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PERFORMANCE AND STABILITY OF GRAIN YIELD AND YIELD COMPONENTS IN SOME WINTER WHEAT VARIETIES

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ABSTRACT

The premise to obtain high grain yield starts with the right choice of cultivars, especially when it comes to winter wheat. Using winter wheat genotypes inappropriate to local conditions can cause significant reduction of average grain yield, as a result of poor yield stability. The objective of this study was to test the performance of 25 winter wheat varieties and assess their yield stability in Central Transylvania, one specific wheat growing area of Romania. Yield and yield stability, and also the stability of some components of yield in six environmental conditions (three years x two fertilization levels) were analysed. Shares of genotype, environment and genotype x environment interaction in phenotypic expression of analysed characters indicated that yield and the main components are strongly influenced by environmental conditions. In comparison with older genotypes, the new lines (T. 67-02 and T. 96-97) and the Andrada variety had higher yield in contrasting environmental conditions.

Key words: stability, winter wheat, yield, yield components.

INTRODUCTION

Grain yield is a highly variable quantitative character, which depends on some yield components, their formation being greatly influenced by environmental conditions (Kraljevic-Balalic et al., 2001).

The climate conditions are the major factors that influence directly or indirectly wheat yields. Thus, the agricultural systems have become vulnerable to climatic variations, especially to extreme changes in certain climate regions (Hoogenboom, 2000; Ogallo et al., 2000).

Yield stability represents the result of genotype adaptability to environmental variation. Adaptability is a natural trait and is a self-defence reaction of genotype in order to survive and reproduce. Stability reflects small or large genotypic reaction to environmental changes, depending on specific adaptability, and in a broad sense, could not be considered as evolutionary favourable in natural conditions. Additional nutrition support can provide a better reaction to the climatic changes so the negative impact of environment can be lower. Mustăţea & Săulescu (2011) stated that the grain yield increase in recently created winter wheat varieties was entirely due to an increase in the number of kernels per unit area, while the grain weight showed a negative, but relatively smaller trend.

Generally, wheat plants have a good capacity of adaptability to the changes of climatic conditions, but this capacity is often questioned when the stress conditions coincide with the periods of formation or filling grains. Thus the reaction of wheat genotypes to the unfavourable conditions differs according to the plant stage development. A measure to counter the negative effects caused by climatic changes is the creation of new genotypes with better resistance or tolerance to adverse changes or which avoid stresses by the fact that the critical phases of development do not coincide with these conditions.

Kamaluddin et al. (2007) stated that grain yield depends on the number of grains/unit area and weight of grains, being also the results of rate and filling grain period (Gebeyehou et al., 1982; Van Sanford and Mackown, 1985; Bruckner and Frohberg, 1987). Mustăţea et al. (2009) showed that high yielding cultivars can differ in yield stability

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and suggested that high yield stability and high grain yield are not mutually exclusive.

Productivity depends on hereditary factors which endowed variety, but in phenotypic expression the climatic conditions have a major role (Knežević et al., 2008).

MATERIAL AND METHODS

The experiment was conducted in the yield trial field of Wheat Breeding Department of Agricultural Research Station Turda, Romania. Twenty five cultivars of winter wheat (Table 1) were grown in randomised complete block design in three replications and two levels of fertilization: the basic level of fertilization NPK (50:50:0) applied after emergence of plants and additional level of fertilization applied in the stage of elongation straw with 50 kg/ha N active substance. Each harvest plot had 5 m length and 1 m width. The data were obtained during a period of three years (2010-2013). The experimental period included years with very different weather conditions, so we can characterized as follows:

- first experimental year (2010-2011) had normal conditions for wheat crop, except in March, April and May with drought stress, which caused a significant reduction of spikes density per unit area, a lower number of grains per spike and finally lower grain yield;
- second experimental year (2011-2012) had severe drought in the autumn months, which led to plant emergence only in spring (March), including damage caused by pests during the winter and also accelerating the early stages of vegetation;
- third year (2012-2013) – manifested normal weather conditions.

Table 1. The origin of winter wheat cultivars used in the yield trials at ARDS Turda

Country	Place of origin	Cultivars
Romania	Turda	Apullum ; Arieşan; Dumbrava; T. 96-97; T. 67-02; Andrada
	Fundulea	Boema; Delabrad; Dropia; Faur; Gruia
	Lovrin	Lovrin 34
	Albota	Trivale
Hungary	Szeged	GK Othalom; GK Kalasz
	Martonvásár	MV Martina; MV Palotas; MV Mandolin; MV Mariska; Maty; MV 06-02
	Kiskun	Serina
Austria		Josef
France	Limagrain	Renan
Russia	Krasnodar	Bezostaia

Statistical analysis

Yields and the main yields components as: number of spikes/m^2, number of grains/spike, and thousand kernels weight were analysed by ANOVA.

Characterization of genotypes stability for the above mentioned characters was achieved using the following statistics parameters:

- coefficient of variation (cv%):

$$cv\ \% = \frac{s \times 100}{\bar{x}}$$

- regression coefficient (b):

$$b\ y/x = \frac{\sum xy - \frac{\sum x \sum y}{N}}{\left(\sum x^2 - \frac{(\sum x)^2}{N}\right)}$$

- coefficient of determination (r^2):

$$r^2 = \frac{\sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$

Calculation of the share of genotype, environment and genotype x environment interaction in phenotypic expression of the analysed characters was performed by the model described by Timariu, in 1975. For each character, we calculated the sum of squared deviations and standard deviation of genotype, environment, genotype x environment interaction and total standard deviation. Based on these values we calculated components of variance and variance share of genotype, environment, genotype x environment interaction and phenotypic variance in absolute and relative terms. *F test* showed in what way the variance of genotype and environment, reported on variance of interaction and error are significant or not.

$S^2_G = (AMP_G - AMP_{GM})/m$;

$S^2_M = (AMP_M - AMP_{GM})/g$;

$S^2_T = S^2_F = S^2_G + S^2_M + S^2_{GM}$;

where: S^2_G – genotypic variance, AMP_G – genotypic deviation mean square, AMP_{GM} – genotype x environments mean square, m – environments, S^2_M – environmental variance, g – genotypes, S^2_T – total variance, S^2_F – phenotypic variance, S^2_{GM} – variance of genotype x environment interaction .

The model proposed by Lein (cited by Ceapoiu, 1968) allowed estimating the coefficient of heritability in the broad sense, as:

$$H = \frac{m\,(g-1)}{g \times m - 1} \; x \; \frac{s_G^2}{s_T^2}$$

Evaluation of each variety's stability for yield and yield components was made according to the model proposed by Finlay and Wilkinson (1963) based on the regression coefficient (b), between genotype performance across environmental conditions and the environmental index which represents the average of all genotypes in each environmental condition. A smaller regression coefficient is considered to indicate a better stability of the genotype for the analysed trait.

RESULTS AND DISCUSSION

The yield of wheat is a quantitative character with polygenic inheritance, greatly influenced by environment, which often causes variations exceeding those caused by genetics. The fact that some varieties produced in a wide range of ecological conditions yields significantly higher than the others, demonstrates the existence of genotypic difference between them.

According to F test for grain yield and for the main yield components studied, a higher influence of environment, except for thousand kernels weight, was observed, meaning that climatic conditions have a crucial role (Table 2). Regarding thousand kernel weight, the influences of genotype and environmental factors are close, which means that TKW is relatively stable, but in variable conditions this character also presents vulnerability and external factors can become important (Figure 1). The highest value for coefficient of heritability in the broad sense was obtained for the character thousand kernels weight (40.82).

Table 2. ANOVA for grain yield and the some yield components for 25 winter wheat genotypes

Statistical parameters and other estimators	Grain yield	Number of grains/spike	Number of spikes /m^2	Thousand kernel weight
F test				
Environment E	14088.13***	1578.23***	10226.75***	298.17***
Genotype G	156.78***	142.52***	3609.82***	292.20***
Interaction E x G	32.93***	33.37***	215.91***	40.83***
Variance (relative values)				
Environment E	93.45	66.65	85.70	16.78
Genotype G	2.53	11.77	2.31	30.08
Interaction E x G	4.02	21.58	11.99	53.14
Phenotipic	100.00	100.00	100.00	100.00
Heritability coefficient	2.40	11.36	0.14	40.82

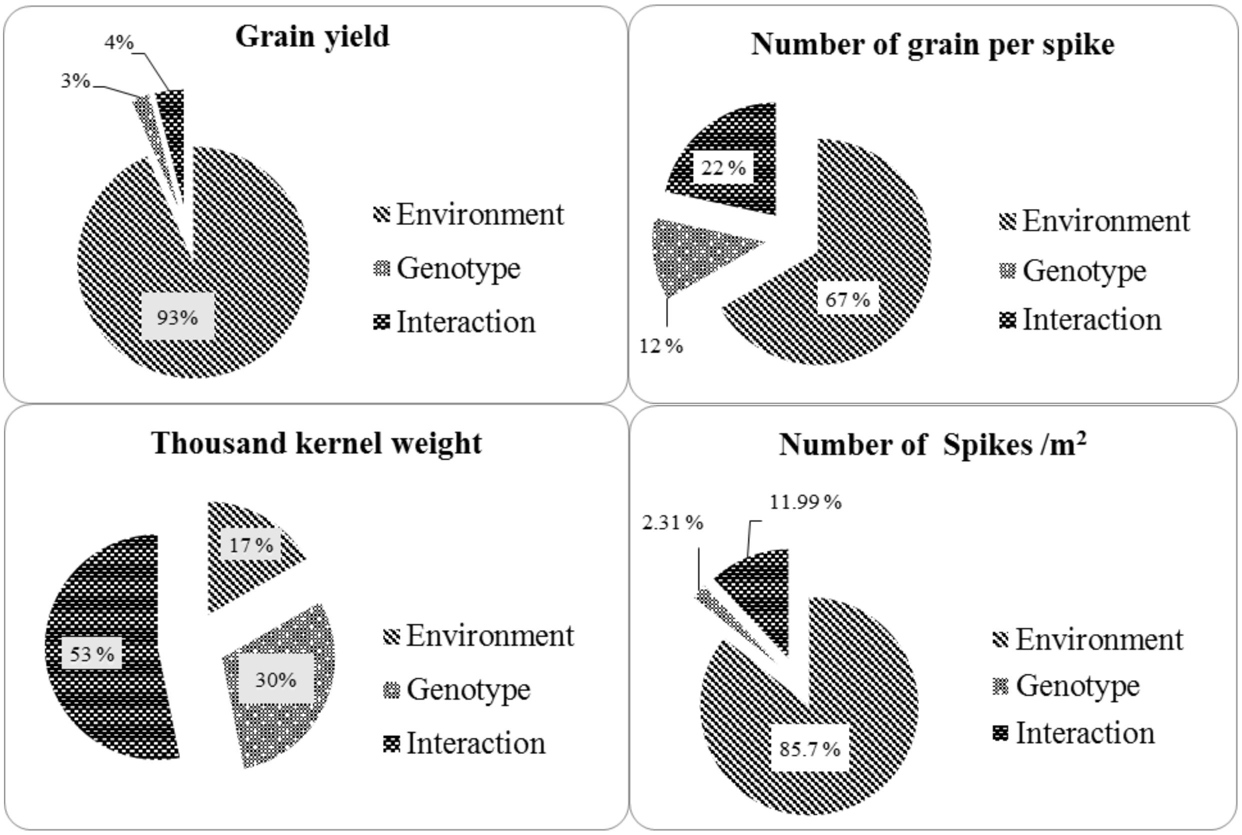

Figure 1. Share of factors (%) in achieving yield and some yield components in winter wheat (Turda, 2010-2013)

Among the tested genotypes, the Romanian Dumbrava, Andrada, Faur, Trivale and lines T. 96-97 and T. 67-02, as well as the foreign cultivars: Renan, MV. Martina and MV Mariska had higher yield than the average of all cultivars Table 3).

Eberhart and Russell (1966) suggested that the stability can be estimated based on regression coefficient (b) associated with deviation from regression (s^2d). A stable genotype is considered one that has b=>1 and s^2d close to 0, that means a medium reaction of genotype to environmental changes, but predictible in its reaction to environment or technological inputs. Moldovan et al. (2003) suggested that s^2d can be replaced by r^2. In this case the value of r^2 must approach 1 (r^2=1).

The coefficient of variation (CV), also known as “relative variability”, equals the standard deviation divided by the mean. In terms of yield, the lowest values of the coefficient of variation were obtained in varieties Serina and Maty, indicating an average variation. The lowest values of coefficient of variation were obtained for the character thousand kernels weight (Table 3).

A grouping of the 25 varieties according to yield and regression coefficient was obtained by distributing the analysed varieties in the four squares resulting from drawing lines that marks the mean values of the two variables on the graph. Obviously, varieties are preferred that possess values above average for yield and simultaneously record a low coefficient of regression. Varieties placed in third quad, matching this condition, are characterized by a higher potential production associated with good stability. Varieties found in quad IV, which possess high average yield but have a stronger reaction to changes of environmental conditions should also be considered.

For grain yield stability (Figure 2), expressed by regression coefficient (b) according to Finlay and Wilkinson method, the genotypes MV Palotas and Dropia are located in the first quarter (I), meaning that these cultivars have below average yield, even in favourable environmental conditions.

Table 3. Average values and stability parameters (s%, b, r^2) for yield and yield components of 25 winter wheat cultivars at ARDS Turda yield trials, in average of 6 environmental conditions (3 years x 2 levels of fertilization), in the period 2011-2013

Cultivar	Grain yield				Number of grains per spike				Number of spikes /m^2				Thousand kernel weight			
	to/ha	CV (%)	b	r^2	No.	CV (%)	b	r^2	pl.	CV (%)	b	r^2	g.	CV (%)	b	r^2
Apullum	5.18	32.7	1.01	0.97	31.75	23.1	1.35	0.77	491.3	30.9	1.14	0.94	42.8	5.30	1.48	0.94
Arieşan	5.27	31.5	0.97	0.95	27.50	13.9	0.46	0.33	500.8	29.0	1.11	0.97	49.2	2.53	0.72	0.74
Boema	5.15	33.8	1.04	1.00	31.28	16.2	0.95	0.79	482.3	30.1	1.09	0.93	43.0	4.54	1.10	0.69
Delabrad	4.98	31.9	0.95	0.99	31.20	16.8	1.09	0.98	507.3	29.7	1.14	0.95	43.2	4.22	1.20	0.96
Dropia	4.86	39.0	1.15	0.99	30.27	18.1	1.05	0.84	467.4	25.5	0.90	0.95	45.4	9.97	2.98	0.95
Dumbrava	5.72	33.8	1.16	0.97	32.66	18.7	1.23	0.93	473.3	19.4	1.39	0.99	47.1	6.30	1.92	0.92
Faur	5.39	34.5	1.10	0.97	30.38	19.5	1.21	0.95	513.8	26.7	1.03	0.94	44.6	1.80	0.36	0.95
Gruia	5.23	27.8	0.87	0.99	31.13	18.1	1.17	0.98	483.7	22.2	0.80	0.92	42.7	2.72	0.11	0.02
Lovrin 34	5.25	29.0	0.89	0.96	31.78	23.7	1.49	0.90	505.8	30.8	1.20	0.94	43.1	3.53	0.20	0.32
Trivale	5.35	30.3	0.97	0.99	30.74	16.4	0.90	0.73	525.6	26.0	1.04	0.96	43.6	3.87	0.93	0.70
GK Othalom	5.06	29.7	0.90	0.99	29.50	10.0	0.49	0.61	523.7	33.1	1.31	0.95	44.8	3.26	0.59	0.37
GK Kalasz	4.75	29.7	0.78	0.84	28.74	12.8	0.94	0.52	508.9	26.8	1.31	0.94	44.4	4.14	0.83	0.46
Serina	5.14	25.2	0.77	0.97	29.96	14.0	0.87	0.99	513.7	27.5	1.09	0.98	43.8	2.20	0.13	0.07
Renan	5.43	28.8	0.95	0.96	28.64	18.8	1.03	0.84	514.9	30.6	1.22	0.99	47.4	5.01	1.49	0.90
Josef	5.00	33.1	1.00	1.00	31.48	15.2	0.95	0.90	492.2	29.3	1.11	0.99	43.0	2.05	0.55	0.90
MV Martina	5.49	35.8	1.14	0.99	34.59	19.3	1.35	0.94	444.0	20.6	0.69	0.91	43.7	2.63	0.12	0.02
MV Palotas	4.84	39.4	1.15	1.00	29.84	18.1	1.05	0.87	470.9	25.3	0.87	0.87	43.9	3.54	0.57	0.31
MV Mandolin	5.28	36.4	1.14	0.99	29.73	16.2	0.95	0.89	497.0	23.2	0.87	0.93	46.8	2.78	0.46	0.29
MV Mariska	5.54	31.1	1.02	0.98	28.34	19.4	1.08	0.88	509.9	21.3	0.81	0.92	45.5	7.72	2.16	0.87
Maty	5.03	27.3	0.82	0.98	34.32	14.7	1.01	0.91	501.0	27.2	1.04	0.96	36.8	4.27	0.46	0.61
MV 06-02	5.28	34.7	1.09	0.98	29.53	19.2	1.09	0.85	480.4	31.5	1.17	0.99	45.1	1.38	0.75	0.76
T 96-97	5.67	30.6	1.03	0.96	29.87	13.0	0.75	0.85	489.4	24.3	0.92	0.99	47.7	3.89	0.89	0.53
T 67-02	5.81	32.5	1.12	0.99	32.02	19.5	1.30	1.00	492.1	18.7	0.69	0.93	43.9	4.85	1.34	0.91
Andrada	5.56	33.8	1.11	1.00	30.88	21.4	1.29	0.87	487.3	18.1	0.67	0.94	46.6	8.63	2.52	0.90
Bezostaia	4.65	30.8	0.82	0.93	27.00	8.5	0.35	0.51	513.2	33.7	1.34	0.99	45.4	5.05	1.36	0.81
Average	5.24	32.1	1.00	-	30.53	17.0	1.00	-	495.6	26.5	1.04	-	44.5	4.25	1.00	-

These genotypes have b-values higher than average, but not ensure high yields. The genotypes located in the second quarter (II), have a higher yield stability (b<1), but the level of their yields are unsatisfactory even in the favourable conditions.

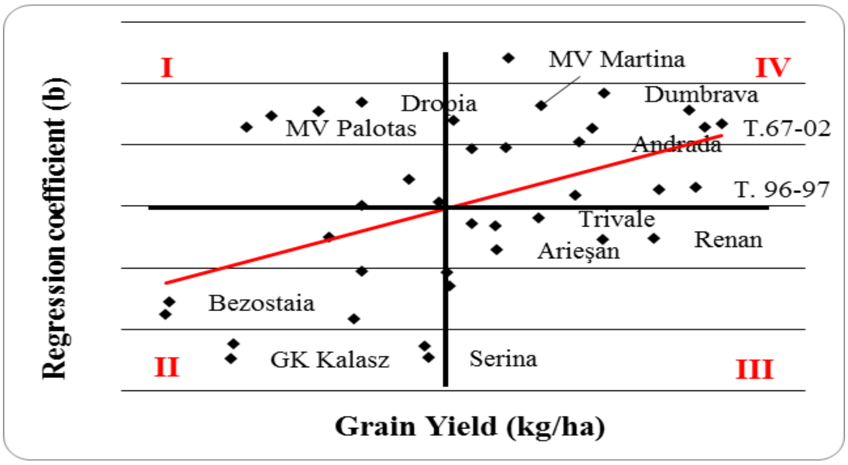

Figure 2. Grain yield and yield stability expressed by the coefficient of regression (Finlay-Wilkinson model)

The cultivars such as: Trivale, Arieşan and Renan were included in the third quarter (III) and they combine a higher level of yield with good stability. These cultivars are capable to produce high yields less dependent on environmental conditions. The varieties from quarter IV proved to be the most productive and recorded coefficients of regression higher than 1 and also yields above the average of the trials.

Regarding the number of grains per spike (Figure 3), genotypes such as Dumbrava, Maty and MV Martina, which produced a large number of grains per spike in favorable conditions, stand out. Especially the cultivar Maty should be noticed, whose regression coefficient is very close to 1. Positioning of most varieties in first and second quarters suggests that they form a relatively small number of grains per ear.

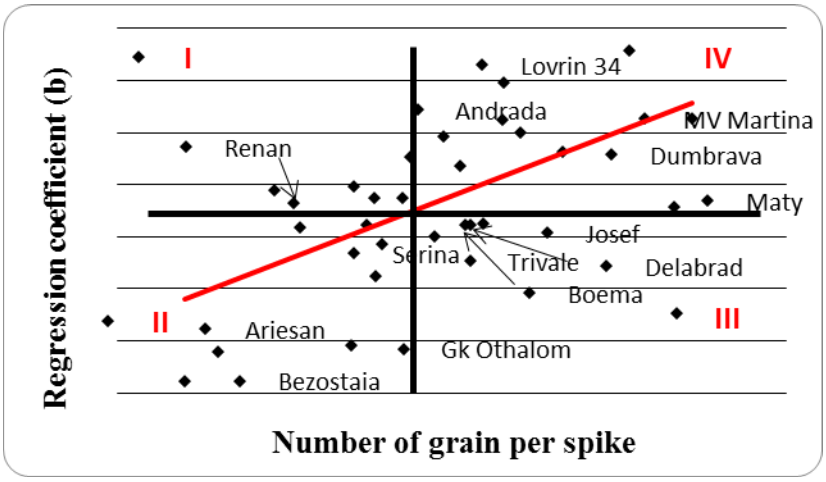

Figure 3. Number of grains per spike and its stability, as described using coefficient of regression (Finlay-Wilkinson model)

Number of spikes per unit area is an important quantitative character which depends directly by different technological and environment factors. Even if the number of spikes/m2 is strongly related with grain yield, the positioning of genotypes (Figure 4) in different frames compared with the yield (Figure 2) and number of grains per spike (Figure 3) suggest that it is a results of different environment conditions during the three years.

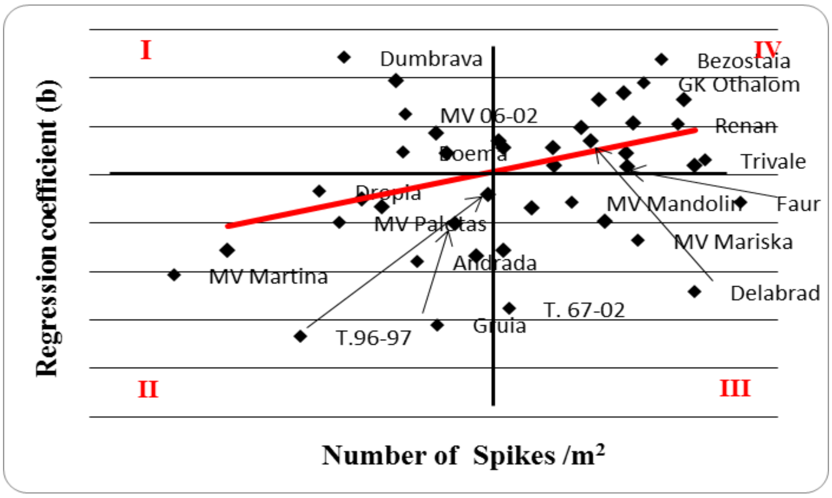

Figure 4. Number of Spikes /m^2 and its stability expression (using Finlay -Wilkinson model)

For thousand kernels weight (Figure 5) the dispersion of points in the four frames is quite balanced. The presence of some low values of regression coefficient suggests a high vulnerability of those genotypes in variable or contrasting conditions. However, the location in the third frame of cultivars like Ariesan, T. 96-97 or MV Mandolin, which are known to have high mass of 1000 grains, confirms the higher genetic determinism of this character. In contrast, genotypes such as Dumbrava, MV Mariska, Andrada, Renan or Bezostaia, situated in the fourth frame, seem to be quite unstable for thousand kernels weight.

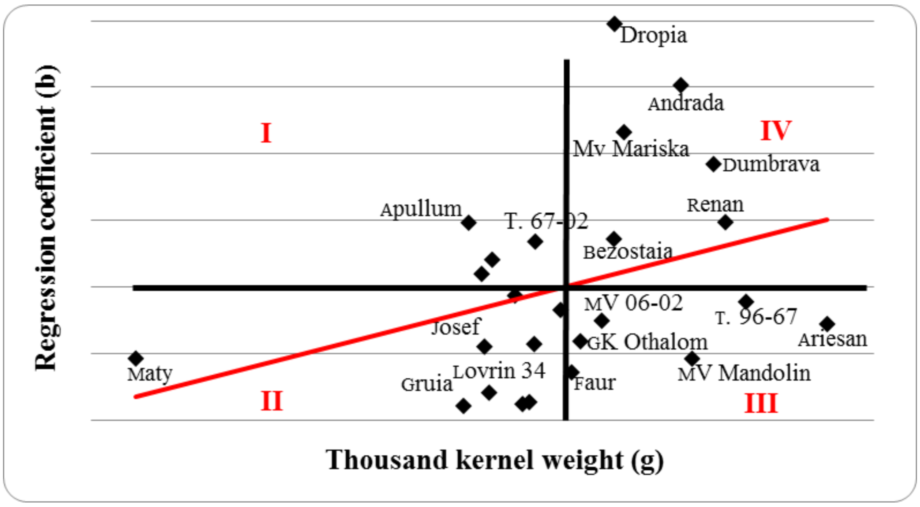

Figure 5. Thousand kernel weight and its stability estimated using Finlay-Wilkinson model

CONCLUSIONS

Based on data from this paper, regarding the yield performance of winter wheat varieties obvious differences between genotypes can be observed.

Wide ranges in cultivar means for yield and yield components were detected. The variability of the studied traits is due to genotype x environment interaction, reflected by broad sense coefficient of heritability that was very low for yield (2.40) and much higher for TKW (40.82).

The values of stability parameters for the analysed characters in this study also indicated large cultivar differences. According to coefficient of variability (CV), the grain yield seems to be very variable trait, follow by the number of spikes per square meter and the number of grains per spike. The lower values for CV were recorded for TKW that is a heritable trait less influenced by environment.

The Finlay and Wilkinson model, based on regression analysis proved to be an useful tool in identifying cultivars with high and stable yield. Additional information was given by the coefficient of determination, which indicated the cultivars stability in reaction to environment changes.

Genotypes that combine high yield with lower coefficient of regression are to be preferred. Also, of interest are the cultivars with high yields and near unity coefficient of regression, having predictable response to environment, indicated by coefficients of determination approaching 1.

Our results demonstrated that stability parameters are applicable for description of quantitative traits other than yield, such as number of grain per spike, thousand kernel weight and number of spikes on square meter. However, the classification of genotypes according to performance stability differs from a trait to another.

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