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THE COMPONENTS OF VARIABILITY OF DRY MATTER STATUS INDICATORS IN WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

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Variability and components of variance for some dry matter status indicators (grain yield, biological yield and grain harvest index) have been studied in 30 winter wheat varieties from different selection centers (Morava, Lepenica, Studenica, Takovcanka, Toplica, Srbijanka, KG 100, Lazarica, Bujna, Matica, Vizija, Pobeda, Rana 5, Evropa 90, Renesansa, Tiha, Mina, Prima, Kremna, Rusija, Pesma, KG – 200/31, KG – 253/4 – 1, KG – 115/4, KG – 165/2, KG – 56/1, KG – 100/97, Perla, KG - 224/98 and KG – 10). The experiment was performed in randomized block design in five replications on the experimental field of Small Grains Research Centre, Kragujevac in three years.

Average estimated values for grain yield, biological yield and grain harvest index differed high significantly among years and among varieties. The highest average value for grain yield had KG 10 variety (792.94g m^{-2}) and the lowest value was found in KG 200/31 (303.88g m^{-2}). During investigated period the highest average value for biological yield was determined in KG 10 (1907.62 g m^{-2}), and the lowest value in Pesma (701.55). The grain harvest index varied from 39% (Lepenica, KG 200/31) to 46% (Renesansa, Tiha, KG 100/97).

The lowest variability for grain yield was established in Rana 5 variety and the highest in Takovcanka (V = 9.60%; 27.71%, respectively). Coefficient of variation for biological yield varied from 4.02% (Matica) to 28.85% (Evropa 90). The lowest variability for grain harvest index was established in Evropa 90 and the highest in Pesma (V = 5.46%; 23.49%, respectively). Phenotypic analysis of variance indicated that genetic factors had higher impact on the expression of GY and BY than ecological factors. Higher share of ecological variance was registered at variability of GHI.

Key words: dry matter, grain harvest index, yield, variability, wheat

Abbreviations: GY – grain yield, BY – biological yield, GHI – grain harvest index, $\overline{X}$ - average value, Sx - standard deviation, Cv - coefficient of variation, Vp – phenotypic variability, Ve – ecological variability, Vg – genetic variability CVp - phenotypic coefficient of variability, CVg - genotypic coefficient of variability

Introduction

Wheat breeding programs have been directed towards such factors as grain yield and quality. The successful process of wheat breeding is based on the knowledge of characteristics of genotypes, environment and its interaction. Understanding causes of genotypic-environment interaction helps to establish breeding objectives identify ideal test conditions and formulate recommendations for areas of optimal cultivar adaptation (Panayotov, 2000; Weikai and Hunt, 2001). The challenge for wheat breeding, in the next decades, with an expanding world population, will be to develop highly productive genotypes, with satisfactory grain quality, whilst at the same time preserving the quality of the environment

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(Shrawat et al., 2008; *Weinkauf, 2008). Development of new varieties with desirable yield and associated traits offers best solution to the existing problems of productivity. Genetic variability exists for various yield and yield related traits in wheat as plant height, number of grains per spike, grain weight per spike, number of spikelets per plant, biological yield, grain harvest index etc. (Shahid et al., 2007; Zecevic et al., 2010). In addition, there exists relationship of various yield related traits with grain yield.* The grain yield of wheat is variable trait that depends on numerous yield components and environmental factors (Gorjanovic and Kraljevic – Balalic, 2006). Variability of yield components and related traits is less studied than the yield. Investigation of variability and components of phenotypic variance for those traits are very important for the cultivar creation. The knowledge of genetic association between grain yield and its components would improve the efficiency of breeding programs by identifying appropriate indices for selecting wheat varieties (Zecevic et al., 2010). Yield performance continues to be of importance in wheat breeding, trough it will be necessary to improve traits involved in yield stability if further yield increases are to be achieved (Bedo et al., 2005).

Considering these facts, the present study was undertaken to measure the variability and components of variability for grain yield, biological yield and grain harvest index in genetically divergent wheat varieties, which can be used as parent cultivars in breeding programs for improvement grain yield and quality of wheat.

Material and Method

The study was carried out on the property of the Small Grains Research Center in Kragujevac (186 m.a.s.l.), Serbia, during three consecutive seasons (2001/02, 2002/03 and 2003/04). The soil type was smonitza in degradation (Vertisol). It is characterized by heavy mechanical composition, unstable, rough structure and low porosity (Jelic, 1996).

The experiment included 30 wheat cultivars and experimental lines, originating from the Serbia: Small Grains Research Center, Kragujevac and Institute of Field and Vegetable Crops, Novi Sad: Morava, Lepenica, Studenica, Takovcanka, Toplica, Srbijanka, KG 100, Lazarica, Bujna, Matica, Vizija, Pobeda, Rana 5, Evropa 90, Renesansa, Tiha, Mina, Prima, Kremna, Rusija, Pesma, KG – 200/31, KG – 253/4 – 1, KG – 115/4, KG – 165/2, KG – 56/1, KG – 100/97, Perla, KG - 224/98 and KG – 10. The basic processing and pre – sowing preparation of the soil was done using standard procedures. The randomized complete block experimental design was used with five replicates in rows 1.5m on, with spacing between rows of 0.20m. Sowing (200 grains per row) was done by hand (one genotype per row), during the optimal planting period for central Serbian conditions, for winter wheat (29. 10. 2001, 15. 11. 2002 and 06.11. 2003). NPK fertilizer, formulated 8:24:16, was applied at the rate of 300 kg ha^{-1} before sowing each season. Eight grams of nitrogen (260 kg KAN ha^{-1}) per row was added at the tillering stage of development each season. Plant samples of each genotype were taken at maturity (five plants). The samples were air – dried and the grain yield (GY, g m^{-2}), total above – ground biomass at maturity – biological yield (BY, g m^{-2}) and grain harvest index (GHI, %), as ratio between GY and BY, were measured (Arduini et al., 2006)

Obtained dates were statistically processed. The following parameters were computed: the average value ($\overline{X}$), standard deviation (Sx) and the coefficient of variation (Cv) as an index of relative variability of the trait. Difference between mean values was tested by LSD test (Hadzivukovic, 1991). All parameters of variability were calculated for each variety and year separately and then presented as average values. Components of variance calculation were based on the results of analysis of variance (Chaudhary et al., 1999).

Results and Discussion

The highest average value for GY was observed in KG 10 variety (792.94g m^{-2}). This variety showed high variability of this property with Cv = 23.12% (Table 1). The lowest value of GY was found in KG 200/31 (303.88g m^{-2}), with high coefficient of variation, too (Cv = 24.11%).

High variability of the GY was found in all investigated varieties. The coefficient of variation was high and varied in the range from 9.60% (Rana 5) to 27.71% (Takovcanka) (Table 1). In wheat breeding programs, higher yield is the ultimate objective. It is a polygenic character and is greatly influenced by the varying environment (Saeed et al., 2010). The grain yield is a quantitative trait whose expression depends on a large number of genes that are strongly influenced by environmental factors that cause high variability, as confirmed by this research.

During investigated period the highest average value for BY was determined in KG 10 (1907.62 g m^{-2}), and the lowest value in Pesma (701.55 g m^{-2}). The GHI varied from 39% (Lepenica, KG 200/31) to 46% (Renesansa, Tiha, KG 100/97). Coefficient of variation for BY varied from 4.02% (Matica) to 28.85% (Evropa 90). The lowest variability for GHI was established in Evropa 90 and the highest in Pesma (Cv = 5.46%; 23.49%, respectively) (Table 1).

Increased yield in winter wheat cultivars have been found to be largely attributable to improved partitioning of biomass to the grain, i.e., higher harvest index. However, there is a biological upper limit to harvest index and therefore breeders need to exploit increased biomass production as the mechanism by which yields are increased (White and Wilson, 2006). Donmez et al. (2001) found that yield was significantly correlated with both harvest index and biomass in experiments with 13 varieties of winter wheat ranging in year of release in the USA from 1873 to 1995, the four newest varieties showed significant genetic gain in biomass. Brancourt-Hulmel et al. (2003), in a study of 14 winter wheat varieties registered between 1946 and 1992 in France, reported genetic gains in yield of between 0.039 and 0.066 t ha^{-1} y^{-1} at two fertilizer N rates and with and without fungicide applications. They also reported significant genetic gains in harvest index but not in biomass amongst these varieties. Shearman et al. (2005) attributed yield increase in eight winter wheat varieties introduced in the UK between 1972 and 1995 to increased harvest index in those varieties introduced before 1980 and increased biomass in va-

Table 1
Average values and variability of grain yield, biological yield and grain harvest index

Genotype \ Indicator	GY, g m^{-2}	S_X	Cv, %	BY, g m^{-2}	S_X	Cv, %	GHI, %	S_X	Cv, %
Morava	620.47	10.50	25.26	1489.66	11.04	9.76	41	2.62	15.31
Lepenica	352.53	5.58	11.50	946.97	12.46	9.62	39	2.06	12.34
Studenica	465.97	14.47	18.42	1117.78	28.65	16.44	42	2.66	13.63
Takovcanka	451.07	22.95	27.71	1104.23	17.03	8.50	41	4.01	21.88
Toplica	434.65	11.99	12.60	1021.97	26.41	12.88	44	1.20	5.61
Srbijanka	443.81	15.02	25.74	1108.87	16.67	10.17	39	3.06	18.37
KG – 100	510.29	10.76	15.77	1290.86	17.93	10.20	41	1.75	10.13
Lazarica	380.62	18.93	22.75	912.86	13.55	6.57	41	3.03	16.96
Bujna	420.16	16.29	16.98	976.80	28.65	14.04	42	5.97	31.19
Matica	511.69	9.88	15.17	1215.43	6.23	4.02	42	2.91	15.39
Vizija	473.80	20.89	22.38	1078.93	46.62	24.84	44	3.31	15.80
Pobeda	447.06	6.00	13.49	1018.62	16.33	16.47	44	3.79	18.66
Rana 5	441.32	7.09	9.60	1053.41	20.68	12.74	44	2.34	10.58
Evropa 90	570.13	17.32	21.51	1417.48	53.28	28.85	45	1.24	5.46
Renesansa	384.60	12.48	16.73	860.26	21.44	16.54	46	3.07	13.52
Tiha	425.96	10.62	17.02	991.24	19.26	13.06	46	3.61	16.08
Mina	507.31	16.79	20.99	1184.38	25.01	13.77	43	2.66	14.19
Prima	325.41	9.94	16.95	763.01	22.20	14.99	42	2.42	13.01
Kremna	454.08	26.36	25.21	1052.30	53.02	24.72	43	3.26	15.83
Rusija	447.22	14.06	18.08	1121.10	36.10	19.39	41	2.17	11.54
Pesma	320.39	12.03	13.47	701.55	28.65	18.67	42	4.52	23.49
KG 200/31	303.88	20.63	24.11	783.67	30.04	19.58	39	2.18	11.27
KG 253/4-1	534.35	11.78	14.60	1268.74	27.05	16.66	45	3.26	13.56
KG 115/4	471.14	16.51	25.47	1090.09	29.25	20.24	43	3.62	19.21
KG 165/2	478.05	7.97	10.20	1141.08	14.67	9.04	44	1.91	8.84
KG 56/1	497.94	17.12	20.12	1136.66	16.32	9.78	44	4.52	21.34
KG 100/97	451.68	20.88	22.99	1017.01	39.35	24.42	46	2.61	11.43
Perla	538.38	19.59	27.16	1255.21	27.68	19.81	42	2.96	16.20
KG 224/98	308.58	5.00	14.73	763.01	9.57	12.75	42	1.46	7.24
KG 10	792.94	7.40	23.12	1907.62	16.83	16.48	41	3.06	17.43
$\overline{X}$	458.85	13.87	18.99	1093.03	24.40	15.17	43	2.91	14.85
	A**	B**	A x B**	A**	B**	A x B**	A**	B**	A x B**
$LSD_{0.05}$	20.94	66.21	114.8	47.37	149.79	259.24	1.04	3.29	5.69
$LSD_{0.01}$	27.57	87.19	151.1	62.37	197.24	341.63	1.37	4.33	7.50

GY: grain yield; BY: biological yield; GHI: grain harvest index rieties introduced after 1983. The results reported by White and Wilson (2006) suggest that genetic improvement in yield was more strongly associated with a genetic gain in biomass than in harvest index. Increased yields in winter wheat cultivars have been found to be largely attributable to improved partitioning of biomass to the grain, i.e., higher harvest index. However, there is a biological upper limit to harvest index and therefore breeders need to exploit increased biomass production as the mechanism by which yields are increased.

According to the results, all studied traits depended significantly of genetic and environmental factors. Significant differences between years indicated that these traits depended on the environmental conditions during the growing year. Examined varieties reacted differently to environmental changes during particular years. Success in breeding depends on genetic and phenotypic variability that influence expression of individual genotypes. Genotype and environment interactions are important sources of variation in crop breeding programs (Mohammadi and Amri, 2009). Accordingly, varieties with low yield and related traits variability are stable and have higher potential for grain yield. However, the existence of the quite high genotype x environment interaction variances point out that selection should be carried out in more environments and it is inevitable to improve different cultivars for every environment (Bilgin et al., 2011).

To compare the variation among indicators of dry matter status in wheat, estimation of variability components, phenotypic (CVp) and genotypic coefficient of variability (CVg) are given in Table 2. The magnitude of CVp values for all the traits were higher than the corresponding CVg values indicating that these characters may influenced of environmental effect. CVp ranged from 7.79% (GHI) to 39.71% (GY). The lowest CVg (3.67) was observed at GHI, and the highest CVg (35.28) at BY.

Variability plays an important role in plant breeding program and observed the limit of selection for different plant properties. High coefficients of variation traits mean a wide possibility to select genotypes in the tested varieties, according to the desired criteria (Zivanovic et al., 2006). It may therefore be considered the varieties selected for this test are the significant source of variability for breeding programs for wheat, which would include the test indicators of dry matter status as criterions. The variation among genotypes for all examined traits showed promise for their improvements in yield and related traits through selection.

Genetic variation (Table 2) ranged from 21% (GHI) up to 74% (BY), as already intimated the coefficient of variation. From a practical point of selection is not desirable that the total variation has a greater share of environmental variance compared to genetic (Zivanovic et al., 2006). Significant larger share of the total variation of genetic variance to the environment means less influence of environmental factors on the realized variation of these traits, which in terms of selection and breeding is considered a very favorable ratio. The high genotypic variance, as it was registered for GY and BY (70% and 74%, respectively), indicates that selection can be successfully applied in this population in terms of these characters. The obtained values of genetic (21%) and ecological (79%) variance for GHI mean higher influence of environment on expression of this trait. Consequence of that is low value of GHI heritability, too (Madic et al., 2002).

Table 2
Components of variability, relative share of Vp and coefficients of variation of wheat plants dry matter status indicators

Trait	year	Vp	Ve	Vg	Relative share of Vp, %		CVp	CVg
					Ve	Vg		
GY	1	40918.51	11414.10	29504.42	30	70	39.71	33.72
	2	2588.96	1069.68	1519.28			31.31	23.99
	3	36750.27	11676.25	25074.02			27.21	22.47
$\overline{X}$		26752.58	8053.34	18699.24			32.74	26.73
BY	1	250274.10	49428.37	200845.70	26	74	39.39	35.28
	2	8581.40	3588.63	4992.78			25.95	18.79
	3	162981.70	57503.47	105478.20			24.44	19.66
$\overline{X}$		140612.40	36840.16	103772.24			29.93	24.58
GHI	1	9.85	6.88	2.97	79	21	7.79	4.28
	2	56.25	44.54	11.71			18.94	7.73
	3	14.09	11.60	2.49			8.72	3.67
$\overline{X}$		26.73	21.01	5.72			11.82	5.23

Vp – phenotypic variability; Ve – ecological variability; Vg – genetic variability;
CVp – coefficient of phenotypic variation; CVg – coefficient of genetic variation.

The knowledge of genetic variation and association between grain yield and related indicators of dry matter status in wheat is regarded to support considerable help to maintain genetic improved to breeding programme. This will assist plant breeders in choosing which traits should be used in their breeding program. High range of variability, heritability, genetic advance and positive correlation coefficient among traits could be an excellent tool for improving or selection genotype (Akbar et al., 2003; Bozokalfa et al., 2010).

Conclusion

Grain yield and investigated related traits depended highly by growing seasons and analyzed varieties. Average values for GY varied from 303.88g m^{-2} to 792.94g m^{-2}, for BY from 701.55 g m^{-2} to 1907.62 g m^{-2} and for GHI from 39% to 46%. In this investigation established high variability of wheat yield and related traits. Phenotypic analysis of variance indicated that ecological factors had lower impact on the expression of GY and BY than genetic factors. On the contrary, expression of GHI was under higher influence of environmental factors than genetic ones.

Considering obtained results, it can be concluded that investigated materials represents a desirable variability source and has, mainly, beneficial relationship between variability components. Therefore, it can be considered as important material for future breeding programs of wheat.

Noting objective difficulties about including physiological parameters as criteria in wheat breeding, further testing this material by other aspects (correlations with indicators of nitrogen status in wheat, heritability) is necessary to more complete and more reliable assessment and conclusion.

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