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VARIABILITY OF SOME INDICATORS OF TRITICALE VARIETIES (× *Triticosecale* Wittm.) COMPARED TO THE GRAIN YIELD

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Abstract

A field trial has been carried out in the Experimental field of the Agricultural University - Plovdiv. The experiment was arranged according to the split-plot method. The following varieties were studied: Lasko, Boomerang, Respect and Attila (split-plot), grown under two levels of nitrogen fertilization - 60 and 180 kg/ha nitrogen (main plot). The variety Lasko differed significantly as less productive. All Bulgarian varieties have approximately the same crude protein content in the grain. Compared to them, Lasko has a higher protein content. From the correlation analysis between grain yields and other indicators, it was found that all structural elements (plant height; the number of spikes per plant; length of spikes; the mass of grains per spike and mass of 1000 grains) are positively related to the grain yields. The crude protein content is negatively related to the grain yields from which it can be concluded that higher grain yields leads to a decrease in the crude protein content in it.

Key words*: triticale, nitrogen fertilization, yield.*

INTRODUCTION

Triticale (×*Triticosecale* Wittm.) is an artificially created grain crop, from a cross between wheat and rye. The structure of the triticale spike derived from wheat and rye is the main factor in the higher productive potential of the grain production, namely, the longer spike inherited from rye and the denser spike inherited from wheat (Đekić et al., 2012; Kondic et al., 2013; Milovanovic et al., 2014; Madic et al., 2015; Stoyanov and Baychev, 2015; Knezevic et al., 2016; Dobreva et al., 2018). The choice of the variety is an important point in the production of high grain yield of triticale. In recent years, especially after Bulgaria acceded to the European Union when the cultivation of varieties established in the EU became possible, the varietal composition of field crops, including triticale, has become very diverse. However, the triticale varieties created in Bulgaria in recent years represent an opportunity for high grain yields (Baychev, 2005; 2009a; 2009b, 2011, 2012, 2013; Stoyanov and Baychev, 2016; Baychev and Stoyanov, 2019). Excepting the right choice of variety, nitrogen fertilization greatly influences the grain yields of triticale (Nogalska et al., 2012; Lalevic and Biberdzic, 2016; Oral, 2018; Georgieva, 2019; Abdelaal et al., 2019). Since triticale is a relatively new cereal crop, there is a need for detailed experiments including different regions, varieties and climatic conditions to achieve more accurate fertilizer recommendations and to determine which varieties are most adapted to the local environmental conditions. In this connection, the present study aims to identify the genotypic specifics of triticale varieties in terms of grain productivity at two rates of nitrogen fertilization.

MATERIALS AND METHODS

1. **Field experiment**

The field trial has been set in the period 2019-2021 at the experimental field of the Agricultural University - Plovdiv (42.110407° N 24.850112° E). Four triticale varieties: Lasko (international triticale standard), Boomerang, Respect, and Attila have been studied. The varieties have been grown at two levels of nitrogen fertilization - 60 and 180 kg/ha nitrogen, introduced in early spring (BBCH2). As a fertilizer has been used ammonium nitrate (NH_4NO_3) with 33.5% nitrogen. The experiment was arranged according to the split-plot design in four replications, with the main plot – nitrogen fertilization and the varieties – split-plot, after sunflower as a previous crop.

The grain yield (GY), (kg/ha) has been recorded at the end of the maturity stage of the harvest plots with a size of 10 m^2, row spacing of 15 cm, planted in the sowing rate of 550 germinated seeds per m^2. The following indices have been determined at maturity before the harvest: PH - plant height (cm); NS - the number of spikes per plant; LS - length of spikes (cm); MG - the mass of grains per spike (g); MT - the mass of 1000 grains (g) and PC - the crude protein contents (%), calculated as the total Kjeldahl nitrogen × 6.25 (AOAC, 1998).

2. **Weather conditions**

Meteorological conditions during the vegetation influenced the productivity of the tested varieties (Figure 1). In the first year, the temperatures in the autumn were close to the minimum temperatures for the growth and development of the crop. The lack of sufficient rainfall with 271.6 mm below the climatic norm for the area differentiated the first year as dry. The second harvest year is characterized by higher temperatures and sufficient rainfall, which are close to the optimal values for the development of the crop. During the third year, the total amount of rainfall is 325.5 mm, which is 92.5 mm less than the norm of the region. According to the temperatures, the values are approaching those of the second year.

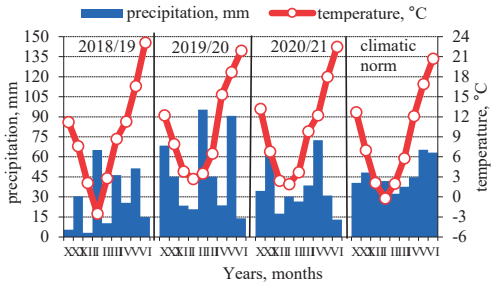

Figure 1. Meteorological conditions during the years

3. **Statistics**

The collected data has been subjected to statistical analysis using the software XLSTAT 2016.02 for interpretation of the results and interferences. Two-way analysis of variance (ANOVA) has been applied to establish the statistically significant effect of the factors and their interaction. Correlation analysis has been used to calculate the relationships between the indices.

RESULTS AND DISCUSSIONS

The main structural components directly influencing the formation of crops and productivity of triticale varieties can be considered independently by factors - variety, conditions of the year and nitrogen fertilization (Table 1). The height of the plants varies depending on the variety from 106 cm for the variety Lasko to 121 cm for the variety Respect. Differences between the varieties are statistically significant, except for Boomerang and Attila, where the difference in the height of the stem is not significant. The influence of the conditions of the year is shown only between the first and the remaining two years of the study. The higher rate of nitrogen fertilization significantly increased the height of the crop by 9 cm. The formation of productive tillers is one of the main factors directly influencing crop productivity. The number of spikes per plant varies between 2.1 and 3.3. These differences, however, are only significant compared with Lasko, and the remaining three varieties can be grouped in terms of their productive tillers. In the second and third years, an equal number of productive tillers (with spikes) is formed and in 2019 when are observed the lowest grain yields, the tillering is also the lowest. The higher nitrogen rate leads to an increase in productive tillering with 0.7 spikes per plant compared to the fertilization with 60 kg/ha N and the differences between both fertilization rates are statistically significant. According to the spike length, there is a statistically significant difference between Lasko and all tested varieties, only between the varieties Respect and Attila, the difference remains non-significant, which sets them in the same statistical group. The longest spike formed the variety with the highest average yield - Boomerang.

Weather conditions during the three years of study did not lead to statistically significant differences in the length of the spikes. Because of the genetic determination of the length of the spike, the increasing nitrogen fertilization has no significant positive impact on the indicator. The mass of the grains per spike is significantly

higher at the higher level of fertilization. By all varieties, the trends of change of this trait are similar to the previous indicator. The highest values of the indicator were reported in the second year of the study when the highest grain yields were noted. The mass of 1000 grains is affected in the same way by the level of fertilization as the previous indicator. Concerning the factor "variety", no significant differences between the varieties were found, which leads to the conclusion that the studied triticale varieties do not differ in this indicator. In the second year of the study, the indicator had the highest values. The content of crude protein in the grain of triticale is positively influenced by the conditions of nitrogen nutrition - with its increase the protein content in the grain also increases. All varieties breaded in Bulgaria have approximately the same content of crude protein in the grain.

Table 1. Differences between the main indices

Factors	PH	NS	LS	MG	MT	PC
Nitrogen fertilization rate						
N_{60}	111[a]	2.5[a]	13.3[a]	1.29[a]	41.2[a]	12.4[a]
N_{180}	120[b]	3.2[b]	14.1[a]	1.62[b]	43.5[b]	14.2[b]
Varieties						
Lasko	106[a]	2.1[a]	11.6[a]	1.41[a]	42.1[a]	14.2[b]
Boomerang	116[b]	3.3[b]	16.1[c]	1.55[c]	41.3[a]	12.1[a]
Respect	121[c]	3.1[b]	14.6[b]	1.49[b]	42.8[a]	12.8[a]
Attila	119[b]	3.1[b]	13.6[b]	1.51[b]	41.5[a]	12.4[a]
Years						
2019	111[a]	2.6[a]	13.3[a]	1.21[a]	41.1[a]	14.6[b]
2020	120[b]	3.2[b]	14.1[a]	1.61[c]	43.2[b]	11.6[a]
2021	119[b]	2.9[b]	13.7[a]	1.31[b]	42.2[a]	13.9[b]

*Values with the same letters do not differ significantly

Compared to them, the variety Lasko has proven to differ with the higher protein content. This is not a coincidence, as Lasko is a variety of the old generation when the problem of shrivelled triticale grain is one of the main problems in the breeding of this crop. Under such conditions, less starch accumulates, which is a factor for increased protein content in the grain. The highest protein content in the grain was reported in the first year of the study when the lowest grain yields were reported. The yield of the grain of the studied triticale varies depending on the conditions during the years and is greatly influenced by the tested levels of nitrogen fertilization (Table 2). In the first year of the study, the average grain yield, regardless of the investigated factors (nitrogen fertilization and variety), was lower than the other two years - 476 kg/ha This is mainly due to the non-typical temperature and rainfall conditions, especially in October - December in terms of soil moisture, and April - June concerning higher average daily air temperatures. At a lower nitrogen fertilizer rate, the grain yield is 403 kg/ha, and the higher fertilization level leads to the formation of 549 kg/ha of grain. The lowest yield was obtained by the Lasko - 427 kg/ha followed by the varieties Respect and Attila - 490 kg/ha. These two varieties are forming the same yield in the first year of the study.

Table 2. Grain yield of triticale varieties, affected by N application rate, kg/ha

Treatment	2019	2020	2021	Average
Main treatment (Nitrogen fertilization rate)				
N_{60}	403[a]	453[a]	425[a]	427[a]
N_{180}	549[b]	590[b]	580[b]	573[b]
LSD 5%	*7.65*	*11.87*	*10.96*	*10.16*
Sub-treatment (Triticale varieties)				
Lasko	427[a]	508[a]	483[a]	473[a]
Boomerang	497[c]	542[c]	519[c]	519[c]
Respect	490[b]	513[b]	502[b]	502[b]
Attila	490[b]	526[c]	506[b]	507[c]
LSD 5%	*4.50*	*4.23*	*4.12*	*4.28*

*Values with the same letters do not differ significantly

Significantly highest grain yield in the first year forms the variety Boomerang- 497 kg/ha. In the second harvest year, the average grain yield of triticale was highest compared to the remaining two years of the survey - 522 kg/ha. The reasons for this are the optimal temperature and precipitation conditions during the critical months of the development of the culture in April - May. The lower level of nitrogen fertilization leads to the formation of 453 kg/ha grain, and the increase of the fertilizer rate to N180 kg/ha leads to the formation of 590 kg/ha grain. The lowest productive variety in the second year is the standard Lasko – 508 kg/ha, followed by the variety Respect – 513 kg/ha, Attila – 526 kg/ha and Boomerang – 542 kg/ha. In the third year of the study, the average grain yield was 502 kg/ha. The values of the parameter are close to the previous year because in climatic conditions the years are similar. The lower nitrogen rate leads to the formation of 425 kg/ha grain and a double increase in the nitrogen rate – to 580 kg/ha grain. Like the second year of the study, the lowest grain yield was formed by the variety Lasko (483 kg/ha),

followed by Respect and Attila (respectively 502 kg/ha and 506 kg/ha) and the highest productive - the Boomerang variety (519 kg/ha). On average for the period, the grain yield of the lower fertilizer rate is 427 kg/ha, and a double increase in nitrogen fertilization leads to a statistically significant increase in grain yield to 573 kg/ha. The lowest grain production in this study is observed by the world standard Lasko – 473 kg/ha. The next in terms of productivity is the variety Respect – 502 kg/ha. The varieties Attila and Boomerang are the most productive, although the yields by the variety Boomerang are the highest on average over the three years (519 kg/ha), and both varieties belong to the same productivity group. From these results, it could be concluded that the varieties Boomerang and Attila are and more adapted to the soil and climatic conditions of the region because their productive potential is higher during the whole tested period. Other researchers also confirm the affection of grain yield to the weather conditions (Gülmezoglu and Kinaci, 2003; Pecio, 2010). Alaru et al. (2009) concluded that the greatest influences on grain yield formation are the conditions of the year, followed by the N rate.

Table 3. Two-way ANOVA analysis of variance

Years	*Source of Variation*	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
2017	N-rate	170820,1	1	170820,1	6677,3	0,00*	4,25
	Varieties	25847,63	3	8615,8	336,7	0,00*	3,00
	Interaction	13180,13	3	4393,3	171,7	0,00*	3,00
2018	N-rate	147424,5	1	147424,5	10609,2	0,00*	4,25
	Varieties	5541,625	3	1847,2	132,9	0,00*	3,00
	Interaction	977,25	3	325,7	23,4	0,00*	3,00
2019	N-rate	191425,8	1	191425,8	13953,5	0,00*	4,25
	Varieties	5376,094	3	1792,0	130,6	0,00*	3,00
	Interaction	50,34375	3	16,7	1,2	0,32^{ns}	3,00

*Significant difference at P<0.05; ns – non-significance

The two-factor analysis of variance (Table 3) shows that both factors (nitrogen fertilization and variety) had a statistically significant effect on grain yield during the three years of the study. The relationship between them is also statistically significant, but only during the first two years of the study. In the third harvest year, the relationship between the two factors (nitrogen fertilization and variety) is non-significant. Our observations confirm the opinion of many authors, that the tested traits are genetically determined, but modified by the nutrient status as well as the environmental conditions (Đekić et al., 2012; Dobreva et al., 2018; Georgieva, 2019; Madic et al., 2018). From the correlation analysis between grain yield and other indicators, it was found that all structural elements (plant height; the number of spikes per plant; length of spikes; the mass of grains per spike and mass of 1000 grains are positively related to grain yield (Figure 2). Despite this summary statement, each indicator is related in varying degrees to the yield, as evidenced by the scatter plots.

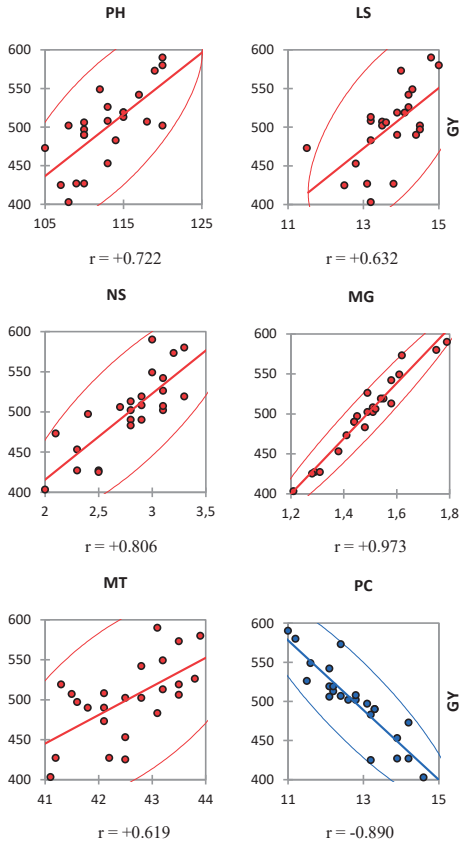

Figure 2. Pearson correlation coefficient (r) and scatter plots between grain yield (GY) and main indices

The lowest positive correlation with grain yield is between the mass of 1000 grains – (r = +0.62 and length of spikes – (r = +0.63). Plant height (r = +0.72) and the number of spikes per plant (r = +0.81) have a stronger influence on the yield. The indicator that has the greatest impact

on yield is the grain mass in the spike (r = +0.97). The only indicator related to the chemical composition of the grain - crude protein content, is negatively related to grain yield (r = -0.89) from which it can be concluded that higher grain yield leads to a decrease in crude protein content in it.

CONCLUSIONS

Across all varieties and averages for the three years of the study, the grain yields of all triticale varieties, fertilized with 180 kg/ha nitrogen is higher by about 34% than by the lower fertilizer rate, 60 kg/ha. The lowest grain production was given by the Lasko variety, while Attila and Boomerang gave the highest yield, for over the three years. Yield parameters differ among the varieties. Lasko significantly had a shorter stem and spike length compared to other varieties. The content of the crude protein in the grain of triticale is positively influenced by the conditions of the nitrogen nutrition. All varieties breaded in Bulgaria have approximately the same content of crude protein in the grain. Compared to them, the Lasko variety has proven to differ with the higher protein content. From the correlation analysis between grain yield and other indicators, it was found that all structural elements (plant height; the number of spikes per plant; length of spikes; the mass of grains per spike and mass of 1000 grains) are positively related to the grain yield. The crude protein content is negatively related to the grain yield from which it can be concluded that the higher grain yield leads to a decrease in the crude protein content in it. The effect of the different soil nutrition regimes on the chemical composition of the grain, as well as the applicability of the varieties in the bakery industry, need to be further investigated.

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