

CHARACTERISTIC OF MORPHOBIOLOGICAL AND ECONOMICALLY VALUABLE TRAITS OF WINTER TRITICALE VARIETIES IN THE TRANSITIONAL-CONTINENTAL REGION OF BULGARIA

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Abstract

A comparative study of modern Bulgarian and Polish winter triticale varieties over four growing seasons was conducted, after a predecessor of sunflower under unfertilized conditions on Pelic Vertisol. The length of the growing season and the days to heading were characterized based on the number of days with active temperature above 5°C, as well as the variability of productivity and the elements of productivity: plant height, number of grains in a spike and mass of 1000 grains. The results on average for the period showed that the Colorit variety had the shortest growing season (163 days) and the shortest period from sowing to heading (112 days). The duration of the growing season was longest for Casino variety (169 days). The period from sowing to heading was the longest for Avocado and Casino varieties (119 days). Environmental conditions had a dominant effect on yield, number of grains per spike and plant height, while the variety had a dominant effect on thousand-grain mass. The Casino and Avocado varieties demonstrated the best results in terms of thousand-grain mass and grain yield, while the Colorit variety showed the highest number of grains per spike.

Key words: elements of productivity, grain yields, length of the growing season.

INTRODUCTION

Among the winter cereals grown in Bulgaria, triticale is of great interest. In essence, triticale (x *Triticosecale* Wittmack) is an amphiploid hybrid between wheat and rye. According to data from the Ministry of Agriculture for 2024, in the Southeast region, where the Institute of Field Crops is located, the areas of wheat (246,672 ha) dominate, followed by barley (47,678 ha), triticale (5,993 ha) and rye (2,437 ha) (MZH). The area of triticale and rye is the largest in the Southeast region (28.9%), compared to the total area occupied in Bulgaria. Its multifunctional applications characterise it as a valuable crop. The usable parts of triticale are the grain, flour, bran, and green biomass, and it can be fractionated to obtain various components, including starch, dietary fibre, and protein, which can be used for both food and non-food applications (Kamanova et al., 2023). Researchers have found that growing winter triticale is more efficient than wheat in years with anomalous climatic conditions (Lyatamborg et al., 2023). Triticale's grain yield advantage was attributed to its higher grain number per spike and its superior biomass

allocation and reproductive efficiency (Miroslavljević et al., 2025).

The main task in agricultural production is the introduction of high-yielding varieties into production. Obtaining high yields of triticale is directly related to the interaction of the genotypes used with environmental conditions. A study presented a mathematical model for quantitative assessment of the response of individual triticale varieties to the environment and the degree of yield obtained (Stoyanov, 2021). It is believed that the agronomic characteristics of crops (such as grain yield, plant height, thousand-grains mass, flowering date, etc.) are particularly valuable. Other accompanying traits are also useful, including number of grains in spike and length of the growing season. The number of grains in the spike is the main trait that characterizes spike productivity in terms of mass. Grain size, expressed as thousand-grain mass, is a characteristic that determines the fullness of the grain and affects germination and viability, as well as productivity potential. This trait is of fundamental importance for seeding management and is relevant in determining yield in a particular crop year. Grain number and

thousand-grain mass complement each other functionally, ensuring optimal grain productivity (Stoyanov, 2017). Analysis has shown that thousand-grain mass and grain number per spike differ significantly in their stability among the studied varieties and according to different stability indices (Stoyanov, 2025). Therefore, key agronomic traits should be monitored and reported for the benefit of future triticale breeding strategies and to support farming.

The aim of the study: A comparative characteristic of biological and economically valuable traits of modern Bulgarian and Polish winter triticale varieties, grown in transitional-continental region of Bulgaria.

MATERIALS AND METHODS

The work was carried out on the experimental field of the Institute of Field Crops, Chirpan, during the period 2019-2023. Eight Bulgarian triticale varieties included in the Official Variety List of Bulgaria (Colorit, Acord, Dobrudzhanets, Doni-52, Borislav, Blagovest, Irmic and Lovchanetz (IASAS)), and two Polish varieties (Avocado and Casino), admitted to the Polish national list (Coboru), were used. The triticale varieties were grown after a predecessor of sunflower on Pelic Vertisol. The cultivation technology follows the adopted standard technology for winter cereal crops. In order to assess the real potential of the varieties under specific environmental conditions, as well as the natural course of the growing season, the experiment was carried out under unfertilized conditions in three repetitions.

Sowing was carried out using a selection seeder. The seeds were sown in the following periods: November 5, 2019; November 15, 2020; October 10, 2021; and October 18, 2022. The seeding rate was 550 seeds per m². The phenological phases of heading and full ripeness were recorded according to the BBCH scale (Zadoks et al., 1974). The phase of the beginning of ear emergence was noted when approximately 10% of the plants had reached this stage (49-51 BBCH). The duration of the periods is based on the number of days with an active temperature above 5 °C. Laboratory tests to determine the number of grains per spike were carried out according to the accepted methodology. From two harvest plots of each

option, ten spikes were collected at the phase of full maturity, after which the grains were separated and weighed. The determination of thousand-grain mass (g) was performed in accordance with BDS EN ISO 520: 2010. Grain harvest was carried out at full maturity (89-92 BBCH). Yield was collected from the three repetitions and converted to hectares basis. Meteorological data were provided by the field synoptic station located on the territory of Institute of Field Crops.

The results were processed using the software product Biostat (Penchev et al., 1989-1991). The means were compared for significance using the least significant difference (LSD) test at $p = 5.0$, $p = 1.0$, and $p = 0.1\%$.

RESULTS AND DISCUSSIONS

The meteorological conditions during the four growing seasons differed in precipitation and temperature but were generally favorable for the growth and development of triticale (Figure 1). During the 2020-2021 and 2021-2022 growing seasons, precipitation exceeded the multi-year average by 41.7 and 54.7 mm, respectively. Very wet months such as January 2021, October 2021, and December 2021 were recorded, with precipitation exceeding normal levels by 64.2, 103.6, and 38.8 mm, respectively.

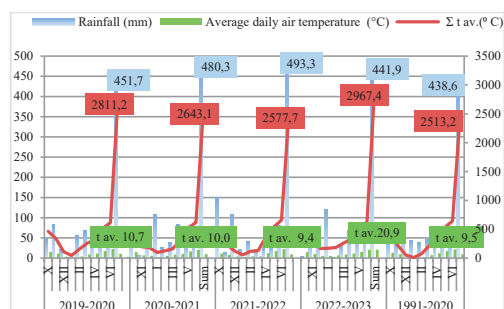


Figure 1. Meteorological data during the growing seasons of triticale

The total air temperature from October to June in 2019-2020 was 297.9°C above the multi-year average, and in 2022-2023 it was 454.2°C. This resulted in an 11.4°C higher average temperature for the last period. Winter periods were warm, due to higher average temperatures in the months of December, January and February. During the fourth period, the average

temperatures these months were 3.1, 4.2, 3.3 and 5.8°C, respectively, which is 1.3, 2.4, 1.5 and 4.0°C higher than the calculated 30-year average (1.8°C).

Table 1 presents the parameters of a descriptive characterization based on four years of data for the varieties. The analysis showed that the coefficient of variation ranged between 11.0 and 12.40% for the length of the growing season. According to this indicator, the varieties did not differ significantly. The shortest period was observed for the Colorit variety (163.3 days), and the longest for Casino (169 days), five days later than the Colorit standard. The Casino variety deviated the most from the others, according to SD = 21.0. For comparison, in Iraq, a growing season of 163–164 days was reported for triticale, and the period from sowing to harvesting was 116 days (Mohammed & Mohammed, 2014).

Heading date is recognized as an important adaptive trait in crop development: a short duration of the pre-anthesis phase in early cultivars and delayed anthesis in late cultivars significantly influence the grain number per spike in different species/spike types, reducing the final grain yields (Miroslavljević et al.,

2018). The date of ear heading significantly affects productivity components contributing to increased grain yield in winter wheat (Tsenov et al., 2020).

The heading phase occurred at different times after sowing, mainly due to the influence of environment temperature. The coefficient of variation indicates average variability and a roughly similar period to heading among the varieties ranging from 19.8 to 22.8% (Table 1). The earliest heading was observed in the Colorit variety (112 days). A comparative study of triticale in the temperate continental zone reported 125 days to heading for Colorit and 128 days for Doni-52, averaged over nine years (Stoyanov et al., 2022). The Polish varieties Casino and Avocado showed a significantly longer period (118.8 and 119 days), seven days later than Colorit, with the difference significant at $p = 0.1$ %. The Bulgarian varieties Acord and Irnik also significantly exceeded the standard for this indicator, with 117.3 and 115.8 days, respectively. A study in Pakistan revealed that the duration from sowing to harvest of triticale varied from 88.8 to 109.3 days, and the total growing season from 120.3 to 142.5 days, depending on sowing time (Khattak et al., 2016).

Table 1. Main variability parameters for the duration from sowing to full ripnesse and from sowing to heading in varieties, with reference to Colorit variety

Varieties	Number of days from sowing to fully ripe			Number of days from sowing to heading		
	lim	$\bar{x}_{av.}$	CV %	lim	$\bar{x}_{av.}$	CV %
Colorit	138–180	163.3	11.0	84–138	112.0	19.8
Avocado	138–185	164.3 ^{ns}	11.9	89–147	118.8 ^{***}	20.1
Acord	138–184	165.0 ^{ns}	12.0	86–151	117.3 ^{**}	22.8
Borislav	138–184	164.0 ^{ns}	11.9	84–144	115.0 ^{ns}	21.3
Blagovest	138–184	164.8 ^{ns}	11.8	84–140	113.5 ^{ns}	20.2
Doni-52	138–185	164.0 ^{ns}	12.1	86–145	114.3 ^{ns}	21.2
Dobrudzhanets	138–184	164.5 ^{ns}	11.8	84–140	113.3 ^{ns}	20.4
Irnik	138–184	164.8 ^{ns}	12.0	86–145	115.8 [*]	20.8
Casino	138–184	169.0 ^{**}	12.4	89–148	119.0 ^{***}	20.3
Lovchanets	138–184	165.0 ^{ns}	11.9	85–140	114.8	19.9
LSD %	$p = 5.0$	3.2		$p = 5.0$	3.4	
	$p = 1.0$	4.3		$p = 1.0$	4.7	
	$p = 0.1$	5.7		$p = 0.1$	6.2	

^{**}, significant at $p = 1\%$; ^{***} significant at $p = 0.1\%$;

A slight to moderate variation in values was also observed for the next trait - plant height (CV = 1.9–12.5%) (Table 2). The data on the average crop height for the tested period showed an increase of 0.4% to 0.8% compared to control, but this difference was not significant. On average over four years, the tallest plants were recorded for Acord and Doni-52 varieties reaching 115.2 cm. A significantly lower value

(86.9% to the control) was recorded for the Casino variety (99.3 cm).

The best results in terms of the thousand-grains mass were obtained for the Avocado, Acord, Blagovest and Casino varieties, with values higher by 12.7, 6.1, 6.7 and 12.6%, respectively, compared to Colorit. For the Blagovest variety, this indicator showed moderate variation over the years, CV = 13.3%.

Table 2. Main variability parameters for plant height and thousand grain mass in varieties, with reference to the Colorit variety

Varieties	Plant height (cm)			Thousand-grains mass (g)		
	lim	$\bar{x}_{av.}$	CV %	lim	$\bar{x}_{av.}$	CV %
Colorit	101.0–134.5	114.3	12.5	35.78–40.37	38.18	5.3
Avocado	102.4–125.3	114.8 ^{ns}	8.3	40.09–46.59	43.04 ^{***}	7.1
Acord	101.1–128.0	115.2 ^{ns}	9.6	38.24–42.34	40.52 ^{***}	4.7
Borislav	101.0–127.3	113.1 ^{ns}	10.6	37.60–40.69	39.43 ^{***}	3.8
Blagovest	103.7–126.7	114.8 ^{ns}	8.2	34.74–46.24	40.73 ^{***}	13.3
Doni-52	105.9–125.7	115.2 ^{ns}	7.1	38.08–40.61	39.20 ^{**}	2.9
Dobrudzhanets	106.5–121.6	113.4 ^{ns}	5.8	37.07–44.28	39.49 ^{***}	8.2
Irnik	105.7–124.7	114.8 ^{ns}	7.6	36.23–40.06	38.05 ^{ns}	4.2
Casino	96.7–101.2	99.3 ⁰⁰⁰	1.9	39.55–47.84	43.00 ^{***}	9.3
Lovchanets	106.9–120.5	112.5 ^{ns}	5.3	34.79–40.20	37.73 ^{ns}	6.1
LSD %	$p = 5.0$	2.3		$p = 5.0$	1.3	
	$p = 1.0$	3.1		$p = 1.0$	1.8	
	$p = 0.1$	4.0		$p = 0.1$	2.6	

^{**}, significant at $p = 5\%$; ^{*}, significant at $p = 1\%$; ^{***} significant at $p = 0.1\%$; ⁰⁰⁰ significant at $p = 0.001$; ^{ns}, non-significant

The most variable trait during the study period was the number of grains per spike (Table 3). Variation in the number of grains per spike indicates a strong genetic influence on the components of grain yield. In addition, the number of grains is strongly influenced by meteorological conditions during the pollination and fertilization of flowers. This statement is supported by the data in Table 4, which shows a high influence of the environment (48.90%). The values of all varieties are significantly lower than the control, with the standart variety Colorit in the first position, averaging 74.1 grains. Dobrudzhanets showed the highest variability among the varieties regarding the number of

grains per spike (27.1%), while the lowest variability was observed for Acord (6.6 %) and Casino (6.9 %). Avocado, Borislav and Doni-52 were approximately homogeneous for this characteristic. High CVs has been reported, on average over the years, for the number of grains per spike and thousand-grains mass - 34.21% and 25.55%, respectively-for another cereal-wheat amphidiploid (Stoyanov, 2017). The results of Triputin et al. (2020) showed average variability for the number of the grains per spike and thousand-grains mass in winter triticale of 19.1% and 14.7%, respectively, whit no such variability reported for plant height.

Table 3. Main variability parameters for grain number per spike and grain yield in varieties, with reference to the Colorit variety

Varieties	Number of grains in spike			Grain yields (kg/ha)		
	lim	$\bar{x}_{av.}$	CV %	lim	$\bar{x}_{av.}$	CV %
Colorit	62.7–52.0	74.1	12.1	4,196.0–5,850.0	4,956.0	17.1
Avocado	48.0–77.4	62.0 ⁰⁰⁰	19.6	4,272.4–7,538.0	5,348.0 ^{**}	27.2
Acord	53.4–62.1	59.0 ⁰⁰⁰	6.6	3,870.0–6,231.3	4,675.0 ^{ns}	23.5
Borislav	51.5–80.1	65.4 ⁰⁰⁰	20.0	2,307.2–6,846.0	4,666.0 ^{ns}	45.0
Blagovest	55.8–68.0	60.6 ⁰⁰⁰	9.6	3,375.0–6,866.0	5,140.0 ^{ns}	28.8
Doni-52	45.6–74.0	61.4 ⁰⁰⁰	20.9	2,921.4–6,852.0	5,001.0 ^{ns}	35.0
Dobrudzhanets	48.8–88.8	64.0 ⁰⁰⁰	27.1	2,453.7–7,110.0	4,983.0 ^{ns}	39.8
Irnik	48.0–74.1	62.9 ⁰⁰⁰	17.3	2,528.6–6,052.0	4,561.0 ^{ns}	32.9
Casino	48.7–67.5	60.2 ⁰⁰⁰	6.9	1,893.1–6,820.0	5,196.0 ^{ns}	44.6
Lovchanets	49.4–78.3	62.5 ⁰⁰⁰	19.1	3,501.7–5,962.1	4,977.0 ^{ns}	24.1
LSD %	$p = 5.0$	3.9		$p = 5.0$	285.3	
	$p = 1.0$	5.3		$p = 1.0$	378.4	
	$p = 0.1$	6.9		$p = 0.1$	490.0	

^{**}, significant at $p = 1\%$; ⁰⁰⁰ significant at $p = 0.001$; ^{ns}, non-significant

The yield characteristics revealed a significance difference in the yield among the varieties Borislav, Doni-52, Dobrudzhanets, Irnik, and Casino, with the coefficient of variation ranging from 32.9 to 45.0%. The yield of the same varieties showed similar average productivity

and approximate uniformity, with the coefficient of variation ranging from 15.06 % to 26.47%, as reported in a study by Stoyanov (2025). In another study, Doni-52 reliably exceeded all standards and the average standard by 11.9% over a 9-year period, indicating the exceptional

productivity and stability of the variety (Stoyanov et al., 2022). The varieties Avocado, Blagovest, and Casino achieved the highest grain yield, exceeding the control by 7.9, 3.7, and 4.9%, respectively. The result for the Avocado variety was statistically significant at $p = 1.0\%$. According to another study, Polish varieties, regardless of environmental conditions, significantly outperformed Bulgarian triticale varieties in terms of productivity, with Blagovest, Avocado, and Casino being note for their high, complex stability (Stoyanov, 2024). Among the Bulgarian varieties, Doni-52 also demonstrated a high grain yield of 0.7%, though this is not confirmed.

According to the data in Table 4, the variety's effect on yield formation was not significant (2.54%), whereas environmental conditions had a substantial influence (80.11%). In contrast, the results of Jańczak-Pieniążek and Kaszuba (2024) showed a significant influence of both genotype and environment on the grain yield of triticale. Other studies have also confirmed that growing conditions affect both the productivity

of winter triticale and the mass of 1000 grains (Kyrylchuk et al., 2023). For example, under sandy soils and irrigation conditions, contrasting with the conditions of the present study, grain yield ranged from 4310 to 4604 kg/ha, with 1000-grain weights ranging from 34.5 to 41.7 g. The vegetation period lasted from 225 to 228 days, the number of grains per spike ranged from 32.6 to 41.3, and the plant height varied from 86.3 to 102.6 cm (Draghici, 2012). The low effect of the variety $\times$ environment interaction (13.52%) indicated a wide variation in yield values over the years. In other environmental conditions, similarly low interactions of environment $\times$ genotype (14.00 %), genotype (11.13 %), and environment (56.43 %) were reported (Stoyanov, 2025).

Other studies confirmed the effect of the variety on yield but found no statistically significant influence on the grain yield and 1000-grain mass due to the strong effect of nitrogen fertilization (Lalević et al., 2022). The impact of environments factors accounted for 92.6% of all variation, compared to 2.3% for genotype and 4.46% for their interaction, as reported in a study by Kendal (2024).

Table 4. Effect of cultivar (G) and environment conditions (E) on key agronomic traits

Source of variation	PH		TGM		NGS		GY	
	df	η (%)	df	η (%)	df	η (%)	df	η (%)
Total	79	100.0	79	100.0	79	100.0	119	100.0
Blocks	1	5.444806E-02	1	0	1	0.62	2	0.25
Options	39	97.16***	39	98.48***	39	93.10***	39	96.17***
G	9	23.51***	9	34.68***	9	13.80***	9	2.54***
E	3	54.71***	3	35.53***	3	48.90***	3	80.11***
G×E	27	18.94***	27	28.28***	27	30.40***	27	13.52***
Error	39	2.79	39	1.52	39	6.29	78	3.58

PH-plant height; TGM-tousand grains mass; NGS-number of grains per spike; GY-grain yield.

Table 5. Effect of cultivar (G) on the duration of phases from sowing to heading and from sowing to full ripeness

Source of variation	Days from sowing to heading				Days from sowing to fully ripe			
	df	SS	η (%)	MS	df	SS	η (%)	MS
Total	39	17311.13	100.0	-	39	11589	100.0	-
Blocks	3	16960.94	97.98***	5653.646	3	11371.38	98.12***	3790.458
Options	9	197.625	1.14**	21.95834	9	87	0.75	9.66667
G	9	197.625	1.14**	21.95834	9	87	0.75	9.66667
Error	27	152.5625	0.88	5.650463	27	130.625	1.13	4.837963

It is evident that the environment exerts a strong dominant influence on the remaining traits – the number of grains per spike and plant height, accounting for 54.71% and 48.90%, respectively. These results contradict the conclusions of Mirosavljević et al. (2018) who reported a very low environmental influence on the number of grains per spike (10.6%) and the

proportion of variance explained by variety across different cereal species (5.3%). In terms of the duration from sowing to harvesting and the growing season, it was found that the environment accounts for the highest portion of the variation (97.98% and 98.12%, respectively), while the genotype only 1.14%), as shown in Table 5.

CONCLUSIONS

The study monitored key agronomic and economic characteristics of ten modern winter triticale varieties over a four-year period, including the duration of the growing season, days from sowing to heading, plant height, number of grains per spike, mass of a thousand-grain mass, and grain yields. The variability of these traits was assessed, and average values were compared with those of the Bulgarian standard variety Colorit. The effects of genotype and environment on each trait were also evaluated.

Varietal differences were primarily observed in thousand-grain mass and days to heading, with Colorit being the earliest to head.

The varieties with the shortest and longest periods from sowing full maturity were identified, as well as those with the best agronomic indicators.

Avocado and Casino demonstrated the highest thousand-grain mass and yields.

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