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GENOTYPIC PLASTICITY AND STABILITY OF YIELD COMPONENTS IN TRITICALE (x *Triticosecale* Wittm.)

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Abstract

In order to establish genotypic plasticity and stability of the yield components in triticale, data from three years field trial have been used. The main structural yield components (number of spikes per m^2; plant height, cm; spike length, cm, number of grain per spike; mass of grain per spike, g) of five triticale varieties are determined. The modified model of Eberhart and Russel was applied. The coefficients of the linear regressions b_k characterize the average variety reaction to changes in the climatic conditions, show his plasticity and give opportunity to prognosticate the researched parameter in the range of the investigated conditions. The main parameter, which estimates the variety stability, is the dispersion S_k. The more the dispersion of the stability S_k to zero tends, the less the empirical values of the signs distinguish from the theoretical values, located on the regression line. The plasticity of the indicator Nr. of spikes/m^2 is with the highest values by the varieties AD-7291, Sadovec and Rakita. According to the varieties Rojen and Zaryad this indicator is with lower values. By the both linear parameters – Plant height and Spike length the triticale varieties react on the same way. The triticale varieties react to the environmental conditions and to the components Nr. of grain/spike and Mass of grain/spike almost equally. The stability values are contrariwise proportional to the varieties plasticity regarding the components Nr. of spikes/m^2 Plant height and Spike length. According to the both signs, related to the grain (Nr. of grain/spike and Mass of grain/spike) no similar tendencies are have been observed. The yield plasticity coefficient correlates positive with all yield components. By the yield stability coefficient there is a positive correlation by the Nr. of spikes/m^2 and the Mass of grain/spike, and negative by the component Plant height.

Key words: *triticale, plasticity, stability, yield components.*

INTRODUCTION

Genetically triticale (x *Triticosecale* Wittm.) is an amphiploid produced by crossing the genomes of two different species - wheat and rye. The first hybrids are fertile progenies arose from an intergeneric (interspecies) hybridization and followed by chromosome doubling between a female parent from the genus *Triticum* and the male parent from the genus *Secale*.

The majority of the today's varieties are descendants of a primary hybrids, which involve either common (*Triticum aestivum* L., 2n=42=AABBDD) or durum (*Triticum durum*, 2n=28=AABB) wheat as a female parent and cultivated diploid rye (*Secale cereale* L., 2n=14=RR) as a male parent (Oettler et al., 2001; Mergoum and Gómez-Macpherson, 2004; Siriamornpun et al., 2004; Varughese et al., 1996; Losert et al., 2017).

One from the most basic positive feature of triticale is its high productive potential. This is due to the composition of the yield components inherited from the wheat and rye (Estrada-Campuzano et al., 2012; Gerdzhikova, 2014; Ivanova and Kirchev, 2014; Ivanova and Tsenov, 2014; Royo and Blanco, 1999; Ramazani et al., 2016; Stoyanov and Baychev, 2015).

Namely the big genetic diversity of the created triticale varieties is a requirement for their different reaction to the environmental conditions. This demand to pay attention on their genotypic plasticity and stability.

MATERIALS AND METHODS

For determining the plasticity and stability of the main structural yield components in triticale, data from a two parallel field trials have been used.

The one was carried out in the northern Bulgaria in the region of Dobrogea (43°39'33.0"N 28°02'05.5"E), and the other – in the southern Bulgaria, the region of Thracian valley (42°08'26.2"N 24°48'21.1"E). Five varieties have been examined – AD-7291 (standart), Rojen, Sadovec, Rakita and Zaryad.

The genotypic plasticity and stability of the tested varieties are determined by the main structural components, which have bearing on the yield like - number of spikes per m^2; plant height, cm; spike length, cm, number of grain per spike; mass of grain per spike, g.
Plasticity (b_k) and stability (S_k) coefficients are calculated on the basis of the Eberhart and Russel model, 1966.
The model of Eberhart and Russel (1) looks like this:

$$(1) \quad Yijk = Y .. + Gi + Pj + rij + eijk ,$$

where G ist the effect of the genotype, and P – of the investigated region.
There was used two-way ANOVA to define statistically significant differences between the examined varieties. To calculate the dependents between the yield and the investigated signs, correlation analysis have been used.

RESULTS AND DISCUSSIONS

The regression coefficient and the deviations from the regression line were being estimated and so the diffraction can be determined by use of dispersion analysis (Table 1).
The model of Eberhart and Russel can be applied under condition that the interaction „genotype G x region P'' is statistically significant, because it is supposed, that the changes in the feature are based on genetic and plants will change estimated parameter by different environment. To give a mathematical expression of the terms „ecological plasticity'' and „stability'' Eberhart and Russel give them the following definition: under ecological plasticity is to understand the average variety reaction to environmental changes, and under stability – the deviation of the empirical data from this average reaction at any condition of the environment.
The coefficients b_k of the linear regressions characterize the average variety reaction to changes in the climatic conditions, show his plasticity and give opportunity to prognosticate the researched parameter in the range of the investigated conditions (Table 2).
Geometrical the regressions coefficients b_k can be interpreted as an angular coefficients of the regression straight lines. It is clarified, that by b_k increase the variety will be more responsive to the growing conditions. In most cases b_k coefficients are positive, but they can also acquire a negative values, as for example yield decrease as result from lodge or disease attack. If the coefficient $b_k > 0$, it means that the variety does not react to the environmental changes.
The plasticity b_k of the indicator Nr. of spikes/m^2, who determine in major ratio the sowing density, is higher than one in the varieties AD-7291, Sadovec and Rakita, as proved the standard AD-7291 is the most plastic. The values of this indicator are lower in the varieties Rojen and Zaryad and the both belong to the same statistical group. According to the both linear parameters– Plant height and Spike length the examined triticale varieties react to the same way. For the most plastic in relation to these signs changes are remarkable the varieties Rojen and Rakita and the varieties Sadovec and AD-7291 are influenced in lower ratio by the environmental changes according the changes in the linear parameters Plant height and Spike length. However, the variety Zaryad reacts different – is more plastic to changes in the Plant height, whereas to the Spike length lower changes are indicated depending on the conditions of the relevant region. Similar to the both previous indicators, the triticale varieties react to the environmental conditions almost on the same way concerning the components Nr. of grain/spike and Mass of grain/spike. The most plastic, regarding the both yield components, are the varieties Rakita and Zaryad, followed by the standard AD-7291, while by Rojen and Sadovec the plasticity of the Nr. of grain/spike and Mass of grain/spike is lowest.
The main parameter, which estimates the variety stability, is the dispersion S_k. The more the dispersion of the stability S_k to zero tends, the less the empirical values of the signs distinguish from the theoretical values, located on the regression line. According to the applied models of Eberhart and Russel, as a goal for „ecological plastic and stable variety'' can be accepted any sort who possess the both values: $b_k > 1$ and $S_k > 0$.
Rates of dispersion S_k which define the variety stability, are in the present research positive in every varieties and at any yield components, what according to Eberhart and Russel them as stable determine, concerning the received yield components (Table 3).

Table 1. The two-way ANOVA mean squares (MS) analysis of variance of triticale genotypes x region

Source of Variation	df	Nr. spikes/m^2	Plant height	Spike length	Nr. grain/spike	Mass grain/spike
Genotype (G)	1	2133.6	2539.2*	10.09**	662.7**	0.163
Region (P)	4	9653.9**	122.1	1.12	91.4	0.564**
Interaction (GxP)	4	2423.2*	467.8**	2.08*	131.9*	0.286*
Within	20	3387.7	125.5	0.58	17.7	0.041

,: Significant at 0.05 and 0.01 probability levels, respectively.*

Table 2. Ecological plasticity of yield components in triticale varieties

Yield components Varieties	Nr. spikes/m^2	Plant height	Spike length	Nr. grain/spike	Mass grain/spike
AD-7291	1.481c	0.811a	0.800b	0.941b	1.576b
Rojen	0.652a	1.091a	1.159b	0.424a	0.151a
Sadovec	1.037b	0.658a	0.663a	0.364a	0.652a
Rakita	1.277b	1.283b	1.884c	1.673c	2.498c
Zaryad	0.552a	1.158b	0.493a	1.598c	1.735b

Values with the same letters do not differ significantly

Table 3. Ecological stability of yield components in triticale varieties

Yield components Varieties	Nr. spikes/m^2	Plant height	Spike length	Nr. grain/spike	Mass grain/spike
AD-7291	0.181a	1.311b	0.025a	0.221a	0.816b
Rojen	1.319b	0.170a	1.995c	0.239a	0.351a
Sadovec	0.653a	1.354b	0.661b	1.300c	0.509a
Rakita	1.802c	0.979b	0.025a	1.468c	1.151b
Zaryad	0.764b	1.970c	0.746b	1.005b	0.385a

Values with the same letters do not differ significantly

It is logical some of the stability values S_k of the examined yield components to be counter proportional to the varieties plasticity b_k. Similar tendencies were determined in the present study. By the component Nr. of spikes/m^2 with the lowest stability is the variety with the highest plasticity namely the standard AD-7291. The variety Sadovec, who exhibits high plasticity is also with low stability, while the varieties Rojen and Zaryad manifest low plasticity to Nr. of spikes/m^2 and have also high stability regarding this sign. By Plant height are observed converse stability and plasticity values by some of the varieties. The varieties AD-7291 and Sadovec are with the lowest plasticity, but also with high stability regarding the Plant height, while by Rojen and Rakita, where the plasticity is high, the stability to the same sign – Plant height, is low. By the variety Zaryad no similar tendencies are observed – the variety is with high stability, although it exhibits a high plasticity to the environmental conditions. The stability of the component Spike length is very low by the varieties AD-7291 and Rakita, which manifest high plasticity to this sign. The variety Rojen is the most stable regarding this linear yield component.

Table 4. Correlations between yield and yield components plasticity coefficients

b_k	Grain yield	Nr spikes	Plant height	Spike length	Nr grains
Nr spikes	0.314				
Plant height	0.629*	-0.311			
Spike length	0.878*	0.351	0.593*		
Nr grains	0.601	0.068	0.718*	0.310	
Mass grain	0.684*	0.438	0.494	0.400*	0.920*

*Significant at 0.05 level

The yield component Nr. of grain/spike is with the lowest stability by the standard AD-7291, followed by Rojen. The variety Zaryad is having values of one and Rakita and Sadovec are with the highest indicators of stability. By the weight component Mass of grain/spike like the most unstable manifest the varieties Rojen, Sadovec and Zaryad, while by AD-7291 and Rakita the stability is high. By the both signs, related with the grain (Nr. of grain/spike and Mass of grain/spike) no similar tendencies for converse proportional to the plasticity relation are observed, in contrast to the previous signs.

In our previous study (Kirchev et al., 2016) the yield plasticity and stability of the same varieties were determined. Through correlation analysis in this investigation is defined the relation between yield plasticity and the examined yield components (Table 4). The yield plasticity coefficient correlate positive with all yield components, as statistically significant values of correlation are indicated by the components Plant height, Spike length and Mass of grain/spike.

Table 5. Correlations between yield and yield components stability coefficients

S_k	Grain yield	Nr spikes	Plant height	Spike length	Nr grains
Nr spikes	0.751*				
Plant height	-0.639*	-0.511*			
Spike length	-0.154	0.210	-0.582*		
Nr grains	0.179	0.422	0.396	-0.420	
Mass grain	0.741*	0.330	-0.013	-0.775*	0.358

*Significant at 0.05 level

By the yield stability coefficient compared correlatively with the yield components, a positive correlation is proven by the Nr. of spikes/m^2 and the Mass of grain/spike. Only by the component Plant heigh there is a negative proven correlation regarding the yield (Table 5).

CONCLUSIONS

The plasticity of the indicator Nr. of spikes/m^2 is with the highest values by the varieties AD-7291, Sadovec and Rakita. According to the varieties Rojen and Zaryad this indicator is with lower values. By the both linear parameters – Plant height and Spike length the tested triticale varieties react on the same way. The triticale varieties react to the environmental conditions and to the components Nr. of grain/spike and Mass of grain/spike almost equally.

The stability values of the examined yield components are contrariwise proportional to the varieties plasticity regarding the components Nr. of spikes/m^2, Plant height and Spike length. According to the both signs, related to the grain (Nr. of grain/spike and Mass of grain/spike) no similar tendencies are have been observed.

The yield plasticity coefficient correlates positive with all yield components. By the yield stability coefficient there is a positive correlation by the Nr. of spikes/m^2 and the Mass of grain/spike, and negative by the component Plant height.

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