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VARIABILITY AND STABILITY OF HARVEST INDEX IN WHEAT (*Triticum aestivum* L.)

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ABSTRACT. Variability and stability of harvest index for the large number of divergent common wheat genotypes originated in different world breeding institutions were studied. The experiment was performed using randomized block design in three replications on the experimental field in different environmental conditions. A total number of 60 plants have been analyzed in the full maturity stage. The analyzed cultivars showed very significant differences in the average values of harvest index. Interaction genotype x environment has been evaluated. The significant influence of cultivars, year and their interaction on expression of the trait was found. The effect of the analyzed trait on phenotypic variability was estimated. The most stable genotypes have been determined for analyzed yield component. On the base of stability and phenotypic variability the genotypes can be used as parents in wheat breeding programs.

INTRODUCTION

Stability and adaptability represent genotype reaction to environmental variation. Adaptability is a natural reaction of genotype in order to survive and reproduce. Stability means very small genotypic reaction to environmental changes, and in a broad sense, could not be considered as evolutionary favorable in natural conditions. However, in agriculture, stability represents desirable reaction of cultivated genotypes, forced and supported by humans, ensuring the similar yield level in different environmental conditions through small genotype-environmental interaction. The border between adaptability and stability is quite hazy, reflecting in different and sometimes mixed up definitions of these two. FEDERER and SCULY (1993) are in favor of further discussions and more suitable definitions. Lin and Binns (1991, 1994) expressed the opinion that very little evidence of obtaining stable genotypes in breeding programs, according to contemporary definitions, had been given. In practice, in developed breeding programs the concept of creating varieties suitable for precisely defined target regions is a common approach. These target regions called mega-envornments (GAUCH, and ZOBEL, 1997) or sub-regions (ANNICCHIARICO, 1997) are of similar environmental, agricultural and economical conditions. The aim of adaptability-stability research of yield, and the yield components, as well, is to find genotypes with desirably small genotype-environmental interaction in these well-defined target regions. That goes for varieties in respect of wide production, as well as, potential parents in breeding programs.

According to above mentioned, the issue of defining genotype reaction to environmental variation is very complex. So is the problem of finding the most appropriate model for partitioning trial variation in stability and genotype-environmental interaction studies. If one decides to use parametric approach, the problem of additive (genotype main effect, and environmental main effect) and multiplicative (genotype-environmental interaction) nature of variation sources requires the combination of additive and multiplicative models in order to partition the total sum of squares in satisfactory way. That is a general idea in combined models commonly consisting of Analysis of variance (ANOVA) as an additive model and linear regression or principal components analysis (PCA) as multiplicative models (FINLAY and WILKINSON, 1963; EBERHART and RUSSEL, 1966; BRADY and GABRIEL, 1978).

The aim of the study is to follow divergent genotype behavior through genotype-environmental interaction, in different environments on the basis of the harvest index variation in common wheat.

MATERIAL AND METHOD

Twelve varieties of hexaploid wheat (*Triticum aestivum L.*) were in study, namely, Partizanka (g1), Jugoslavia (g2), Kragujevačka 56 (g3), Lasta (g4) orignated in Serbia, Skopjanka (g5) (F.Y.R.M.), Dobrudža (g6) (Bulgaria), Fundulea 29 (g7) (Romania), Bezostaja 1 (g8), Kavkaz (g9), Mironovskaja 808 (g10) (Russia), Etoile de Choisy (g11) (France), and Blueboy (g12) (U.S.A.). The trial was designed as a randomized block design in three replications, with 20cm row space, and 1.2m long rows, in two localities (Kragujevac and Novi Sad) for three vegetation periods (1994/95, 1995/96 and 1997/98).

Environmental conditions in these two localities appeared to be somewhat different since Novi Sad is in northern part of Serbia (N 45^{o} 15’ of latitude, and E19^{o} 49’ of longitude with about 80m of elevation), while Kragujevac lays in the central part of Serbia (N 44^{o} 02’ of latitude, and E20^{o} 56’ of longitude with 186m of elevation), about 160km SE from Novi Sad (fig. 1).

Growth conditions are somewhat different in two localities in study. Novi Sad is in the flat area of Vojvodina, south Backa (Northern Serbia), while Kragujevac is in the valey in the mountin area of Sumadija (Central Serbia). According to long-term results, climatic conditions differ in average rainfalls about 50mm and average year temperature about 1^{o}C, in favor of Kragujevac. Soil structure is distinct, as well. Novi Sad lays on chernozem on loess and loess-like sediments, calcereous, medium deep, while Kragujevac is on smonitza soil (vertisol) brownized.

Analysis of variance (ANOVA) was used for total sum of squares partitioning. For additional informations about nonadditive sorces of total variation observed, principal components analysis (PCA) was conducted. PCA was calculated from correlation matrix to eliminate the influence of different standard deviations (EUWIJK and van KROONENBERG 1998). The variances of all variables are equal to 1. Consequently, the total variance in correlation matrix is equal to the number of variables. Two methods were combined to isolate explainable and agriculturally important variation and to examine the nature of genotipe-environmental interaction occured.

RESULTS AND DISCUSSION

The harvest index (HI) was defined as ratio of economic yield to total aboveground biomas yield. DONALD (1962). This “trait” was chosen because it represents plant efficiency in translocating nutritive matter from vegetative to generative plant part an can serve as useful indicator of productivity. Harvest index has been recommended as selection criterion for increasing yield of cereals by (BOROJEVIC, 1983; SHARMA et. al., 1987; DALAL et al., 1995). One of the possibility in increasing of grain yield production can be to increase HI up to 0.50 or more at the level of biomass already produced by semidwarf wheat cultivars. Whean biological yield is more or less constant economic yield is proportional to HI and economic yield is in correlation with biomass yield, while biomass yield and HI are uncorrelated. Cultivars with improved harvest index expressed increasing of physiological efficiency of nutrient reutilisation, capacity to mobilize photosynthates and efficiency of them translocation from leaves and stem into grains (ĐOKIC, 1988; GENT and KIYOMOTO, 1989).

In this investigation the harvest index was analyzed as the ratio between grain weight per plant, and the plant weight. Depending on two distinctly quantitative traits, this index carries vast variability. The HI value ranged from $\overline{x}$ = 22.1% for variety Blueboy in NS94/95, to $\overline{x}$ = 55.7%, for the same variety in NS95/96 (Tab. 1).

Partitioning the total sum of squares by ANOVA brought forward that all the sorces of variation had statistically highly signifivant F values, except replications. Environmental differences contributed more to total trial sum of squares than genotypic diversity. At a glance, GE interaction made almost 40% of trial variation. Within the interaction, all three sources of variation contributed almost evenly to GE interaction sum of squares (Tab. 2).

Biplot showed that environmental conditions (Fig. 1) differed in main effect, rather than in interaction, except NS95/96. Locality KG appeared to be more predictable holding no interaction differences, and expressing differences partly in main effects. Locality NS varied in main effects, as well as, in interaction. Genotypes scattered in the positive part of PCA axis, showing differences in main effect, and interaction, as well. The sensitivity of HI under environmental variation noticed BEDAK et al. (1999), as well. Environmental conditions were particularly suitable for the examined genotypes (both season and the genotypes had the same PCA sign). This could be connected with weather conditions, causing certain stem shortening, which was favorable for nutritive matter translocation, particularly on a good chernozem soil. Varieties expressed different reaction in plant height reducing, consequently that had the impact on HI, as well. In that environmental conditions the best interaction reaction exhibited varieties Jugoslavia (g2), and Lasta (g4), and in some extent Fundulea 29 (g7), being less stable variety, and Skopjanka (g5) being closer to overall average. The most stable genotype appeared to be variety Dobrudža (g6), having a position on PCA axis nearly zero, but with HI value lower than grand mean.

Table 1. Mean values ($\overline{x}$) for harvest index (HI) for three vegetation periods (1994/95., 1995/96., and 1997/98) on two localities, Kragujevac (KG) and Novi Sad (NS). Gmean stands for genotypic mean values, while Emean stands for environmental mean values, PCA1 stands for corresponding first component.

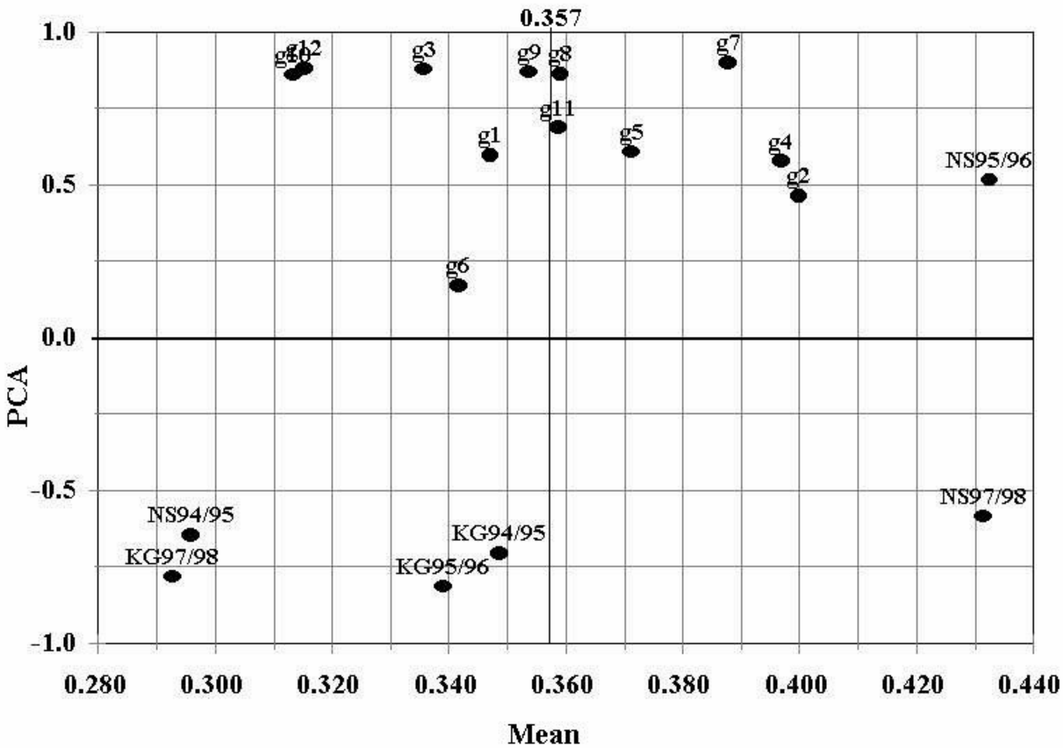
Varieties	**Localities and vegetation periods**						**Gmean**	**PCA 1**
	KG94/95	KG95/96	KG97/98	NS94/95	NS95/96	NS97/98		
Partizanka	0.369	0.305	0.314	0.359	0.345	0.391	**0.347**	**0.594**
Jugoslavija	0.398	0.353	0.285	0.378	0.533	0.452	**0.400**	**0.462**
Kragujevačka 56	0.357	0.355	0.284	0.288	0.297	0.433	**0.336**	**0.877**
Lasta	0.335	0.479	0.325	0.360	0.409	0.473	**0.397**	**0.575**
Skopljanka	0.401	0.351	0.383	0.329	0.300	0.463	**0.371**	**0.607**
Dobrudža	0.271	0.309	0.220	0.323	0.451	0.476	**0.342**	**0.170**
Fundulea 29	0.413	0.421	0.299	0.270	0.481	0.443	**0.388**	**0.899**
Bezostaja 1	0.353	0.271	0.261	0.297	0.548	0.426	**0.359**	**0.862**
Kavkaz	0.385	0.348	0.291	0.243	0.456	0.401	**0.354**	**0.867**
Mironovskaja 808	0.317	0.307	0.307	0.213	0.331	0.405	**0.313**	**0.859**
Etoile de Choisy	0.326	0.338	0.316	0.270	0.482	0.421	**0.359**	**0.685**
Blueboy	0.261	0.231	0.228	0.221	0.557	0.395	**0.315**	**0.879**
Emean	**0.349**	**0.339**	**0.293**	**0.296**	**0.433**	**0.432**	*0.357*	
PCA 1	**-0.707**	**-0.814**	**-0.783**	**-0.647**	**0.515**	**-0.585**		

$LSD_{0.05}$= 0.04
$LSD_{0.01}$= 0.05

Table 2. ANOVA for harvest index (cm) for three vegetation periods (1994/95., 1995/96., and 1997/98) on two localities, Kragujevac (KG) and Novi Sad (NS).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
Trial	83	1.4190	0.1660	337.11	0.0000
Replication [R(YL)]	12	0.0070	0.0010	1.18	0.3011
Environment (E)	5	0.7020	0.1400	284.50	0.0000
Year (Y)	2	0.1480	0.0740	150.32	0.0000
Location (L)	1	0.1930	0.1930	390.67	0.0000
Y x L	2	0.3610	0.1810	365.61	0.0000
Genotype (G)	11	0.1620	0.0150	29.89	0.0000
Interaction GE	55	0.5480	0.0100	20.17	0.0000
Y x G	22	0.1780	0.0080	16.38	0.0000
L x G	11	0.1750	0.0160	32.25	0.0000
Y x L x G	22	0.1950	0.0090	17.91	0.0000
Error	132	0.0650	0.0005		
Total	215	1.4850			

Figure1. Biplot for harvest index for three vegetation periods (1994/95., 1995/96., and 1997/98) on two localities, Kragujevac (KG) and Novi Sad (NS). Genotype codes are listed in Material and Methods values, PCA1 stands for corresponding first component. Grand mean is given at the top of the figure.



CONCLUSION

In a conclusion could be stated that two localities in study were greater source of variation for, harvest index, than years. This is understandable since weather conditions are only one part of a whole locality variation. Varieties in study were fairly stable, particularly at the Kragujevac site opening a chance of better prediction at that locality. Locality Novi Sad provoked different genotype reaction to environmental changes, but in favorable year conditions, varieties performed better at this site for studied traits. Generally speaking, genotypes reaction for harvest index differed in main effect, as well as, in interaction making phenotypic expression for this trait more unpredictable.

References

[1] ANNICCHIARICO, P. (1997): *Additive main effects and multiplicative interaction (AMMI) analysis of genotype-location interaction in variety trials reported over years*. Theor. Appl. Genet., 94: 1072-1077.

[2] BEDAK, N., YILDRIM, Z., YILDRIM, M.B. (1999): *Agronomic performance of tall and semidwarf genotypes of durum wheat*. Turkish Journal for Field Crops, 4 (1): 16-20.

[3] BOROJEVIC, S. (1983): *Genetic changes to increase yield potential in wheat*. Proc. 6th Int. Wheat Genetics Simposium, Kyoto, japan, pp.953-957.

[4] BRADY, D. and GABRIEL, K.R. (1978): *The biplot as a diagnostic tool for models of two-way tables*. Technometrics, 20: 47-68.

[5] DALAL, S. K., YUNUS, M., SINGH, S. (1995): *Comparison of some selection criteria in two spring wheat crosses*. Indian J. Genetics & Plant Breeding, 55, 90-93.

[6] DONALD, C.M. (1962): *In search of yield*. Austr. J. Agric. Res., 28, 171-178.

[7] DJOKIC, D. (1988): *Indicators of accumulation and use of nitrogen in wheat as agronomic and breeding criterion of productivity*. Agrohemija, 1, 7-23.

[8] EBERHART, S.A. and RUSSEL, W.A. (1966): *Stability Parameters for Comparing Varieties*. Crop Sci., 6: 36-40.

[9] EUWIJK, F.A. and VAN KROONENBERG, P.M. (1998): *Multiplicative models for interaction in three-way ANOVA, with applications to plant breeding*. Biometrics, 54(4): 1315-1333.

[10] FEDERER, W.T. and SCULLY, B.T. (1993): *A parsimnious statistical design and breeding procedure for evaluating and selecting desirable characteristics over environments*. Theor. Appl. Genet., 86: 612-620.

[11] FINLAY, K.W. and WILKINSON, G.N. (1963): *The analysis of adaptation in a plant breeding programme*. Aust. J. Agric. Res., 14: 742-754.

[12] GAUCH, H.G. and ZOBEL, R.W. (1997): *Identifying Mega-Environments and Targeting Genotypes*. Crop Sci., 37: 311-326.

[13] GENT, M.P.N., KIYAMOTO, R.K. (1989): *Assimilation and distribution of photosynthate in winter wheat cultivars differing in harvest index*. Crop Sci., 29, 120-125.

[14] LIN, C.S. and BINNS, M.R. (1991): *Assasment of a method for cultivar selection based on regional trial data*. Theor. Appl. Genet., 82: 505-509.

[15] LIN, C.S. and BINNS, M.R. (1994): *Concepts and methods of analyzing regional trial data for cultivar and location selection*. Plant Breeding Reviews, 12: 271-297.

[16] SHARMA, S.K., SHING, V.P., SHING, R.K. (1987): *Harvest index as a criterion for selection in wheat*. Indian J. Genetics & Plant Breeding, 47, 119-123.