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Variability and stability of yield and quality of grain of several bread wheat cultivars

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Abstract. *Breeding for grain yield and quality is central in research work on wheat in Bulgaria. Combining the two genetic systems is difficult and requires long and systematic efforts. The aim of this investigation was to analyze the ecological plasticity and stability of grain yield and quality of cultivars already in production. Such information would be valuable with a view of their proper distribution. The quality and production potential of cultivars Aglika, Slaveya and Iveta were determined applying several different approaches for analysis of the genotype x environment interaction. Data were used from several different trials involving these cultivars in a group of 33 Bulgarian varieties during two successive years at eight locations in Bulgaria. The data on the different quality indices are from trials conducted at DAI during a period of six years. The focus is on the complex evaluation of grain yield and quality with respect to their level of realization and plasticity under different combinations of environmental conditions in two groups of trials. Grain yield and its components of the three investigated varieties were significantly higher in comparison to the standards. The model cultivars Sadovo 1 and Pobeda had larger grain and higher tillering capacity although their yields were lower. Number of grains per spikes, which determines the higher productivity of the investigated cultivars, had values with 30 % higher than the values of the model varieties. The values of the indices determining wheat grain strength and bread making quality (valorimetric value, dough resistance and sedimentation) of the three cultivars were significantly higher than the values of the standard Pobeda, which confirmed their genetic potential of strong wheats. No significant variations between cultivars and standard varieties were observed for the indices test weight and wet gluten. The investigated cultivars Aglika, Slaveya and Iveta are a good breeding achievement because they successfully combine high yield with high grain quality. In this respect all three cultivars considerably exceed the level of variety Bezostaya 1, which was at the basis of the successful breeding for combining high yields with high grain quality in the recent past. Cultivar Slaveya, although well established in the group of fillers, demonstrated quality indices of strong wheat. The cultivars possess good adaptability and plasticity under changeable environments with regard to grain yield and its main components. According to the complex indicator of quality level (bread making strength index), all three genotypes demonstrated excellent plasticity and adaptability ranking first among over thirty analyzed cultivars developed in Bulgaria.*

Keywords: wheat, grain yield, quality, plasticity and stability, genotype x environment interaction

Abbreviations: Test W – test weight, SDS – sedimentation value, WGC – wet gluten content, Dough T – dough tolerance, Val – valorimetric value, Loaf V – loaf volume, BMSI – bread-making strength index

Introduction

Yield and quality are the most important properties of wheat grain which are directly related to its end use (Gut and Bichonski, 2007; Dencic et al., 2008; Shewry, 2009). They are also directly related to the efficient production of grain and its traditional use as bread, pastry and fodder (Fufa et al., 2005; Meng et al., 2009). Therefore breeding in Bulgaria and in many other countries worldwide is focused on these properties (Rajaram and Braun, 2009; Tsenov et al., 2009; Williams et al., 2008). The breeding for combining high yield with grain quality is very difficult, complex and long (Baenziger et al., 2001; Trethowan et al., 2001; Knott et al., 2009). Furthermore, the realization of the genetic potential for yield and end-use quality largely depends on the specific environment (Williams et al., 2008; Hristov et al., 2010). The breeding goal of high stable yields through seasons and high end-use quality sets increasingly higher requirements to the new wheat varieties (Tsenov et al., 2009; Tsenov et al., 2008). The climatic changes in the recent years are yet another challenge to the breeding work for combining high levels of yield and end-use quality (Reynolds et al., 2009; Graybosch and Peterson, 2010). The efficient solving of these problems is inextricably bound up with the study on the nature and regularities of the genotype x environment interaction (Atanasova et al., 2010; Sharma et al., 2010). The high and environment-adequate adaptability of wheat varieties of different quality and yield has been subjected to long-term investigations (Fischer and Edmedes, 2010; Williams et al., 2008). This is related to the evaluation of the specific response of each cultivar under different soil and climatic conditions (Stoeva et al., 2006; Tsenov et al., 2004). Therefore collecting data on the actual levels of grain yield and quality and their stability across locations and through seasons is especially important. Various models for evaluation of the developed lines and varieties are used for this purpose (Yan, 2001; Chapman, 2008).

The high-quality cultivars Aglika, Slaveya and Iveta developed in Bulgaria were released in 1997 and 2000, respectively, and are now grown in mass production. Since they combine high levels of yield and end-use quality, they were subjected to purposeful investigation after their official release (Tsenov et al., 1998; Tsenov et al., 2009; Tsenov et al., 2010).

The aim of this investigation was to analyze the above bread wheat cultivars for their ecological plasticity and stability with regard to productivity and end-use quality under different environments.

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Material and methods

Grain yield, its components and the complex bread-making strength index (BMSI) were calculated after summarizing the results from the competitive yield trials at DAI during 2000 – 2006 and from an ecological trial carried out during 2003 – 2004 at eight locations in Bulgaria by Agronom I Holding (Dobrich). Detailed description of the methodology used can be seen in Tsenov et al. (2004), Tsenov et al. (2006) and Tsenov et al. (2010).The following traits were analyzed: grain yield (GY), number of productive tillers (NPT), 1000 kernel weight (TKW), number of kernels per spike (NKS), kernel weight per spike (KWS). The bread making strength index was also analyzed since it is to a certain extent determining in grain commercialization, its correlations with the other quality indices were significant and high. The values of BMSI were calculated using a table after analyzing the indices wet gluten (%) and dough relaxation (mm) (according to Bulgarian National Standard 13375-88) were determined at the Laboratory of Agronom I Holding, Dobrich. To directly compare the investigated cultivars with the standards, the methods of descriptive statistics were applied using the module XLStart 2009. The plasticity and stability of the investigated cultivars were analyzed with the statistical program GGEbiplot (Yan, 2001). The ranking of cultivars by yield or quality and plasticity was done by calculating parameter [X-b_i] by the method of Kang (1991).

Results and discussion

There were several factors which contributed to the significantly higher grain productivity of the investigated cultivars. First, this was the higher number of grains along the entire spike axis (Table 1). In all three cultivars this trait was with about 30 % higher than in the standard Sadovo 1.

Table 1. Performance of the cultivars at Competitive yield trails of DAI during 2000-2006

Trait	Statistic parameters	Aglika	Slaveya	Iveta	Sadovo 1	Pobeda
GY	Minimum	6.40	6.0	6.3	6.4	6.4
	Maximum	9.0	9.2	9.3	8.5	7.9
	CV	0.09	0.12	0.10	0.10	0.07
	SE	0.19	0.24	0.20	0.18	0.12
	Mean	7.86^{A}	7.49^{A}	8.14 ^{A}	7.16^{B}	6.98^{B}
NPT	Minimum	512	568	564	528	488
	Maximum	800	784	826	1004	944
	CV	0.13	0.10	0.15	0.20	0.18
	SE	22.24	18.38	19.64	37.85	32.94
	Mean	656.0^{B}	659.2^{B}	688.5^{A}	725.1^{A}	686.1^{A}
TKW	Minimum	37.9	39.8	41.1	44.7	42.5
	Maximum	46.2	52.5	48.0	53.5	48.8
	CV	7.41	18.05	8.95	4.32	3.14
	SE	0.06	0.09	0.08	0.04	0.04
	Mean	42.9^{C}	45.2^{B}	45.7^{B}	49.4^{A}	45.3^{B}
NKS	Minimum	21.3	21.4	24.0	14.9	17.4
	Maximum	42.3	32.5	44.0	28.8	32.2
	CV	28.35^{A}	25.28	28.96	20.57	23.09
	SE	0.24	0.18	0.30	0.16	0.15
	Mean	35.7^{A}	33.1^{B}	36.1^{A}	24.6^{C}	28.1^{B}

A, B, C - different letter in the same row indicated significant difference ($p<0.05$)

Second, these cultivars had significantly higher resistance to rusts in comparison to the standard which lead to longer than normal grain filling. As a result cultivars Aglika, Slaveya and Iveta formed more grains per spike, which were with 3-5 points smaller than the standard Sadovo 1. This combination of levels of the individual productivity components is typical of cultivar Pliska. It was successfully transferred to cultivars Aglika and Slaveya. In cultivar Iveta it was transferred from cultivar Obriy. Third, the higher resistance to lodging was the reason for higher yields especially at high fertilization norms and in moist years. Last, but not least, all three cultivars had high cold resistance, which was the reason for the good stand establishment leading to higher and more stable grain yield by years (Tsenov et al., 2010). When investigating a large set of cultivars during three successive years (designated with E on Figures 1 and 3), cultivars Aglika (3) and Slaveya (31) fell within the zone with best combination of high grain yield and stability levels. The position of cultivar Iveta (10) reveals high level of grain yield but moderate stability across environments.

In this trial the standard Sadovo 1 (28), although considered very stable (Tsenov et al., 2006), was positioned only in the forth concentric circle of stability, in the lower left part of the figure. Such high stability against the background of different environmental combinations in rather contrasting years and soils is a very important prerequisite for good results in production (Tsenov, 2007).

Detailed data for the effect of important agronomy factors on the performance of cultivar Aglika have been presented by Ivanova et al. (2009), and on the performance of cultivars Slaveya and Iveta – by Tonev et al. (2007).

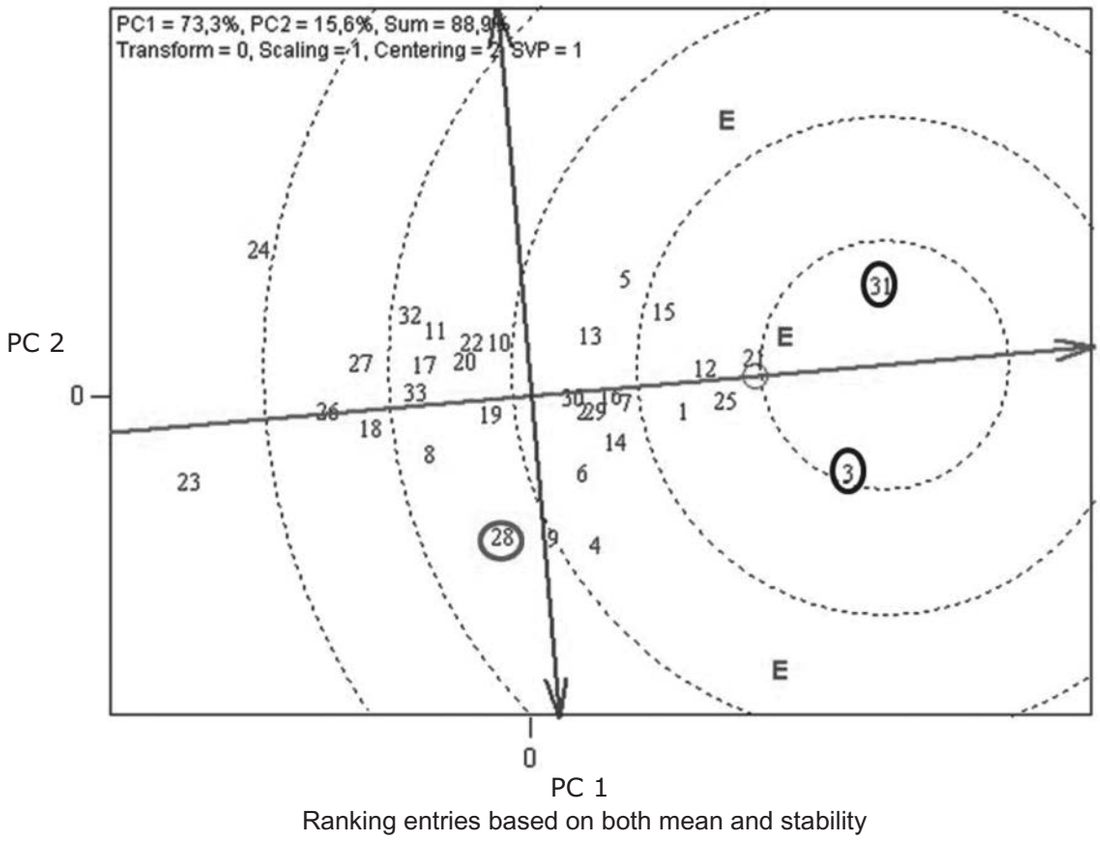

Figure 1. Stability of the cultivars in respect to grain yield / Key: (3) Aglika, (10) Iveta, (31) Slaveya, (28) Sadovo 1

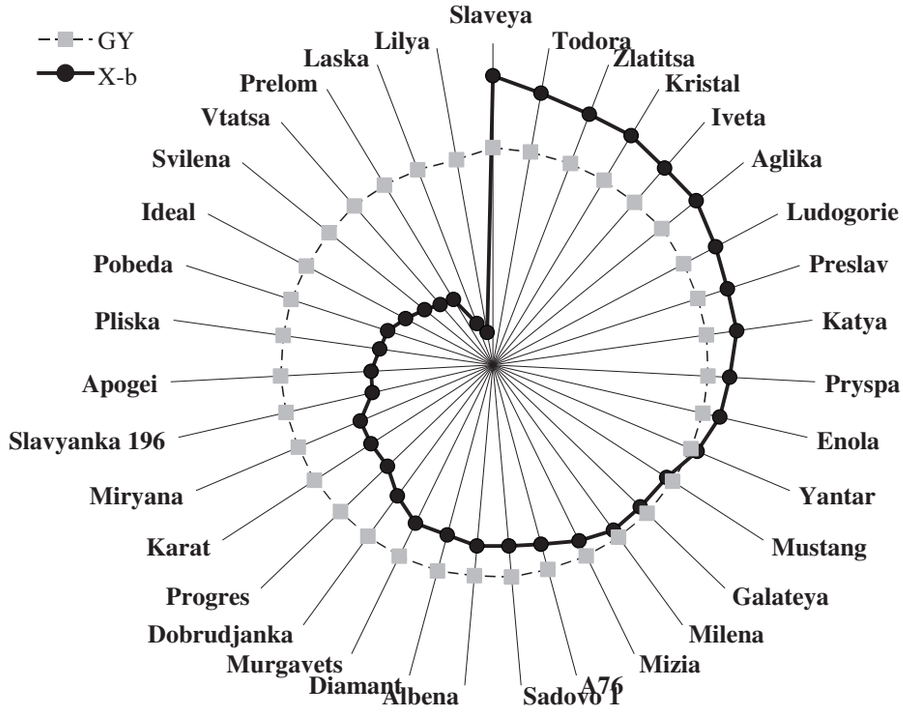

Figure 2. Plasticity of the cultivars in respect to grain yield

The ranking of the cultivars according to parameter [X-b_i] clearly shows the advantage of the investigated cultivars (Figure 2). Slaveya demonstrated the most suitable combination of grain yield and plasticity. It ranked first among 35 winter wheat cultivars investigated. Cultivars Aglika and Iveta ranked 5th and 6th, respectively. Therefore the above three varieties are highly valuable due tot heir good realization of a high production potential under changeable environments. A comparison revealed that cultivars currently occupying large production areas such as Enola and Sadovo 1, ranked 11th and 18th, respectively.

The data on some quality indices (Table 2) clearly indicated the advantage of Aglika, Slaveya and Iveta with regard to dough strength. These cultivars typically form grain less compact than the grain of the standards, especially cultivar Pobeda. The values of wet gluten yield were also lower, bit the differences were not significant and more importantly – their variation was much lower. In this respect cultivar Iveta was a better achievement than the other two cultivars. Therefore the sedimentation, valorimetric value and dough tolerance were significantly higher and entirely met the criteria of strong wheat (Atanasova et al., 2010).

According to Atanasova et al, (2009) cultivar Aglika demonstrated high stability of grain quality under two entirely contrasting environments. The same was valid for the performance of Slaveya. This cultivar, although officially being referred to second quality group (the group of fillers), demonstrated high quality combined with high stability of its expression. Similar response of this cultivar has also been reported by Tsenov et al. (2009) and Tsenov et al. (2010). BMSI stability of the cultivars was investigated in two successive years at eight locations in Bulgaria (Figure 3). The position of the three cultivars in comparison to Pobeda (26) and Sadovo 1 (31) is an evidence for their high and stable quality.

The ranking of cultivars by Kang's method (1991) (Figure 4) according to plasticity of BMSI positioned Aglika, Slaveya and Iveta among the first six cultivars, while the quality standards Slavyanka 196 and Pobeda ranked 22nd and 25th, respectively. It should be noted that the level of stability of the realized quality of some cultivars

Table 2. Variation, mean values and some main parameters of the studied indices of end-use quality averaged for the 2001-2006

Index	Variety	Minimum	Maximum	CV	SE	Mean
Test W	Bezostaya1	81.0	82.4	0.720	0.42	81.8 [b]
	Sadovo1	80.5	82.9	1.210	0.70	83.0 [b]
	Pobeda	82.5	83.4	0.444	0.26	82.5 [b]
	Iveta	82.0	84.1	0.777	0.85	79.5 [a]
	Slaveya	78.0	81.8	2.057	1.16	80.2 [b]
	Aglika	78.6	82.5	2.061	1.17	38 [a]
SDS	Bezostaya1	37	40	3.254	0.88	42 [a]
	Sadovo1	40	45	5.143	1.53	44 [a]
	Pobeda	43	46	2.813	0.88	61 [c]
	Iveta	47	65	4.888	3.15	57 [b]
	Slaveya	50	62	5.156	3.71	65 [c]
	Aglika	57	71	5.058	4.16	21.7 [a]
WGC	Bezostaya1	20.2	22.7	4.918	0.75	22.5 [a]
	Sadovo1	20.7	23.7	5.704	0.91	24.8 [b]
	Pobeda	23.6	25.7	3.607	0.63	23.9 [b]
	Iveta	21.8	26.1	4.773	1.08	22.6 [a]
	Slaveya	21.9	23.0	2.120	0.34	22.9 [a]
	Aglika	22.1	23.9	3.231	0.52	3.10 [a]
Dough T	Bezostaya1	1.20	3.20	8.528	0.58	3.15 [a]
	Sadovo1	3.00	3.30	4.562	0.10	6.50 [b]
	Pobeda	6.00	7.30	8.793	0.40	8.15 [b]
	Iveta	2.45	8.45	10.473	1.37	7.45 [b]
	Slaveya	5.15	10.20	16.390	1.48	10.45 [c]
	Aglika	8.45	14.20	11.978	1.70	41.0 [c]
Val	Bezostaya1	38	45	7.180	2.08	45.7 [b]
	Sadovo1	37	50	7.420	4.33	45.3 [b]
	Pobeda	40	49	8.512	2.73	60.5 [a]
	Iveta	51	68	5.012	2.66	61.3 [a]
	Slaveya	58	63	3.843	2.67	68.7 [a]
	Aglika	65	75	6.549	3.18	707 [b]
Loaf V	Bezostaya1	690	730	2.405	12.02	685 [b]
	Sadovo1	660	725	4.172	20.21	697 [b]
	Pobeda	675	725	3.007	14.81	782 [a]
	Iveta	715	870	3.011	11.11	772 [a]
	Slaveya	755	780	1.527	8.33	815 [a]
	Aglika	745	900	4.873	15.37	

* - values designated with the same letters did not differ at level of significance ($p<0.05$)

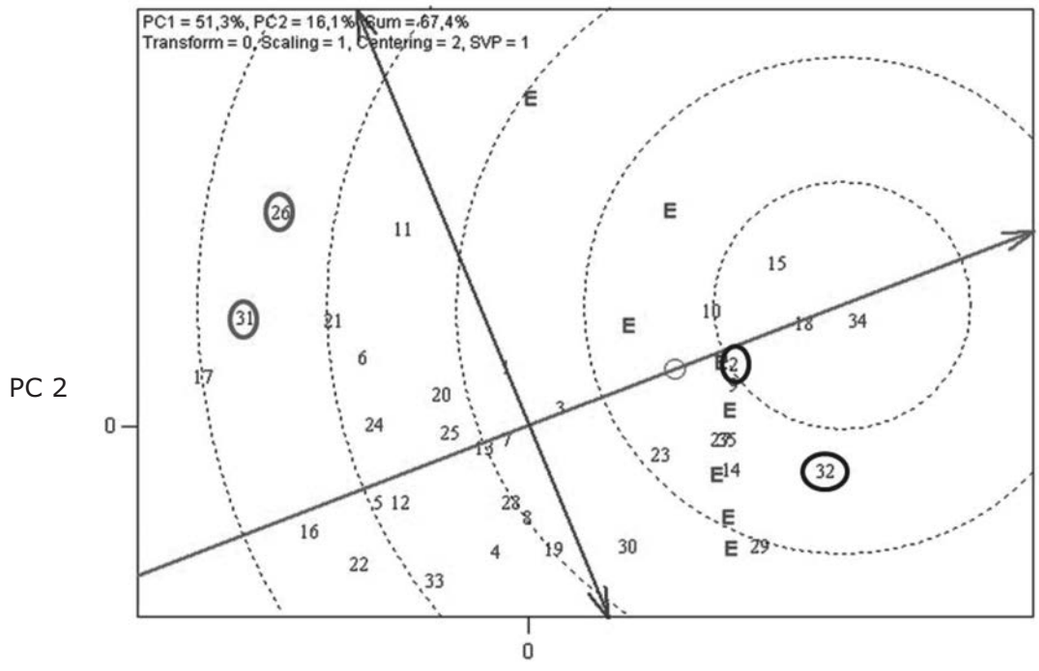

Figure 3. Stability of the cultivars in respect to bread-making strength index (BMSI) / Key: (2) Aglika, (10) Iveta, (32) Slaveya, (26) Pobeda, (31) Sadovo 1

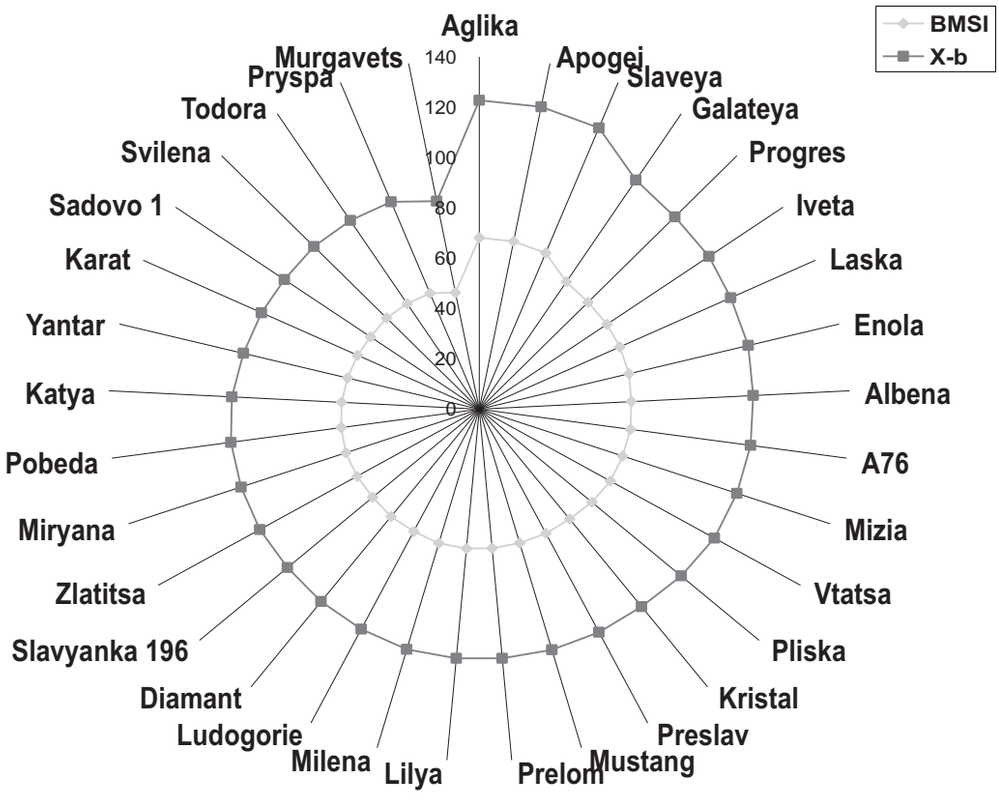

Figure 4. Plasticity of the cultivars in respect to bread-making strength index (BMSI)

from first quality group was very low. Such cultivars were Preslav, Mustang and Milena. At the same time the quality of cultivars from second quality group was stable (Galateya, Enola and Vratsa, ranking 4th, 8th and 12th, respectively). These data allow the conclusion that the level of quality is important but the level of its realization is even more important.

It can be concluded that as a result from long-term breeding for combining high-quality varieties it is entirely possible to combine high yield with end-use quality. Cultivars Aglika, Iveta and Slaveya are a good example in this respect. Their high genetic potential for end-use quality was accompanied with high grain yield which to a large extent resulted from their high tolerance to biotic and abiotic stress successfully transferred from the parental components (Tsenov et al., 1998; Tsenov et al., 2010). The high production potential was due to the ability of the three cultivars to form higher number of grains per spike, a prerequisite for good adaptability under variable environments (Tsenov et al., 2008).

Conclusion

The three investigated cultivars are a good breeding achievement because of their successful combination of high grain yield with quality. Cultivar Slaveya, although belonging to the group of fillers, demonstrated values of a strong wheat. Cultivars Aglika, Slaveya and Iveta possessed good adaptability and plasticity under changeable environments with regard to grain yield and its main components. By end-use quality (BMSI), the three cultivars demonstrated excellent plasticity and adaptability ranking first among more than 30 cultivars investigated in different wheat production regions in Bulgaria.

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CONTENTS 1 / 2

CONTENTS 2 / 2

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The introduction must answer the following questions: What is known and what is new on the studied issue? What necessitated the research problem, described in the paper? What is your hypothesis and goal ?

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Results are presented in understandable tables and figures, accompanied by the statistical parameters needed for the evaluation. Data from tables and figures should not be repeated in the text. **Tables** should be as simple and as few as possible. Each table should have its own explanatory title and to be typed on a separate page. They should be outside the main body of the text and an indication should be given where it should be inserted.

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Discussion: The objective of this section is to indicate the scientific significance of the study. By comparing the results and conclusions of other scientists the contribution of the study for expanding or modifying existing knowledge is pointed out clearly and convincingly to the reader.

Conclusion: The most important consequences for the science and practice resulting from the conducted research should be summarized in a few sentences. The conclusions shouldn't be numbered and no new paragraphs be used. Contributions are the core of conclusions.

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Todorov N and Mitev J, 1995. Effect of level of feeding during dry period, and body condition score on reproductive performance in dairy cows, IX th International Conference on Production Diseases in Farm Animals, Sept.11 – 14, Berlin, Germany, p. 302 (Abstr.).

Thesis:

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