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Original article

Study of Elements of Productivity and Determine the Correlation Relationships between Them in Common Winter Wheat Varieties with Origin from Belarus

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Abstract

The survey was conducted during the period 2015-2017 in the experimental field of IPGR Sadovo. The elements of productivity of 29 common winter wheat varieties (*Triticum aestivum* L.) with origin from Belarus and two Bulgarian varieties – Sadovo 1 and Enola were studied. The coefficient of variation has been calculated and the correlation dependencies between the elements of productivity are determined. The influence of factors genotype, environment and their interaction on the studied features is assessed. A low variation in the trait was recorded in the number of spikelets per spike, spike length and number of grains per spike. With high variation is characterized the number of grains per other spikes. The strongest correlation dependence is observed between features grain number per plant with grain number per other spikes, followed by the grain weight per plant with grain weight per other spikes. The plant height is in negative correlation with all studied elements of productivity. The factor genotype has the greatest influence on the plant height and the cultivation conditions have a leading role in the productive tillering.

Keywords: Common Winter Wheat, Elements of Productivity, Degree of Variation, Correlation, Genotype, Environment, Source of Variation.

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INTRODUCTION

Improving the productivity of wheat has always been a major and constant task before crop breeding in our country. The variety as an element of technology is one of the most important factors for its improvement. The results of a number of researchers show that the yield potential in modern varieties is not fully realized (the plateau is not reached yet) and can be increased through breeding (Reeves et al., 1999; Dencic & Kobiljski, 2010). Of particular importance for practical breeding is creation of a genotype combining traits that define it not only as high yielding but also with increased plasticity and stability in different growing conditions, as well as high resistance to diseases and pests (Dimova et al., 2002). The right choice of initial material is crucial for creation of a new variety. The selection of breeding material is based on certain characteristics, which are taken into account through qualitative and/or quantitative traits. They are characterized by the presentation of the suitability of a specific genotype to a breeding program. One of the most commonly used indicators in the selection of initial material for common winter wheat is the yield realized by the tested breeding lines. Its magnitude is a complex indicator that has relation with other features, such as the characteristics of the spikes (Rachovska and Uhr, 2010; Boyadzhieva, 1988; Donmez et al., 2001), productive tillering (Nikolova and Panayotov, 2008), photosynthetic activity of the plant (Stoyanov, 2013). There are some dependencies between these indicators, which allow indirect determination of the crop yield, as well as the potential productive capacity of the plants. Rachovska and Uhr (2010) reported a positive correlation between spike length and yield. They also pointed to a relationship between the weight of grains in spike and the yield. Chamurliiski et al. (2011) reported similar results, pointing to a positive correlation between the number of grains per spike and the yield. One of the most significant problems in parent selection in breeding is the small difference in gene variation, controlling important indicators in modern wheat varieties. Therefore, different methods are used to include new sources of economically important features in crop breeding. An important stage in the planning of breeding schemes is the preliminary study of varieties, which will be used as donors of quantitative or qualitative traits and the type of inheritance.

Material and Methods

During the period 2015-2017, 29 varieties of common winter wheat originating from Belarus and two Bulgarian varieties – Sadovo 1 and Enola, were studied in the experimental field of the Institute of Plant Genetic Resources – Sadovo (Table 1). The sowing took place in the optimum period October 10-15. The studied materials were sown in 2 rows with the length of the experimental plot – 2 m2, at the row spacing – 20 cm and the distance between rows – 5 cm. The standard IPGR technology for cultivation of common winter wheat was used. The agrotechnical activities were carried out in the optimum terms. The agrotechnical activities were carried out in the optimum terms. Biometric measurements were made on 20 plants of each genotype and the following productivity indicators were recorded: PH – plant height (cm), TT - total tillering, PT – productive tillering, SL – central spike length (cm), NSS – number of spikelets per central spike, NGS – number of grains per central spike, WGS – grain weight per central spike (g), NGOS – number of grains per other spikes, WGOS – grain weight per other spikes (g), NGP – number of grains per plant, WGP – grain weight per plant (g). Mathematical data processing was performed by applying correlation and variance analysis using statistical program SPSS 19 for Windows. To determine the variation degree of each of the traits, a coefficient of variation was calculated based on average values in the study period. It is accepted that variation is considered weak if the coefficient of variation is up to 10%, medium – greater than 10% and less than 20%, strong – above 20% (Deshmukh et al.,1986; Dimova and Marinkov, 1999).

Table 1. Studied varieties of common winter wheat (*Triticum aestivum L.*)

№	**Variety**	**№**	**Variety**	**№**	**Variety**	**№**	**Variety**
1.	Laska	9.	Korona	17.	Avangardnaya	25.	Sakret
2.	Sonata	10.	Uzrym	18.	Rasvet	26.	Oda
3.	Kapela	11.	Vasilisa	19.	Uzlet	27.	Kanver
4.	Darja	12.	Suzore	20.	Beloruskaya 80	28	Toma
5.	Arina	13	Viza	21.	Rostan	29.	Elegya
6.	Pogiuk	14.	Sofia	22.	Anuta	30.	Sadovo 1- St.
7.	Augustina	15.	Kredo	23.	Lyubavaya	31.	Enola
8.	Suita	16.	Harmony	24.	Sudarinya		

The aim of the present study is to investigate the elements of productivity and to determine the correlation between them in common winter wheat varieties from Belarus and Bulgaria.

Results and Discussion

The results of biometric measurements of productivity elements of the studied wheat varieties are presented in Table 2. The data show that the values of the characteristics of the varieties from Belarus are exceeded in comparison with the Bulgarian varieties. The standards Sadovo 1 and Enola are characterized by the lowest total and productive tillering. The obtained results for the signs: number of grains per other spikes, number of grains per plant and weight of grains per plant are similar. With respect to the variation coefficient of the individual traits, the results show that low variability was observed in the indicators of number of spikelets per central spike, length of central spike and number of grains per central spike. High variation is observed for the number of grains per other spikes. Regarding other indicators the variation is average. All these results highlight the relatively low genetic diversity among the studied winter wheat varieties.

Table 2. Results of biometric measurements of the structural elements of productivity

Variety	PH	TT	PT	SL	NSS	NGS	WG	NGO	WGO	NGP	WG
Laska	85.80	4.0	3.6	11.2	21.2	45.9	1.56	76.20	2.46	122.1	4.02
Sonata	98.00	3.9	3.8	9.87	21.4	47.9	1.84	85.00	3.07	132.9	4.91
Kapela	71.30	4.5	3.7	11.7	22.6	49.6	1.42	96.70	2.82	146.3	4.24
Darja	96.60	4.0	3.7	12.3	23.3	51.9	1.72	95.70	3.10	147.6	4.82
Arina	101.8	3.6	3.5	12.3	24.3	50.4	2.23	85.70	3.64	136.1	5.87
Pogiuk	83.90	3.5	3.3	11.0	21.9	49.7	2.27	86.10	4.16	111.5	6.43
Augustina	76.40	4.4	3.9	12.5	24.3	54.1	1.81	105.3	3.38	159.4	5.19
Suita	77.60	4.4	3.9	11.9	21.8	39.7	1.51	74.80	2.73	114.5	4.24
Korona	93.80	4.0	3.8	9.86	21.5	53.8	1.90	93.80	3.22	147.6	5.12
Uzrym	78.20	4.3	4.0	10.6	21.7	54.0	1.98	87.40	3.25	141.4	5.23
Vasilisa	85.60	4.0	3.8	11.4	23.2	51.3	2.00	82.40	3.15	133.7	5.16
Suzore	103.0	3.6	3.3	13.3	23.3	44.4	1.82	64.60	2.58	109.0	4.40
Viza	89.90	3.6	3.4	9.78	20.7	47.9	1.94	70.10	2.76	118.0	4.70
Sofia	93.10	3.3	3.2	10.3	22.2	55.6	1.78	85.60	2.97	141.2	4.75
Kredo	81.80	3.4	3.3	11.2	23.2	51.3	2.02	65.80	2.75	117.1	4.78
Harmony	103.7	3.4	3.1	13.9	22.7	55.3	1.94	85.70	2.43	141.0	4.37
Avangardnaya	92.30	3.8	3.6	11.1	24.1	51.3	1.84	91.60	2.89	142.9	4.73
Rasvet	96.30	4.0	3.6	12.2	22.3	60.0	2.18	118.9	3.89	178.9	6.06
Uzlet	86.20	3.7	3.6	12.0	23.9	53.4	2.22	80.40	2.96	133.8	5.19
Beloruskaya 80	98.20	4.3	3.8	11.1	23.3	58.4	2.00	102.0	2.58	160.4	4.58
Rostan	97.20	4.0	3.6	11.3	22.5	52.8	1.99	92.50	3.00	145.3	4.98
Anuta	94.10	3.5	3.2	12.7	22.3	52.3	2.10	68.90	2.27	121.2	4.37
Lyubavaya	88.10	4.3	3.9	12.4	22.4	50.9	2.22	93.40	3.48	144.3	5.70
Sudarinya	93.90	3.6	3.3	11.1	23.8	52.6	1.97	84.10	2.43	136.7	4.39
Sakret	83.30	4.0	3.6	11.6	23.0	52.5	2.19	100.0	3.74	152.5	5.94
Oda	83.50	3.9	3.5	12.9	25.3	57.7	2.28	86.90	2.80	144.6	5.08
Kanver	80.50	3.3	3.2	12.2	24.5	49.9	2.00	70.20	2.38	120.1	4.38
Toma	89.00	3.5	3.3	10.2	22.9	62.3	2.17	83.90	2.57	146.2	4.73
Elegya	80.80	4.1	3.8	11.0	21.9	47.4	1.79	109.2	3.30	156.6	5.09
Sadovo 1- St.	**108.5**	**2.3**	**2.0**	**9.26**	**20.0**	**39.1**	**2.12**	**36.00**	**1.95**	**74.20**	**4.07**
Enola	**89.08**	**2.8**	**2.0**	**10.8**	**22.1**	**47.3**	**2.069**	**42.4**	**1.781**	**89.8**	**3.85**
Mean	89.7	3.8	3.5	11.5	22.7	51.3	2.0	83.9	2.9	134.4	4.9
Minimum	71.3	2.4	2.0	9.3	20.0	39.1	1.4	36.0	1.8	74.2	3.9
Maximum	108.5	4.5	4.0	14.0	25.3	62.3	2.3	118.9	4.2	178.9	6.4
Std. deviation	9.0	0.5	0.5	1.1	1.2	5.1	0.2	17.4	0.5	21.3	0.6
Coef. var., %	10.0	12.	13.	9.6	5.2	9.9	11.2	20.7	18.5	15.8	12.8
Standard error	1.61	0.0	0.0	0.20	0.21	0.91	0.04	3.12	0.10	3.82	0.11

Table 3 presents the results of the performed correlation analysis. Very strong positive correlations were found for three of the analyzed dependencies. The value of the correlation coefficient between the total and productive tillering is 0.924, accordingly the increasing of total tillering will increase the productive tillering. The second signs pair includes the weight and the number of grains and indirectly related to the tillering. The number of grains per plant depends strongly from the number of grains per other spikes (r=0.955), and the weight of grains per plant depends from the weight of grains of the other spikes (r=0.939). These results show that the other spikes have important significance and the genotypes with a big number can be considered as perspective productive. In confirmation of the mentioned above there is a strong correlation between the total and the productive tillering and the number of grains per other spikes, with coefficient values of 0.761 and 0.775.

A high correction between the number of grains and the weight of grains per spike was also found by Stoyanov (2013). Although the grain weight per spike is a direct component of the yield and highly correlates with it (Rachovska and Uhr, 2010), Stoyanov (2013) gives preference to the feature grain weight per spike as a more valuable breeding trait, which will be sufficient reliable in the breeding process. At the same time, Zhang et al. (2012) reported that a higher number of grains per spike does not always determine a higher yield. As the weight of grains per spike is directly related to the yield as a component of it, it is important to determine the presence or absence of correlation between the other characteristics of the spike with this indicator. This would allow new lines to be evaluated at an early stage in their breeding process. Slafer et al. (2014) reported that differences in grain yield are due to the number of grains per unit area, which is most strongly influenced by the number of grains per spike. They consider that the increasing of grain yield is related to creation of a compromise combination between the number of grains per spike with their size and productive tillering. The results of the correlation analysis also show that the plant height is in negative correlation with all other studied traits. Mathematically, it is proved only with the total and productive tillering. In historical terms the key factor for improving wheat productivity is lowering the stem height and increasing the effectiveness of nutrition (Nonaka, 1983; Borojevic, Ka. and Borojevic, Ks., 2005). Such results are also reported by Dencic and Kobiljski (2010), who consider that the main factors affecting wheat productivity are low stem and early ripening, which lead to increased transfer efficiency of assimilates from leaves and stems to the grain. In the other comparisons, which are half of all, it was found that the correlation dependencies are respectively: weak for 24 of the total, medium – 15 and significant – 11.

Table 3. Correlation dependencies between the productivity elements of common winter wheat genotypes

Variable	**PH**	**TT**	**PT**	**SL**	**NSS**	**NGS**	**WGS**	**NGOS**	**WGOS**	**NGP**	**WGP**
PH	1										
TT	-0.490**	1									
PT	-0.400*	0.924**	1								
SL	-0.032	0.237	0.182	1							
NSS	-0.166	0.181	0.224	0.606**	1						
NGS	-0.011	0.225	0.282	0.164	0.452*	1					
WGS	0.259	-0.377*	-0.269	0.054	0.225	0.390*	1				
NGOS	-0.225	0.761**	0.775**	0.221	0.285	0.581**	-0.078	1			
WGOS	-0.218	0.510**	0.614**	0.087	0.101	0.274	0.220	0.716**	1		
NGP	-0.165	0.702**	0.718**	0.237	0.370*	0.730**	-0.023	0.955**	0.566**	1	
WGP	-0.099	0.306	0.435*	0.094	0.167	0.372*	0.542**	0.587**	0.939**	0.477**	1

***** Correlation is significant at the 0.05 level

****** Correlation is significant at the 0.01 level

Table 4 presents the percentage ratios of the different correlation dependencies between studied traits. From all 55 comparisons, with very strong, strong and significant correlation are 29% of comparisons. They are closely linked to the productivity and to the tillering of wheat. The remaining 71% of the comparisons have a weak and medium correlation.

Table 4. Scale of percentage correlation between quantitative traits in common winter wheat genotypes

Scale of correlation	**Number of correlations between different traits**	**% correlation**
r = 0 – 0.25 weak	24	43.6%
r = 0.25 – 0.50 medium	15	27.3 %
r = 0.50 – 0.75 significant	11	20 %
r = 0.75 – 0.90 strong	2	3.6 %
r > 0.90 very strong	3	5.4 %
	55 comparisons	100 %

It can be summarized that for the most important attributes related to productivity and tillering there are very strong to significant correlation dependencies. This fact defines varieties from Belarus as highly productive and perspective.

Two-way ANOVA test was applied to determine whether the variability of the studied traits depends more from genetic factors or from growing conditions. The power of influence of the sources of variation – genotype, environment and their interaction on the elements of productivity, is assessed. The results of the analysis are shown in Table 5. The higher values of the experimental importance of the Fisher criterion (F exp.) than the table ones proves that there is a significant difference between genotypes with respect to the compared quantitative traits with significance at the 0.01 and 0.001 level. The influence of the genotype is mostly shown in the signs: weight of grains per central spike, number of grains per central spike, total tillering, number of spikelets per central spike, number of grains per other spikes, number of grains per plant, length of the central spike and plant height. The values of ŋ, expressed as a percentage of these indicators, range from 20.9 to 46.1. The growing conditions have a significant importance for productive tillering (28.9%), the interaction of the genotype x environment has a leading role for the weight of grains per other spikes (23.8%) and the weight of grains per plant (26.1%). Regarding three of the studied productivity elements, the environmental factor has an insignificant effect on the specific trait. These are the number of grains per central spike (0.1%), the weight of grains per central spike (1.2%) and the number of spikelets per central spike (1.7%). Probably, these traits for all studied genotypes are controlled by genes less dependent by environmental factors, and therefore can be defined as more conservative than others. The relative share of accidental errors, mainly due to differences in soil fertility, is in the range of 7.6-59.5%, which is within the acceptable range for the field experience.

Table 5. Analysis of variance to assess the impact of sources of variation on the elements of productivity

Elements of productivity	Sources of variation	SS	df	Variance	F exp.	F tab.	η,%
Plant height	Genotype: Factor A	24145.6	30	804.9	50.1***	2.1	46.1
	Environment: Factor B	18168.0	1	18168.0	1131.1***	11.1	34.7
	Interaction: AxB	6094.2	30	203.1	12.6***	2.1	11.6
	Error	3983.6	248	16.1			7.6
	Total	52391.4	309				100
Total tillering	Genotype: Factor A	65.4	30	2.2	3.7***	2.1	25.8
	Environment: Factor B	14.4	1	14.4	24.2 ***	11.1	5.7
	Interaction: AxB	26.5	30	0.9	1.49 n.s.	1.51	10.5
	Error	147.3	248	0.6			58.1
	Total	253.7	309				100
Productive tillering	Genotype: Factor A	61.5	30	2.1	5.2***	2.1	23.8
	Environment: Factor B	74.6	1	74.6	188.7***	11.1	28.9
	Interaction: AxB	24.3	30	0.8	2.0**	1.8	9.4
	Error	98.1	248	0.4			37.9
	Total	258.6	309				100
Central spike length	Genotype: Factor A	364.7	30	12.2	16.7***	2.1	41.6
	Environment: Factor B	197.9	1	197.9	272.4***	11.1	22.6
	Interaction: AxB	132.9	30	4.4	6.1***	2.1	15.2
	Error	180.2	248	0.7			20.6
	Total	875.7	309				100
Number of spikelets per central spike	Genotype: Factor A	418.8	30	14.0	4.1***	2.1	26.3
	Environment: Factor B	26.7	1	26.7	7.9**	6.7	1.7
	Interaction: AxB	309.6	30	10.3	3.1***	2.1	19.4
	Error	837.2	248	3.4			52.6
	Total	1592.3	309				100
Number of grains per central spike	Genotype: Factor A	7711.0	30	257.0	3.0***	2.1	21.5
	Environment: Factor B	22.2	1	22.2	0.3 n.s.	1.5	0.1
	Interaction: AxB	6750.5	30	225.0	2.6***	2.1	18.9
	Error	21316.4	248	86.0			59.5
	Total	35800.1	309				100.0
Grain weight per central spike	Genotype: Factor A	14.5	30	0.5	3.0***	2.1	20.9
	Environment: Factor B	0.8	1	0.8	5.2***	11.1	1.2
	Interaction: AxB	14.1	30	0.5	2.9***	2.1	20.4
	Error	39.7	248	0.2			57.4
	Total	69.1	309				100.0
Number of grains per other spikes	Genotype: Factor A	90476.5	30	3015.9	5.4***	2.1	28.2
	Environment: Factor B	26036.4	1	26036.4	47.0***	11.1	8.1
	Interaction: AxB	66962.9	30	2232.1	4.0***	2.1	20.9
	Error	137514.8	248	554.5			42.8
	Total	320990.6	309				100.0
Grain weight per other spikes	Genotype: Factor A	88.2	30	2.9	3.8***	2.1	21.4
	Environment: Factor B	33.5	1	33.5	43.2***	11.1	8.1
	Interaction: AxB	98.4	30	3.3	4.2***	2.1	23.8
	Error	192.5	248	0.8			46.7
	Total	412.7	309				100.0

Number of grains per plant	Genotype: Factor A	135923.4	30	4530.8	6.2***	2.1	29.9
	Environment: Factor B	29188.66	1	29188.7	39.9***	11.1	6.4
	Interaction: AxB	108334	30	3611.1	4.9***	2.1	23.8
	Error	181605.3	248	732.3			39.9
	Total	455051.4	309				100.0
Grain weight per plant	Genotype: Factor A	118.5	30	4.0	3.8***	2.1	20.6
	Environment: Factor B	44.9	1	44.9	42.7***	11.1	7.8
	Interaction: AxB	149.8	30	5.0	4.7***	2.1	26.1
	Error	260.9	248	1.1			45.4
	Total	574.1	309				100

****** Correlation is significant at the 0.01 level; ******* Correlation is significant at the 0.001 level; **n.s.** – Correlation is insignificant

Conclusion

Common winter wheat varieties with origin from Belarus exceed the value of total and productive tillering, number of grains per other spikes, number of grains per plant and weight of grains per plant in the Bulgarian varieties Sadovo 1 and Enola.

A low variation in the trait was recorded in the number of spikelets per spike, spike length and number of grains per spike. With high variation is characterized the number of grains per other spikes.

Very strong correlation dependence is observed between the following elements of productivity: grain number per plant with grain number per other spikes, grain weight per plant with grain weight per other spikes, productive with total tillering.

The genotype produces the strongest proven influence as a source of variation by the features plant height and length of the central spike. The growing conditions have the greatest impact on productive tillering. The interaction of two factors (genotype x environment) have an initial importance for the grain weight per other spikes and the grain weight per plant.

The evaluated elements of productivity and correlation dependencies between them determine the studied varieties as perspective and highly productive, and they can be used as sources of initial material for improving productivity in common winter wheat in the breeding process.

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