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COMPARATIVE STUDY OF PRODUCTIVE AND QUALITY INDICATORS OF WHEAT VARIETIES IN NORTH-EASTERN BULGARIAN REGION

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Abstract

The field experiment was carried out in the selected area of Pristoe village, Shumen area in the period 2017-2019. The 2test was set by the block-plot design method in four replications with a plot size of 15 m^2, after sunflower predecessor. The purpose of the study was to establish the productivity and quality of some common wheat varieties, grown in North-Eastern Bulgarian region. The varieties 'Avenue' 'Joker' 'Apache' and 'Neven' were tested. The indices; length of spike (cm), number of spikelets per spike number of grains per spike, grain yield (kg/ha), thousand kernel (grain) weight (g), test weight (kg), vitreousness (%), wet gluten content (%), gluten deformation index (mm) were reported. The results showed that the highest grain yield was obtained from Avenue variety - 7900 kg/ha, followed by Joker - 7400 kg/ha and the lowest one - from Neven variety 6600 kg/ha. The highest values of test weight and the vitreousness content was reported for Neven (84.7 kg and 89.6%) respectively. Joker variety show the best values of the investigated technological properties of the grain among the tested varieties wheat.

Key words*: wheat, yield, thousand kernel (grain) weight, test weight, gluten.*

INTRODUCTION

Taking into account the market conditions nowadays, as well as the main possibilities for increasing and improving wheat yield and quality, it is crucial to create and introduce new high productive varieties and to develop effective technologies for their cultivation (Georgieva & Kirchev, 2020; Chamurliiski, 2019; Matev & Kirchev, 2010; Mitkov et al., 2019; Zhelyazkov et al., 2017; Tityanov et al., 2020).

Wheat is one of the most distributed crop worldwide, as it is of primary importance for people`s living. There is a great diversity of wheat varieties possessing different biological properties. The present-day selection aims at creating and introducing new lines and varieties combining tolerance towards the biotic and abiotic environmental stress factors, high productivity and grain quality in order to meet market needs (Manilov, 2022; Uhr, 2015; Uhr et al., 2021; Chipilski et al., 2022).

The factor *variety* along with its genetic makings has crucial importance for yield productivity and quality. Values of these indicators are genetically determined. Nevertheless, they are influenced by the applied agro-machinery, the climatic factors during vegetation and the specific agro-ecological conditions of the region (Atanasov et al., 2020; Tsenov et al., 2020; Mitkov et al., 2009; Mitkov et al., 2018; Yanev et al., 2021). In this relation, in recent years there have been developed varieties with high genetic potential and have been examined regarding their productivity, grain quality and adaptability towards environmental conditions (Dimitrov et al., 2016; Ilieva 2011; Kirchev & Delibaltova, 2016; Tsenov et al., 2022). The constant introduction of new wheat varieties and their examination in separate micro-regions of the country is always of present interest. A number of studies have reported that wheat varieties reveal their productive possibilities differently in particular agro-ecological regions of the country (Ilieva, 2011; Ivanova et al., 2010; Tonev et al., 2018).

Therefore, studies related to the cultivation of wheat varieties in different country regions have particular scientific and practical significance.

The present research study aims at establishing the productive possibilities and quality of some common wheat varieties cultivated in the region of north-eastern Bulgaria.

MATERIALS AND METHODS

The study was performed in the period 2016-2019 in the region of the village of Pristoe - north-eastern Bulgaria. The experiment was set by the block method in 4 repetitions, with size of the crop plot - 15 m^2. There were examined four common wheat varieties - Avenue, Apash, Joker and Neven, which were sowed after a predecessor sunflower. Plants were cultivated under standard technology. The pre-sowing soil tillage was performed with 2-3 times of disking. The sowing was conducted within optimum terms - with 550-590 g.s. m^2 at a sowing norm of 25-28 kg/ha. The Phosphorus and Potassium fertilizers were applied after the first tillage, as well as 1/3 of the Nitrogen fertilizer (N_{16}). In the early spring the soil was fed two times with the rest of the Nitrogen fertilizer. In the end of the tillering stage herbicide spraying was applied for weed control: against broad-leaved weeds - Sekator 100 ml/ha, and ag ainst wheat weeds - Tsiklop 700 ml/ha. Soligor fungicide 700 ml/ha was used for disease control, and Proteus insecticide in a doze 650 ml/ha - for pest control. Spraying with Kelpak - 2000 ml/ha was applied aiming at growth improvement. For the purpose of the present study the following indicators were examined: grain yield (kg/ha) spike (ear) length (cm), number of spikelets and grains in a spike (ear), as well as the qualitative indicators -TGW (g), hectolitre mass (kg), vitreousness (glassiness) (%), wet gluten content (%) and gluten deformation index (mm).

The received data related to the values of yield structural elements, grain yield and the qualitative indicators were mathematically processed via the method of the dispersion analysis. The differences between options were established via Duncan`s multiple range test.

The examined varieties were grouped via a hierarchical cluster analysis. The method of intergroup connection was used (Ward, 1963). The Euclidean intergroup distance was used as a measure of similarity:

$$D(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

A dendrogram was built in order to present graphically the clusters. The dotted horizontal line of the dengrogram showed the rescaled distance with which the clusters were formed. A correlation analysis was carried out aiming at establishing the presence of statistically significant correlations between the examined indicators.

Data processing was performed via SPSS 26 Statistical Program.

The main climatic factors determining growth and productivity of wheat plants are air temperature, sum of precipitations, their combination and their distribution during the vegetation period.

Analysing these factors showed that the values of average monthly temperatures during the experimental years did not differ considerably than those during a long-term period. These factors completely met the requirements of common wheat from germination and sprouting to ripening (Figure 1).

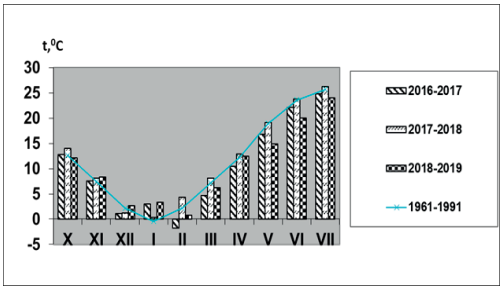

Figure 1. Average monthly air temperature, ^0C

Significant differences were observed in the quantity of precipitations during the separate crop years (Figure 2).

The sum of precipitations in the period October-July 2016-2017 was 675 mm. These amounts were distributed equally and were completely sufficient for securing plants with moisture during the whole vegetation period.

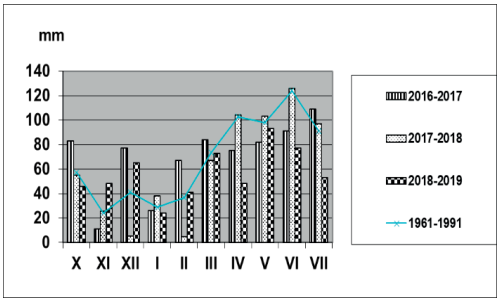

Figure 2. Rainfall, mm

Precipitations, especially during the critical stages of wheat vegetation, had a positive effect on the productive possibilities of plants.

In 2017-2018 the largest quantity of precipitations was reported, i.e. in the second experimental year (705 mm). Precipitations during wheat vegetation were unequally distributed an insufficient, especially in the stages of jointing-heading, precipitations during ripening were abundant.

In 2018-2019 the sum of precipitations during plant vegetation was 655 mm. The precipitation quantity during the vegetation period was equally distributed.

Among the three experimental years the most favorable for plant growth was the first year (2016-2017), followed by the year 2018-2019 and not so favorable - the second year (2017-2018), which affected growth, yield and quality of wheat varieties.

RESULTS AND DISCUSSIONS

Results related to the examined structural elements of yield showed that these indicators changed under the influence of the meteorological factors during the experimental years. The highest values of yield main structural elements were registered in 2017, followed by 2019, and the lowest values - in 2018 (Table 1).

Ear length had the highest values in the crop year 2016-2017 for Joker variety - 11.6 cm, followed by Avenue - 11.2 cm and Apache - 10.6 cm., and the lowest values had Neven variety - 9.2 cm.

Table1. Structural elements of the yield

Indices	Varieties	Years of study			
		2016-2017	2017-2018	2019-2020	Average for the period
Length of the spike, cm	Avenue	11.2 c	10.0 b	10.6 c	10.6
	Apache	10.6 b	10.2 b	9.8 b	10.2
	Joker	11.6 d	10.6 c	11.0 c	11.0
	Neven	9.2 a	7.8 a	8.4 a	8.4
Number of spikeletts per spike	Avenue	25.0 c	21.0 c	23.0 c	23.0
	Apache	21.0 b	19.0 b	20.0 b	20.0
	Joker	24.0 c	22.0 c	21.0 b	22.3
	Neven	19.0 a	17.0 a	18.0 a	18.0
Number of grains per spike	Avenue	68.0 c	63.0 d	66.0 c	65.6
	Apache	64.0 b	61.0 b	63.0 b	62.6
	Joker	71.0 d	62.0 c	67.0 d	66.6
	Neven	59.0 a	53.0 a	56.0 a	56.0

*Means within columns followed by different lowercase letters are significantly different ($P<0.05$) according to the LSD test

The received data were mathematically significant. In the second experimental years ear length of the examined varieties was within the bounds from 7.8 to 10.6 cm, and in the crop year 2018-2019 values of these indicators were slightly higher. It was mathematically proven that averagely for the experimental period (2016-2019) the longest ear had Joker variety – 11,0 cm., which exceeded Avenue, Apache and Neven varieties with 3.7%, 7.8%, and 30.9%, respectively.

Wheat plants formed the smallest number of ears - from 17.0 (Neven variety) to 22.0 (Joker variety) in 2017-2018 compared to 2016-2017 and 2018-2019.

The biggest number of earlets per ear was formed in the experimental year 2016-2017, which was due to the favorable combination of temperature and moisture during the vegetation period. The values of this indicator were within the bounds from 19.0 for Neven variety to 25,00 for Avenue variety. Differences between varieties were mathematically significant, as Joker variety domineered over Apache variety with 3.0 pieces of ears. In the third experimental year the number of earlets per ear varied from 18.0 to 23.0, as the differences between the tested varieties were statistically proven.

Averagely for the experimental period (2016-2019) Avenue variety had the greatest number of earlets per ear - 23.0, followed by Joker variety - 22.3 and Apash and Neven varieties - 20.0 and 18.0, correspondingly.

The greatest number of grains per ear was reported for Joker variety - from 62.0 to 71.0, followed by Avenue variety - from 63.0 to 68.0, and the smallest number of grains was reported for Neven variety - from 53.0 to 59.0.

Differences between the tested varieties were statistically proven.
The dispersion analysis (Table 2) showed that the genotype, as well as the years with their specific climatic conditions had statistically proven influence on yield structural elements. The strongest influence of these indicators was established for the number of grains per ears, followed by the number of earlets and the ear length.

Table 2. Analysis of variance ANOVA

	Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Length of the spike	Year*	6,24875	2	3,124375	4,938639	0,01	3,259446
	Varieties *	46,0075	3	15,33583	24,24105	0,00	2,866266
	Interaction ns	2,88125	6	0,480208	0,759056	0,61	2,363751
	Within	22,775	36	0,632639			
Number of spikeletts per spike	Year*	43,875	2	21,9375	12,29183	0,00	3,259446
	Varieties *	157,2292	3	52,40972	29,36576	0,00	2,866266
	Interaction*	33,45833	6	5,576389	3,124514	0,01	2,363751
	Within	64,25	36	1,784722			
Number of grains per spike	Year*	278,7917	2	139,3958	20,88762	0,00	3,259446
	Varieties **	848,7292	3	282,9097	42,3923	0,00	2,866266
	Interaction ns	40,70833	6	6,784722	1,016649	0,43	2,363751
	Within	240,25	36	6,673611			

*F-test significant at P<0.05; ** F-test significant at P<0.01; ns non-significant

The interaction between the tested factors was significant only for the number of earlets per ear. It was not proven for the ear length and the number of grains per ear.
Data in Table 3 showed that averagely for the experimental period Avenue variety domineered over the rest of the varieties included in the experiment.

Table 3. Grain yield - kg/ha

Varieties	Years of study			Average for the period (kg/ha)
	2016-2017 (kg/ha)	2017-2018 (kg/ha)	2018-2019 (kg/ha)	
Avenue	8300 d	7500 d	7900 d	7900
Apache	7500 b	6800 b	7100 b	7133
Joker	7800 c	7100 c	7300 c	7400
Neven	6800 a	6400 a	6600 a	6600

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test

As a result of the higher moisture that plants were secured with, as well as the equal distribution of precipitations, higher yields were received in 2016-2017 in comparison to 2017-2018 and 2018-2019.
For the conditions of the first year they varied from 6800 kg/ha for Neven variety to 8300 kg/ha for Avenue variety. Joker, Apache and Neven varieties received yields, which were 500 and 800 and 1500 kg/ha lower compared to Avenue variety.
Differences between all varieties were statistically proven.
The experimental year 2017-2018 was characterized with greater amount of precipitations during the vegetation period - 705,0 mm, but they were unequally distributed. Thus, it led to lower yields of the tested varieties compared to 2016-2017 and 2018-2019. The received data related to grain yield varied from 6400 to 7500 kg/ha, and in the third experimental year they were within the bounds from 6600 kg/ha for Neven variety to 7900 kg/ha for Avenue variety.
Averagely for the three experimental years Avenue variety received grain yield 7900 kg/ha, which domineered over Joker, Apache and Neven with 6.7%, 10.7% and 19.6 kg/ha, correspondingly.
The dispersion analysis related to the effect of Variety and Year factors, as well as their interaction on grain yield, showed reliable influence of the studied factors and insignificant interaction between them (Table 4).

Table 4. Analysis of variance ANOVA

Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Year*	3758750	2	1879375	78,63951	0,00	3,259446
Variety*	10831666,7	3	3610556	151,078	0,00	2,866266
Interaction^{ns}	264583,333	6	44097,22	1,845179	0,12	2,363751
Within	860350	36	23898,61			

*F-test significant at P<0.05; **F-test significant at P<0.01; ns non-significant

Table 5 presented data related to the physical and technological properties of grain of common wheat varieties included in the study.

In the first experimental year the mass of 100 grains had the highest values for Neven variety - 52.0 g. Differences between varieties were statistically proven. In 2017-2018 the mass of 1000 grains was within the bounds from 41.0 to 48.0 g, while in 2018-2019 the registered mass of 1000 grans varied from 45 g for Joker variety to 50 g for Neven variety. Differences were mathematically significant. Averagely for the period (2016-2019) Neven variety was registered with the biggest grain - 50.0 g, followed by Avenue - 45.6 g, and the smallest grain was established for Apache and Joker varieties - 43.6 g.

Table 5. Physical and technological properties of the grain

		Thousand kernel (grain) weight (g)	Test weight (kg)	Vitreousness (%)	Wet gluten content (%)	Index deformation gruten (mm)
Years	2016-2017	46.8 ^{b}	80.0 ^{b}	87.3 ^{c}	28.3 ^{a}	10.4 ^{a}
(A)	2017-2018	43.7 ^{a}	77.0 ^{a}	84.5 ^{a}	27.4 ^{a}	9.6 ^{a}
	2018-2019	46.7 ^{b}	80.3 ^{b}	86.0 ^{b}	28.0 ^{a}	10.1 ^{a}
Variety	Avenue	45.6	77.6	85.6	25.5	10.4
(B)	Apash	43.6	74.6	82.7	25.3	11.3
	Joker	43.6	79.3	85.6	31.0	9.3
	Neven	50.0	84.7	89.6	29.6	9.0
2016-2017	Avenue	47.0 $^{b.}$	79.0 ^{b}	86.0 ^{b}	27.0 ^{b}	10.5 ^{b}
	Apash	44.0 ^{a}	75.0 ^{a}	84.0 ^{a}	25.0 ^{a}	12.5 ^{c}
	Joker	44.0 ^{a}	81.0 ^{c}	88.0 ^{c}	31.0 ^{d}	10.0 ^{b}
	Neven	52.0 ^{c}	85.0 ^{d}	91.0 ^{d}	30.0 ^{c}	8.5 ^{a}
2017-2018	Avenue	44.0 ^{c}	74.0 ^{b}	85,0 ^{c}	24.5 ^{a}	9.8 ^{b}
	Apash	41.0 ^{a}	73.0 ^{a}	81,0 ^{a}	26.0 ^{b}	10.0 ^{b}
	Joker	42.0 ^{b}	77.0 ^{c}	84,0 ^{b}	30.0 ^{d}	9.4 ^{b}
	Neven	48.0 ^{d}	84.0 ^{d}	88,0 ^{d}	29.0 ^{c}	9.0 ^{a}
2018-2019	Avenue	46.0 ^{b}	80.0 ^{b}	86,0 ^{c}	25,0 ^{a}	11.0 ^{c}
	Apash	46.0 ^{b}	76.0 ^{a}	83,0 ^{a}	25.0 ^{a}	11.5 ^{c}
	Joker	45.0 ^{a}	80.0 ^{b}	85,0 ^{b}	32.0 ^{c}	8.5 ^{a}
	Neven	50.0 ^{c}	85.0 ^{c}	90,0 ^{d}	30.0 ^{b}	9.5 ^{b}
Anova	A	*	*	*	n.s	n.s
	B	*	*	*	*	*
	AB	n.s	n.s	n.s	n.s	*

*Means within columns followed by different lowercase letters are significantly different (P<0.05) according to the LSD test

*F-test significant at P<0.05; ** F-test significant at P<0.01; ns non-significant

The hectoliter mass of the examined varieties in the experimental year 2016-2017 varied from 75.0 kg. for Apache variety to 85.0 kg. for Neven variety. Differences were statistically proven.

In the second and third experimental years the values of the hectoliter mass were within the bounds from 73.0 to 84.0 kg and from 76.0 to 85.0 kg, for 2017-2018 and 2018-2019, correspondingly.

Averagely for the experimental year the hectoliter mass of Neven variety had the highest value - 84.7 kg., followed by Joker variety - 79.3; Avenue variety - 77.6 kg, and

the lowest value was reported for Apache variety - 74.6 kg.

The common vitreousness of grain is an important indicator showing the quality of wheat grain. Lower values of this indicator were reported in the crop year 2017-2018, which could be explain with the presence of larger amount of precipitations in June and July - the stage of ripening. The per cent of vitreousness (glassiness) of the varieties was from 81.0% for Apash to 88.0% for Neven.

Taking into account the whole experimental period, the highest per cent of vitreousness was reported for Neven variety - from 88.0% to 91.0%, which statistically proven domineered over the rest from 4.7% to 8.7 %.

Results related to wet gluten content in the tested varieties showed that this indicator was influenced to a great extent by the genotype and did not depend on the climatic conditions of the crop years. Averagely for the period 2016-2019 the per cent of wet gluten in grain varied from 25.3 to 31.0. The highest content of wet gluten was reported for Joker variety - 31.0%, followed by Neven variety - 29.6%, and the lowest content had Avenue and Apache varieties - with 25.5% and 25.3%, correspondingly.

With relation to gluten allocation, the received data showed that Joker and Neven varieties were characterized with the highest values possessing strong gluten, while Avenue and Apache varieties had values over 10 mm, where gluten was determined as weak.

Results of the cluster analysis were presented graphically via a dendrogram. It showed that the tested varieties were grouped in one main cluster (Figure 3). The cluster was more homogenous and included Avenue and Joker varieties, which were similar in the following indicators: ear length, number of earlets per ear, number of grains per ear, mass of 1000 grains, vitreousness and gluten allocation. Later Apache variety joined the cluster with close indicators as follows: length of ear and mass of 1000 grains.

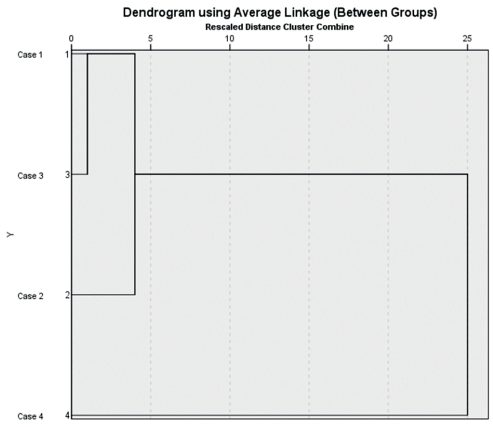

Figure. 3. Dendrogram rescaled distance cluster combine

The correlation coefficients showing the interrelation between the studied indicators were given in the correlation matrix (Table 6)

A strong positive correlation was established between the ears length and the number of grains per ear r = 0.993. A weaker correlation dependence was established between the grain yield and the number of earlets per ear r = 0.963, the number of grains and the number of earlets per ear r = 0.951, the hectoliter mass and the vitreousness r = 0.982. All given correlation coefficients were statistically proven at a level of significance $\alpha = 0.001$.

Table 6. Values of the coefficient of corelatiom

	Grain yield	Length of spike	Number of spikelets per spike	Number of grains per spike	Thousand kernel (grain) weight	Test weight	Vitreousness	Wet gluten content	Allocation of gluten
Grain yield	1	0.834	0.963*	0.880	-0.597	-0.589	-0.457	-0.404	0.389
Length of spike		1	0.910	0.993**	-0.911	-0.723	-0.690	-0.158	0.385
Number of spikelets per spike			1	0.951*	-0.666	-0.520	-0.420	-0.167	0.221
Number of grains per spike				1	-0.857	-0.669	-0.618	-0.145	0.331
Thousand kernel (grain) weight					1	0.867	0.892	0.249	-0.586
Test weight						1	0.982*	0.693	-0.909
Vitreousness							1	0.596	-0.877
Wet gluten content								1	-0.898
Allocation of gluten									1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

CONCLUSIONS

Averagely for the experimental period (2016-2019) the highest grain yield was performed by Avenue variety - 7900 kg/ha, followed by Joker variety - 7400 kg/ha and Apache - 7133 kg/ha., and the lowest yield had Neven variety - 6600 kg/ha. The higher productivity of this variety was due to the higher values of yield structural elements.

The examined common wheat varieties in the region of north-eastern Bulgaria formed grain with the highest values of the indicators hectoliter mass and vitreousness (glassiness) for Neven variety (84.7 kg and 89.6%).

Taking into account the examined technological properties of grain - wet gluten - the highest indicators had Joker variety - 31.0%, while gluten allocation was the lowest for Neven variety - 9.0 mm. Gluten allocation for Joker and Neven varieties was under 10 mm, which led to the presence of strong gluten.

For the production of forage and alcohol in the region of North-eastern Bulgaria we recommend the cultivation of Avenue and Apache varieties, and for the production of bread - Neven (it has lower yield characterizing with good indicators) and Joker varieties.

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