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Ecological Plasticity and Stability of Some Agronomical Performances in Triticale Varieties (x Triticosecale Wittm)

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Abstract. For the aims of the study were used three years data for the yield, plant height, test weight and mass of 1000 grains of triticale varieties with different genotypes (Kolorit, Musala and Trismart), cultivated on the experimental field of the Crop Science Department at the Agricultural University of Plovdiv, Bulgaria. In order to determine the ecological plasticity and stability of the tested parameters, the modified model of Eberhart and Russel was applied. The yield plasticity varies from 0.825 by Trismart variety to 1.189 by Musala variety. The Musala variety is distinguished with the highest values of the plasticity b_k and this variety significant is the most plastic. By the component yield with the lowest stability is the variety with the highest plasticity- Musala. The variety Trismart, who is distinguished with the highest stability, possesses also the lowest plasticity. According the component plant height all varieties manifest high stability and only the variety Musala can be accepted as ecological plastic regarding this parameter, because it possesses plasticity values of $b_k>1$. The yield plasticity coefficient correlates positive with the plant height and the mass of 1000 grains. According the yield stability coefficient by all examined components are determined negative proven correlations.

Key words: triticale, plasticity, stability, yield.

Introduction

Agriculture is the sector, which is mostly influenced by the climatic conditions. The meteorological conditions of the year are of primary importance for the correct growth and development of the agricultural crops (Xu, 2016). The formation of certain trends in the yield components is directly subordinated to the environmental conditions and the manifestation of their values in contrasting environmental conditions helps to distinguish those genotypes, which exhibit stability with respect to the yield and its components (Stoyanov & Baychev, 2018). The estimation of the relative contributions of the variety, the environmental conditions and the genotype x environment interaction to variety performance is required for determining the adaptation capacity (Subira et al., 2015). The sustainable agricultural development and changes in cultivation practices can ensure the adaptation of the sector to the climate changes (Brouziyne et al., 2018; Nastis et al., 2012). In this connection the imposition of cultures with higher resistance to unsuitable climatic condition as triticale could be a possible solution. Created artificially by crossing rye and wheat genome, triticale nowadays becomes increasingly popular, because of its high productive potential. Triticale is a crop with

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high economic efficiency especially in areas with extreme droughts, high temperatures, poor soil nutritional regime, insufficient rainfall, where other cereal crops cannot be grown successfully (Oral, 2018). The big genetic diversity among the created triticale varieties is the reason for the ecological plasticity, stability and productivity of the crop (Ferreira et al., 2015; Mühleisen et al., 2014).

The aim of the study is to determine the impact of the climatic conditions on the stability and plasticity of some agronomical performances in triticale varieties.

Material and Methods

In order to achieve the aims of the study, a field experiment with duration of three years was set on the experimental field of the Crop Science Department at the Agricultural University of Plovdiv, Bulgaria. The meteorological data during the investigation period are presented on Table 1.

Agrochemical analysis of the soil after harvesting of the predecessor, before sowing, determines the conditions of mineral nutrition of the plants after emergence until the onset of the spring vegetation (Table 2). During the three years of experience, the soil reaction is slightly alkaline with pH 7.78 (2016) 7.54 (2017) and 7.66 (2018), which is characteristic for the alluvial meadow soils, in particular the soil on the experimental field of the Crop science Department (Popova & Sevov 2010).

Table 1. Climate conditions during triticale vegetation.

Year	Temperature (monthly average, ^{0}C)								
	X	XI	XII	I	II	III	IV	V	VI
2016/2017	10.8	6.6	2.2	-3.9	3.2	9.7	12.7	17.6	23.7
2017/2018	13.3	8.2	4.9	2.9	3.9	7.1	16.4	19.4	22.6
2018/2019	13.7	7.3	2.8	2.5	4.7	10.6	12.6	18.2	23.4
Long-term average	12.9	7.2	2.2	-0.4	2.2	6.0	12.2	17.2	20.9
	Precipitation (sum, mm)								
2016/2017	5.6	32.9	2.4	70.1	11.1	47.9	26.1	52.7	15.4
2017/2018	70.4	47.6	23.7	21.7	96.7	45.5	24.9	112.3	14.4
2018/2019	34.3	62.5	17.9	30.9	17.2	8.8	76.5	21.3	13.2
Long- term average	40.1	48.4	44.3	42.1	32.7	38.2	45.1	65.3	63.4

Table 2. Agrochemical analysis of soil before sowing.

Year	pH	Mineral nitrogen, mg/kg soil	P_2O_5, mg/100 g	K_2O, mg/100 g
2016	7.78	15.24	79.41	65.66
2017	7.54	19.49	84.35	54.27
2018	7.66	18.87	78.76	64.23

There were used three triticale varieties with different genotypes– Kolorit, breeded at the Dobruja Agricultural Institute – Gen. Toshevo, Bulgaria (country standard), Musala, breeded at the Sadovo seed company - Bulgaria and Trismart, breeded at the Caussade semences - France. The genotypic plasticity and stability of the tested varieties are determined by the yield and some components of the yield as plant height (cm), test weight (kg/100 l grain) and mass of 1000 grains, g. The coefficients of plasticity (b_k) and stability (s_k) are determined according the model of Eberhart and Russel (Eberhart & Russel, 1966):

$$Yijk = Y..+ Gi + Pj + rij + eijk$$

where G is the effect of the genotype, and P the effect of the examined area.

The modified version of the model (Penchev & Stoeva, 2004), was also used for the calculations:

$$Yijk = Y..+ Gi + Qj + GQij + eijk$$

where G is the effect of the genotype, Q the effect of the climatic conditions and GQ the interaction between them.

Two-way analysis of variance (ANOVA) was applied to establish the statistically proven effect of the factors and their interaction. Correlation analysis was used to calculate the relationships between the traits studied. For the results processing is used the software product MS Excel Data analysis.

Results and Discussion

The regression coefficient and the deviations from the regression line were being estimated, so the applied dispersion analysis allows the diffraction to be determined (Table 3). The model of Eberhart and Russel can be applied only, if the interaction between the genotype and the climatic conditions is statistically significant, because future changes are based on genetics and plants will probably change the estimated parameter by different environmental conditions. According Eberhart & Russel (1966) the ecological plasticity is the average variety reaction to the environmental changes, and stability is the deviation of the empirical data from the average reaction at any environmental condition.

The average variety reaction to the changes in the climatic conditions is characterized by the coefficients b_k of the linear regressions (Table 4). Those coefficients indicate not only the plasticity of the varieties, but also allow to forecast the researched parameter in the range of the tested conditions. The regression coefficients b_k is an angular coefficient of the regression straight lines and it is established, that the variety is more responsive to the growing conditions by an increase in the values of b_k.

Normally the values of b_k are positive, but in some cases like for example yield decrease as a result of logging, the regression coefficient can acquire a negative value. When the values of the regression coefficients b_k are higher than one, it means, that the variety does not react to the changes in the environment.

The yield plasticity varies from 0.825 by Trismart variety to 1.189 by Musala variety. The Musala variety is distinguished with the highest values of the plasticity b_k and this variety proven is the most ecologically plastic. The standard Kolorit and Trismart variety manifest lower values, as the differences between them are statistically unproven and they are placed in the same statistical group. A specific genotypic response to the conditions during the harvest year and big variety fluctuation are have been reported by many authors (Barnett et al., 2006; Baychev & Mihova, 2014; Madic et al., 2018; Stoyanov & Baychev, 2018). According to the indicator plant height it can be concluded, that by the variety Musala the parameter is the most plastic, because the values are the highest (1.088), followed by the standard and Trismart variety, where the differences in the values of b_k are statistically non-significant. The plasticity b_k of the indicator test weight is with the highest values by the Trismart variety, followed by the standard Kolorit with values of 1.344 and at least Musala variety with values of 1.109. The differences between the varieties are significant and they are placed in different groups. As the most plastic in a relation to the parameter mass of 1000 grains is distinguished the standard, followed by the variety Musala, while the plasticity of the examined parameter by the variety Trismart is influenced in lower ratio by the environmental changes.

The dispersion S_k is the parameter, which assesses the ecological stability of the varieties. If the dispersion of the stability S_k tends more to the zero, then the empirical values of the signs distinguish less from the theoretical values, located on the regression line. According the applied model of Eberhart and Russel any variety can be accepted as ecological plastic and stable under condition that it possesses values of $b_k>1$ and of $S_k>0$. In the present research the dispersion rates are higher than zero by all tested varieties observing all examined parameters, what according the used model can determine them as stabile (Table 5). The tendency determined in previous studies with another triticale varieties, (Kirchev & Georgieva, 2017), that the stability values of the examined components can be counter proportional to the variety's plasticity, is established also in the present study. By the component "yield" with the lowest stability is the variety with the highest plasticity- Musala. The variety Trismart, who is distinguished with the highest stability, possesses also the lowest plasticity. According the component plant height all varieties manifest high stability and only the variety Musala can be accepted as ecological plastic regarding this parameter, because it possesses plasticity values of $b_k>1$. The stability of the component test weight is very low by all varieties, which can determine them as ecological plastic regarding this sign. The stability of the component test weight is the highest by the variety Musala. All varieties are stable regarding the last component- mass of 1000 grains, but only the standard can be determined also as ecological plastic with values above one. According many authors (Madic et al., 2018; Mihova et al., 2017; Stoyanov & Baychev, 2018), the values of the mass of 1000 grains remain relative stable in contrasting environmental conditions.

The relation between the yield plasticity and stability with the examined plant parameters is defined through correlation analysis (Table 6).

Table 3. The two-way ANOVA analysis of variance of triticale genotypes x climatic conditions. Legend: *significance at $p<0.05$.

Source of Variation	df	Yield		Pl. height		Test weight		Mass of 1000 grains	
F*; F-criteria		F	Fcrit	F	Fcrit	F	Fcrit	F	Fcrit
Genotype (G)	2	864.59*	3.55	25.42*	3.55	59.42*	3.55	88.83*	3.55
Climatic conditions (Q)	2	68.07*	3.55	7.72*	3.55	62.21*	3.55	23.52*	3.55
Interaction (G x Q)	4	10.71*	2.92	7.90*	2.92	12.71*	2.92	3.05*	2.92

Table 4. Ecological plasticity of yield and some yield components in triticale varieties. Legend: Values with the same letters do not differ significantly.

Indicators Varieties	Yield	Pl. height	Test weight	Mass of 1000 grains
Kolorit	0.984a	0.997a	1.344b	1.296c
Musala	1.189b	1.088a	1.109a	0.978b
Trismart	0.825a	0.974a	1.545c	0.724a
LSD 5%	0.17	0.01	0.19	0.26

Table 5. Ecological stability of yield and some yield components in triticale varieties. Legend: Values with the same letters do not differ significantly.

Indicators Varieties	Yield	Pl. height	Test weight	Mass of 1000 grains
Kolorit	0.145a	1.045a	0.265b	0.487a
Musala	0.124a	1.240b	0.350c	0.435a
Trismart	0.205b	1.114a	0.189a	0.629b
LSD 5%	0.01	0.05	0.06	0.06

Table 6. Correlations between yield and yield components plasticity and stability coefficients. Legend: *significance at p<0.05.

$b_{k;} s_k$	b_k			s_k		
Indicators	*1*	*2*	*3*	*1*	*2*	*3*
1.Yield	1			1		
2.Plant height	0,967*	1		-0,771*	1	
3.Test weight	-1,000*	-0,959*	1	-0,032	-0,612	1
4.Mass of 1000 grains	0,377	0,127	-0,402	-0,259	-0,416	0,974*

The yield plasticity coefficient correlates significantly positive with the plant height. The correlation with the yield and the mass of 1000 grains plasticity is also positive, but non-significant. There is a strong negative correlation between the grain yield plasticity and the test weight, which defines these two indicators as opposite to the environmental plasticity of the variety. A similar negative correlation was found between the plant height and the test weight. These results can summarize the relationships between the plasticity of a variety in terms of its yield and its height as negative with respect to one of the main quality indicators of grain in cereals – the test weight.

In the present research the ecological stability of the grain yield of the examined triticale varieties correlates negatively with all other investigated indicators. Statistically significant values are indicated only by the plant height (+0.771). A proven positive relationship by the stability of the studied parameters exists between the two quality indicators - the mass of 1000 grains and the test weight (+0.974).

Conclusion

The Musala variety can be defined as ecological plastic regarding the signs – yield, plant height and test weight. The standard manifest plasticity regarding the components test weight and mass of 1000 grains, while by the variety Trismart the ecological plasticity is established only in term of the component test weight. The positive dispersion rates by all tested varieties observing all examined parameters enable to determine them as stabile. From the performed correlation analysis, it was established, that the yield plasticity coefficient correlates positive with the plant height and the mass of 1000 grains.

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