genotypes.

3. The highest positive correlations were between yield and grain weight/spike, yield and HW and HW and grain weight/spike. For those characters there were also identified a very positive correlation with the N doses.

In the case of PCA analysis, seven variants which had both positive components were fertilised with N_{100} and are all ranked in firsts seven position in the yield classification.

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