Response of Bulgarian triticale cultivars to unfavorable environments

Hristo Stoyanov
Dobrudzha Agricultural Institute – General Toshevo
E-mail: *hpstoyanov@abv.bg*

Citation
Stoyanov, H. (2020). Response of Bulgarian triticale cultivars to unfavorable environments. *Rastenievadni nauki, 57*(6) 17-29

Abstract
The potential for high yield from cultural plants such as triticale is related to the increase of the stability and plasticity of the cultivars. Therefore, it is necessary to test the different genotypes under variable conditions of the environment. However, specific deviations from the normal weather are being observed increasingly more often, related to limited and local phenomena, which, however, are the reason for strong decrease of yields. In order to study the response of triticale under such conditions, eleven cultivars, bred in Dobrudzha Agricultural Institute, were tested under two contrasting periods - 2014/2015 (favorable) and 2017/2018 (extremely unfavorable). The parameters days to heading, plant height, number of productive tillers, number of grains in spike, 1000 kernel weight, weight of grains in spike, yield and test weight were determined. The absolute and relative differences for each parameter and cultivar between two compared periods were established. The obtained results showed that the heading during the period unfavorable for triticale occurred with averagely 9 days earlier. In economic year 2017/2018, plant height did not follow the tendency typical for the investigated genotypes – cultivars Atila, Bumerang and Blagovest were with lower height than the typically shorter cultivars such as Vihren and Kolorit. The number of grains in spike during the unfavorable period was influenced by the considerably higher air temperatures in May, which was the reason for the lower yields. The late harvesting had significant effect on 1000 kernel weight, yield and test weight due to the long-lasting intermittent rainfalls in July of 2018. Cultivar Bumerang was characterized with highest yields and high plasticity based on the differences in the components of the yields between the two contrasting periods; this makes it highly valuable for growing in practice under the different soil and climatic conditions of Bulgaria.

Key words: abiotic stress; yield; components of yield; triticale; conditions of the environment

INTRODUCTION

Obtaining high yields from the cultural plants is related to the growing of cultivars, which are adaptable to certain soil and climatic conditions. This is associated with certain reactions of the plant organism to the unfavorable effects of the environment typical for the region, for which the respective cultivar was bred. Under the contemporary conditions of the climate, non-specific weather dynamics is being more frequently observed, which differs to a much higher degree from the long-term tendency typical for a certain geographic or micro-geographic region. This conditions untypical reactions in the plants of the grown cultivars and leads to rather low yields. Contemporary breeding is not able to quickly respond to such changeable environments. Nevertheless, it is characterized as a dynamic process aimed at developing on the one hand of a wide range of diverse genotypes, and on the other – of genotypes adaptable to a wide range of conditions. Such a process implies a detailed and thorough study on the response of a large number of developed lines to the variable and contrasting influences of the environment.

Triticale, although a typical cereal crop, is more tolerant to the unfavorable conditions of the environment (Motzo et al., 2015; Randhawa et al., 2015; Mendez-Espinosa et al., 2019). As early as the initial breeding stages of this crop, Larter et al. (1970) demonstrated with the first triticale cultivar they developed that the crop is considerably more tolerant to extremely unfavorable soil and climatic conditions. Lelley (2006) and Mergoum et al. (2009) also demonstrated the ability of triticale to realize high results when grown on acid, saline and poor soils, or in highly eroded soil horizons. The contemporary triticale cultivars also show very good tolerance to abiotic stress both with regard to yield and to its components (Cheshkova et al., 2018; Kendal et al., 2019; Bezabih et al., 2019; Aseeva & Zenkina, 2019; Suresh et al., 2020; Giunta et al., 2020).

Regardless of the high stress tolerance observed in triticale, there are certain combinations of the weather elements (temperature, precipitation, atmospheric humidity) which are capable of suppressing the normal development of the crop to such a degree that they reduce the absolute value of the yield. Such meteorological effects are related to sudden or long-lasting droughts, long periods with low temperatures without snow cover, long, abundant, uneven and intensive rainfalls during the maturation stages, etc. Under the conditions of South Dobrudzha, all of the above events were registered in certain periods of growing (Tsenov et al., 2012; Stoyanov, 2016; Stoyanov, 2018). Baychev (2013) clearly differentiated the response of the Bulgarian triticale cultivars he was investigating under contrasting environments. Similar conclusions on more recent triticale cultivars were made also by Stoyanov & Baychev (2018). Derejko et al. (2020) pointed out that while investigating contemporary triticale cultivars under the conditions of 58 locations in Poland during five successive economic periods, the growing conditions (environment and location) were with the highest importance for the formation of yield. The authors also observed that the period of growing was more important against high agronomy background, while the location was more significant against a low one. Such investigations allowed discriminating those genotypes which managed to a high degree to realize high yields or decreased less their yields under variable growing conditions. This is important from an economic point of view since in the last decade increasingly more dramatic changes in the weather are being observed, which are also becoming more frequent in comparison to the typical local weather.

The aim of this study was to analyze the behavior of Bulgarian triticale cultivars under the influence of unfavorable growing conditions in comparison to periods with environmental conditions typical for the region of South Dobrudzha.

MATERIAL AND METHODS

To realize the above aim, eleven triticale cultivars developed at Dobrudzha Agricultural Institute – General Toshevo were used: Kolorit, Atila, Akord, Respekt, Bumerang, Irnik, Dobrudzhanets, Lovchanets, Doni 52, Blagovest and Borislav. The investigated genotypes were grown as a whole-area crop in experimental plots of 10 m^2, in four replications in a standard block design within the framework of a competitive varietal trial. Planting was mechanized, within the standard dates for triticale (10^{th} – 15^{th} October), at density 550 gs/m^2. A wooden frame sized 0.25 m^2 was used to determine the number of tillers per m^2 in each experimental plot. Plant height (cm), absolute (t/ha) and relative yield (RY, %), test weight (kg/100 l), 1000 kernel weight (g) were also determined. The days to heading (number of days from 01.01), number of grains in spike and weight of grains in spike were established per cultivars. The data were compared to the adopted standards – AD-7291, Vihren, Rakita and the world standard for triticale Lasko and Presto.

Based on the results for productivity and the specificity of the meteorological parameters, two periods were identified, which were characterized as rather different with regard to the growth and development of the plants – 2014/2015 and 2017/2018. The differences in each yield parameter during the two periods were analyzed and the effect of the unfavorable conditions was assessed.

The absolute and relative difference between the two contrasting periods was determined for the investigated cultivars and parameters according to formulae 1 and 2.

$$AD = \overline{x}_{Nj} - \overline{x}_{Sj} \quad (1)$$

$$RD = \frac{\overline{x}_{Nj}}{\overline{x}_{Sj}} \quad (2)$$

where:

AD – absolute difference

RD – relative difference

x_{Nj} – value of the j[th] parameter during the period with favorable conditions for the development of triticale

x_{Sj} – value of the на j[th] parameter during the period with unfavorable conditions for the development of triticale

Based on the relative difference between the two periods, an index, which summarizes the effects from all investigated parameters was calculated using the formula

$$ADI = \prod_{j=1}^{n} \frac{\overline{x}_{Nj}}{\overline{x}_{Sj}} \quad (3)$$

where:

ADI – Additive Difference Index

j – the specific studied parameter

n – number of studied parameters

Microsoft Excel 2003 was used for summarizing the data and for all analyses carried out.

RESULTS AND DISCUSSION

Meteorologically, the studied periods were very distinct with regard to both the average monthly temperature and the monthly precipitation (Table 1). The observed differences both between the separate years and according to the long-term period implied different development of the plants and differing values of yield and its components. Nevertheless, the meteorological data did not give a sufficiently clear idea about the peculiarities, which influenced the growth and development of the studied cultivars. Table 2 presents specific expressions over the separate stages of the crop growth, which can be directly related to the effects on certain physiological processes or yield components.

Economic year 2017/2018 was characterized with the accumulation of a large number of negative events related to the growth and development of triticale. Considerable differences were observed in the expression of the main meteorological elements in comparison to economic year 2014/2015, and especially in comparison to the long-term tendency. Such occurrences, however, are of local nature and are highly unpredictable. Such single events as considerably high temperatures at the beginning of May, intensive rainfalls in June and extremely unusual intermittent rainfalls in July had a strong unfavorable effect since they were not typical for this region and the investigated genotypes were not bred specifically to these conditions.

The above peculiarities concerning the conditions of the environment were not uniform according to the expressions of the individual investigated genotypes. This was related to the fact that the greater part of the observed parameters were influenced both by the environmental conditions and the genotype, and by the interaction of the two factors, as reported by a large number of researchers (Fox et al., 1990; Alaru et al., 2004; Santiveri et al., 2004; Schwarte et al., 2005; Gibson et al., 2008; Szemplinski & Dubis, 2012; Baychev, 2013; Racz et al., 2013; Tuulos et al., 2015; Kirchev & Georgieva, 2017). Nevertheless, the effect of the two factors and their interaction on the yield and its individual parameters was not identical, but was related to the specificity of the genetic system controlling it (Farshadfar & Sutka, 2003). The more complex a given parameter is, the greater the possibility to observe varied reactions under the same conditions of the environment. Therefore, in order to clarify to what extent the unfavorable conditions influenced the studied genotypes, it was necessary to consider independently yield and its components.

Table 1. Meteorological parameters for the period of study

Parameter	Year	Sep	Oct	Noe	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
AMT, ºC	2014/2015	17.5	11.2	5.6	3.1	1.4	2.0	5.0	10.1	16.4	19.4	22.4
	2017/2018	19.0	11.8	7.5	4.7	1.7	1.1	4.6	13.4	17.7	20.4	22.2
	1960/2018	16.9	11.6	6.7	1.9	-0.3	1.1	4.6	9.9	15.2	22.0	21.4
TMP, mm	2014/2015	31.4	57.9	33.2	87.0	33.2	79.5	67.7	8.5	12.9	31.3	27.2
	2015/2016	20.8	78.3	55.1	0.4	86.3	40.7	52.7	20.8	117.1	55.7	2.8
	1960/2018	46.4	42.3	43.5	42.0	37.2	34.5	35.9	40.3	52.4	59.1	52.1

AMT – Average monthly temperatures; TMP – Total monthly precipitations

Table 2. Peculiarities in contrasting growing periods

Months	2014/2015		2017/2018	
	Specificity of the growing period	Effect on the growth and development of the plants	Specificity of the growing period	Effect on the growth and development of the plants
October	Good available moisture reserves	Good optimal density and distribution of the plants in the crop	Low available moisture in soil	Long and uneven emergence of plants
November December January February	A warmer winter period in comparison to the long-term tendency but with occurrence of low temperatures in January	Optimal tillering typical for the crop	A considerably warmer winter period	A longer period of tillering of the plants
March	Good available moisture reserves in soil and low temperatures	Normal growth after the winter period	Good available moisture reserves in soil and moderate temperatures	Accelerated growth
April	Moderate temperatures and drought	Retarded growth, no heading	High temperatures and no moisture	Acceleration of the generative processes
May	Moderate temperatures	Normal occurrence of the pollination and fertilization processes	Very high air temperatures	Lower pollen viability
June	A comparatively dry period	Good nutrition of grain, no lodging	Uneven rainfalls	Occurrence of lodging
July	Rainfalls in the second half of the month	Harvesting within the optimal dates	Long-lasting rainfalls	Longer period of harvesting

Table 3. Values of the investigated parameters for economic year 2014/2015

Cultivar	DH	PH, cm	NPT	Yield		M1000, g	TW, kg/100l	WGS, g	NGS
				kg/da	RY, %				
Mean standard (B+P+K)/3	*130*	*120*	*637*	*675*	*100,0*	*43,3*	*72,7*	*1,06*	*25*
AD 7291	130	108	598	589	87,3	41,9	73,0	0,98	24
Vihren	131	113	598	609	90,2	45,1	73,5	1,02	23
Rakita	131	126	644	725	107,4	42,6	72,5	1,12	26
Lasko	131	131	802	765	113,3	42,6	75,5	0,95	22
Presto	131	134	771	777	115,1	42,2	76,0	1,01	24
Kolorit	129	122	668	691	102,4	42,1	72,0	1,04	25
Atila	131	132	651	763	113,0	46,9	74,5	1,17	25
Akord	132	129	672	767	113,6	45,4	75,0	1,14	25
Respekt	132	124	677	704	104,3	43,7	75,0	1,05	24
Bumerang	131	129	722	779	115,4	48,0	75,0	1,08	23
Irnik	131	128	635	793	117,5	40,1	72,5	1,25	31
Dobrudzhanets	130	115	641	643	95,3	41,8	74,0	1,00	24
Lovchanets	132	119	718	649	96,1	40,0	72,5	0,90	23
Doni 52	132	126	794	803	119,0	41,4	74,5	1,01	24
Blagovest	132	125	741	747	110,7	41,2	74,0	1,01	24
Borislav	131	115	688	839	124,3	51,9	73,0	1,22	24
Average	**131**	**124**	**689**	**728**	**107,8**	**43,6**	**73,9**	**1,06**	**24**
LSD 0,05	*0,4*	*3,7*	*31,3*	*35,9*	*5,32*	*1,56*	*0,60*	*0,05*	*1,0*
LSD 0,01	*0,5*	*4,9*	*41,2*	*47,2*	*6,99*	*2,06*	*0,79*	*0,06*	*1,4*
LSD 0,001	*0,7*	*6,2*	*52,6*	*60,3*	*8,93*	*2,63*	*1,01*	*0,08*	*1,7*

DH – days to heading, PH – plant height, NPT – number of productive tillers, RY – relative yield, M1000 – thousand kernels weight, TW – test weight, WGS – weight of grains in spike, NGS – number of grains in spike.

Table 4. Values of the investigated parameters for economic year 2017/2018

Cultivar	DH	PH, cm	NPT	Yield		M1000, g	TW, kg/100l	WGS, g	NGS
				kg/da	RY, %				
Среден стандарт (В+Р+К)/3	*120*	*128*	*668*	*708*	*100,0*	*41,6*	*66,5*	*1,07*	*26*
AD-7291	119	117	694	637	90,0	40,8	65,8	0,92	22
Vihren	120	126	675	745	105,3	42,3	68,0	1,10	26
Rakita	121	131	754	717	101,3	39,7	65,4	0,95	24
Lasko	121	126	803	631	89,2	39,5	67,8	0,79	20
Presto	121	123	829	624	88,2	44,0	68,8	0,75	17
Kolorit	120	126	576	661	93,4	42,9	66,0	1,15	27
Atila	125	116	701	609	86,1	45,6	68,6	0,87	19
Akord	124	120	642	584	82,5	43,5	68,4	0,91	21
Respekt	126	106	776	563	79,6	41,8	68,8	0,73	17
Bumerang	124	120	659	745	105,3	45,7	70,0	1,13	25
Irnik	122	119	760	634	89,6	39,6	66,6	0,83	21
Dobrudzhanets	121	107	736	664	93,8	42,7	69,2	0,90	21
Lovchents	121	112	772	624	88,2	40,4	68,8	0,81	20
Doni 52	122	122	771	700	98,9	42,2	68,6	0,91	22
Blagovest	122	113	790	636	89,9	40,3	67,2	0,81	20
Borislav	121	112	704	602	85,1	48,6	66,4	0,85	18
Average	**122**	**119**	**728**	**649**	**91,6**	**42,5**	**67,8**	**0,90**	**21**
LSD 0,05	*0,9*	*3,5*	*33,0*	*26,4*	*3,73*	*1,26*	*0,67*	*0,06*	*1,5*
LSD 0,01	*1,2*	*4,6*	*43,4*	*34,7*	*4,90*	*1,65*	*0,88*	*0,08*	*1,9*
LSD 0,001	*1,6*	*5,9*	*55,4*	*44,3*	*6,26*	*2,11*	*1,13*	*0,11*	*2,5*

DH – days to heading, PH – plant height, NPT – number of productive tillers, RY – relative yield, M1000 – thousand kernels weight, TW – test weight, WGS – weight of grains in spike, NGS – number of grains in spike.

1. Days to heading

During the period favorable for the growth and development of triticale (2014/2015), cultivars Kolorit (129 days) and Dobridzhanets (130 days) were the earliest to start heading; they were at the level of the early standard AD-7291 (Table 3). The standards Vihren and Rakita were equal by their time to heading (131 days). At the level of the standard Rakita were cultivars Atila, Bumerang, Irnik and Borislav. Significantly later days to heading had cultivars Akord, Respekt, Lovchanets, Doni 52 and Blagovest.

In economic year 2017/2018, the cultivars started heading considerably earlier (with an average of up to 9 days). The earliest to begin heading were the standards AD-7291 (119 days), Vihren (120 days) and Kolorit (120 days). Rakita significantly exceeded the rest of the standards (121 days) by days to heading. Considerably later were Atila, Akord, Respekt and Bumerang. At the level of Rakita were Lasko, Presto, Dobrudzhanets, Lovchanets and Borislav.

The greatest absolute difference in the parameter was observed in the cultivars, which began heading earlier, during the unfavorable period – AD-7291, Vihren, Rakita, Lasko, Presto, Lovchanets, Doni 52, Blagovest and Borislav. This was related to the fact that during economic year 2017/2018 the cultivars started heading within a considerably wide range (7 days), while in 2014/2015 the heading occurred within 3 days. Such data showed that the individual genotypes responded differently to the stress conditions of the environment. The higher temperatures during April – May of 2018 were the reason the earlier genotypes to develop considerably faster. On the other hand, the later cultivars, with the aim to avoid the higher temperatures, which would impede the proper pollination and fertilization, retarded their development by heading later, and therefore were closer to the values typical for the favorable period.

The results for the two periods of growing, regardless of their contrasting nature, showed that the greater part of the cultivars followed a tendency to approximate the mean value of the parameter. Similar conclusions also made Stoyanov (2018), Stoyanov & Baychev (2018) and Baychev (2013) on the same cultivars, comparing other unfavorable periods of growing.

2. Plant height

In 2014/2015, the standards AD-7291 and Vihren were with the lowest height. This was a peculiarity of the two cultivars since they have a wheat type of development characterized with shorter plants (Tsvetkov, 1989). Considerably higher was the standard cultivar Rakita (rye type of development), which significantly exceeded the mean standard by height. The world standards Lasko and Presto were significantly higher than Rakita. Cultivars Atila, Akord, Bumerang and Irnik were also very high, Atila being the highest (132 cm). Cultivars Dobrudzhanets and Borislav were at the level of Vihren. Cultivars Respekt, Doni 52 and Blagovest were at the level of the standard Rakita. Kolorit and Lovchanets were characterized with lower height, at the level of the mean standard (120 cm).

Quite different data were observed with regard to economic year 2017/2018. Cultivars Vihren (126 cm), Rakita (131 cm), Lasko (126 cm) and Kolorit (126 cm) were with the highest plants. Such data are not typical for these cultivars, even under very contrasting conditions of the environment (Baychev, 2013; Stoyanov, 2018), with the exception of Lasko. At the same time, typically high cultivars such as Atila (116 cm), Bumerang (120 cm), Blagovest (113 cm) and Presto (123 cm) demonstrated considerably lower values of this parameter. In these cultivars, the greatest absolute difference between the values of the two compared periods was observed. This was an indication that the untypical conditions of the environment (considerably higher temperatures during the vegetative growth in April and May of 2018) had a very strong effect on the vegetative development of these cultivars. The results, obtained by Bezabih et al. (2019) on seven triticale cultivars under the conditions of Ethiopia showed that plant height may vary significantly under different conditions of the environment. Air temperature and the availability of good moisture reserves in soil were crucial for this parameter.

3. Number of tillers

During the favorable 2014/2015, the standards AD-7291 and Vihren had the same values for number of tillers and were with significantly lower tillering than the standard Rakita. The world standard Lasko was with the highest tillering (802 tillers per m^2), followed by Doni 52 and Presto. Cultivars Kolorit, Atila, Akord, Irnik, Dobrudzhanets were at the level of the standard Rakita. Significantly higher tillering was registered in Respekt, Bumerang, Lovchanets, Blagovest and Borislav.

In economic year 2017/2018, the highest number of tillers was registered in cultivar Presto (829 tillers per m^2), and the lowest – in cultivar Kolorit (576 tillers per m^2). Rakita was with higher values than the standard, and Vihren and AD-7291 - with lower. Only three cultivars exceeded significantly Rakita – Lasko, Presto and Blagovest. Respekt, Irnik, Dobrudzhanets, Lovchanets and Doni 52 had significantly stronger tillering than the standard Vihren.

Concerning the absolute difference between the two compared periods, various reactions were observed depending on the genotype. In some cultivars (Rakita, Irnik, Respekt and Dobrudzhanets), significantly higher values were determined in economic year 2017/2018 in comparison to 2014/2015. This indicated that in spite of the unfavorable conditions for formation of a good seed set in 2017/2018, the conditions for the occurrence of the tillering process were considerably better. The winter and post-winter periods were characterized with very high temperatures, which in fact facilitated the formation of considerably more tillers. In such cultivars as Kolorit, Akord, Bumerang and Doni 52, however, the absolute difference was negative, i.e. a lower number of tillers were formed during economic year 2017/2018. The reason for this was their comparatively long emergence in the autumn (in contrast to the rest of the cultivars) and the non-uniform formation of productive tillers during the plant development. The respective late-emerging plants formed less tillers. Data on the strong effect of the environment on the number and formation of productive tillers has been reported by Alaru et al. (2004) and Kirchev & Georgieva (2017). There is no general tendency in most of the cultivars and this was due to the significant effect of the factor genotype x environment, as reported by Villegas et al. (2010), Giunta et al. (1992) and Racz et al. (2013).

4. Number of grains in spike

In economic year 2014/2015, cultivar Rakita was with better seed set (26 grains per spike), which significantly exceeded Vihren (23 grains in spike) and AD-7291 (23 grains in spike). All investigated cultivars, with the exception of Irnik (31 grains in spike), were significantly below the values of Rakita. Cultivars Presto, Kolorit, Atila, Akord, Respekt, Dobrudzhanets, Lovchanets, Doni 52 and Blagovest were significantly above the seed set formed in Vihren and AD-7291. Cultivars Bumerang and Borislav were at the level of the two standards Vihren and AD-7291. The world standard Lasko (22 grains in spike) formed the lowest number of grains and was significantly below all standards.

In economic year 2017/2018, the grains observed in the investigated cultivars were with 3 less, on the average. The highest values were realized by cultivars Kolorit (27 grains in spike) and Bumerang (25 grains in spike). Respective significantly lower seed set was determined in Presto (17 grains in spike), Atila (19 grains in spike), Respekt (17 grains in spike) and Borislav (18 grains in spike). Above the standard Vihren with a better seed set (26 grains in spike), significantly higher values were not observed.

Very high absolute differences between the two observed periods were determined in cultivars Presto, Atila, Akord, Respekt, Irnik and Borislav. The rest of the cultivars were close to the mean value between the two periods. The reason for the observed differences in the seed set could be found in the higher temperatures during the anthesis of the studied cultivars. The considerably warmer weather was the reason for the lower viability of the pollen leading to lower seed set. In cultivars Kolorit and Bumerang, a positive difference was observed showing higher seed set during the unfavorable period. This difference was related to the lower number of productive tillers as a result from the non-uniform development of the plants. In crops characterized with lower tillering, the seed set was higher (Stoyanov, 2018; Stoyanov, 2020). This, however, was strictly dependent both on the genotype and on the environmental conditions (Giunta & Motzo, 2004; Stoyanov, 2020).

This parameter was characterized with exceptional susceptibility in such a crop as triticale (Kavanagh & Hall, 2015). Therefore, even the smallest changes in the conditions of the environment may influence its values. A number of authors (Santiveri et al., 2004; Gibson et al., 2008; Dogan et al., 2009; Villegas et al., 2010; Cifci et al., 2010; Racz et al., 2013; Madic et al., 2018) pointed out that the conditions of the environment had serious effect on the seed set of this crop. Kinaci & Gulmezoglu (2007), comparing two rather contrasting periods, observed almost twice as low number of grains in spike as a result from the low available moisture in soil and the high temperatures during the period after heading. Ugarte et al. (2007) emphasized the importance of the thermal stress in the period from heading to anthesis for the number of obtained grains.

5. 1000 kernel weight

During economic year 2014/2015, the standard Vihren was with higher values of 1000 kernel weight (45.1 g), which significantly exceeded Rakita (42.6 g) and AD-7291 (41.9 g). Cultivars Lasko, Presto, Kolorit, Respekt, Dobrudzhanets, Doni 52 and Blagovest were at the level of the standard Rakita. Cultivar Akord was at the level of the standard Vihren. Cultivars Atila, Bumerang and Borislav were with the highest values, significantly exceeding all three standards. At the same time, cultivar Borislav differed from the rest of the varieties with its very high values of 1000 kernel weight.

The same tendency of Atila, Bumerang and Borislav exceeding significantly all three standards was established in 2017/2018. In fact, the tendency between the cultivars remained the same, but the mean value was with 1.1 g lower.

Concerning the absolute differences between the two economic years, highest was the difference in 1000 kernel weight of cultivar Borislav. Such response is typical for the cultivar since the parameter is a main component of its yield (Baychev et al., 2016; Stoyanov & Baychev, 2016). Greater differences were observed in the older standard varieties Vihren and Rakita and the world standard Lasko. The main reason for the decrease of 1000 kernel weight in the investigated genotypes were the untypical and long-lasting rainfalls during July of 2018. In this month, there were rainfalls in 13 out of 31 days. This caused elongation of the harvesting time with more than 20 days. The respective late harvest lead to unfavorable values of the grain parameters (Clarke, 1981; Czarnecki & Evans, 1986; Farrer et al., 2006). The literature on triticale does not give information about researches generalizing results about the effect of the late harvesting on 1000 kernel weight, and about the effect of the environmental conditions during the period from readyfor-harvest to actual harvesting. Such researches on contemporary wheat cultivars are also rare. Pool et al. (1958) and Johnson (1959) reported such effects. Czarnetski & Evans (1986) pointed out that the effects on 1000 kernel weight at late harvesting of wheat could vary from insignificant to considerable and were largely dependent on the genotype and the environment, but without observing effects from the interaction of the two factors. These authors mentioned a decrease of the parameter with 1.4 %, which corresponded to our results (2.5 %).

Very important for this parameter were also the temperature and rainfalls during the formation of grain (May-June in this case). Kucerova (2007), Đekić et al. (2013), Villegas et al. (2010), Motzo et al. (2015), Stoyanov (2018) reported such effects on triticale under variable conditions of the environment. Effect of the thermal stress on the values of the parameter was observed by Ugarte et al. (2007). These authors emphasized that the high temperatures in the period from heading to anthesis caused serious decrease in 1000 kernel weight. Kinaci and Gulmezoglu (2007) registered serious decrease of 1000 kernel weight in triticale due to the low precipitation in the period after heading. Such data demonstrate that the accumulation of the effects from different events may cause strong decrease of 1000 kernel weight.

6. Weight of grains in spike

In economic year 2014/2015, Rakita was with the highest values of weight of grain in spike (1.12 g) among the standard varieties, significantly exceeding AD-7291 and Vihren. At the level of Rakita were cultivars Akord and Bumerang. Atila, Irnik and Borislav significantly exceeded Rakita by this parameter. Cultivars Presto, Kolorit, Respekt, Dobrudzhanets, Doni 52 and Blagovest were at the level of Vihren, with significantly lower values than Rakita. Lasko and Lovchanets were with significantly lower values than Vihren. Cultivars Irnik (1.25 g), Borislav (1.22 g) and Atila (1.17 g) were with the highest values of weight of grains in spike. The world standard Lasko (0.95 g) and cultivar Lovchanets (0.90 g) were characterized with very low values.

In 2017/2018, lower values of the parameter were observed in a greater part of the investigated cultivars. Highest spike productivity was registered in cultivars Vihren (1.10 g), Kolorit (1.15 g) and Bumerang (1.13 g). Results significantly above those of the better standard Vihren were not observed. Very low results for the parameter were determined in the world standard Lasko (0.79 g), Presto (0.75 g) and cultivar Respekt (0.73 g), which were significantly below the values of the standard AD-7291 (0.92 g).

The highest absolute differences in the parameter between the two periods were read in cultivars Presto, Akord, Respekt, Irnik and Borislav. These values followed the tendency of the number of grains in spike. This was related to the fact that in the investigated genotypes, a major element in the spike productivity were the grains formed in the spike. The weight of grains in the spike is a complex parameter, which follows the change of both the number of grains in spike and 1000 kernel weight. Since both parameters were affected by different factors of the environment, their influence on the weight of grains in spike were related to both the effect of the high temperatures during heading and anthesis and to the rainfalls in July of 2018. A cumulative effect on the weight of spike has been reported also by Kinaci and Gulmezoglu (2007), who observed up to 3 times lower values during the unfavorable period.

7. Yield

During 2014/2015, the standard with the better behavior was cultivar Rakita (725 kg/dca). Vihren (609 kg/dca) and AD-7291 (589 kg/dca) differed significantly from both Rakita and the mean standard. The world standard Lasko and cultivar Presto also realized high yields, significantly above the mean standard, 765 and 777 kg/dca, respectively, and the exceeding was with 14.6 and 16.4 %. Cultivars Atila, Akord, Respekt, Bumerang, Irnik, Doni 52, Blagovest and Borislav significantly exceeded the mean standard. Cultivars Irnik (18.8 %), Doni 52 (20.3 %) and Borislav (25.8 %) were with the highest exceeding of the mean standard; their yields were 793, 803, 839 kg/dca, respectively. Kolorit, Dobrudzhanets and Lovchanets were at the level of the mean standard.

During 2017/2018, which was unfavorable for the development of triticale, only Bumerang (745 kg/dca) and the standard Vihren (745 kg/dca) exceeded the mean standard with 5.3 %. At the level of the mean standard were Rakita (717 kg/dca) and Doni 52 (700 kg/dca), while all other cultivars demonstrated significantly lower yields than the mean standard. Lowest results were obtained from cultivars Akord (584 kg/dca), Respekt (563 kg/dca) and Borislav (602 kg/dca).

The complex accumulation of negative effects from the changes in the environmental conditions according to the conditions typical for the region lead to an average difference in yield from the studied cultivars of 79 kg/dca. The highest absolute difference was observed in cultivars Kolorit, Akord, Irnik, and especially in cultivar Borislav. In cultivar Borislav, the difference between the values in the favorable period 2014/2015 and the unfavorable 2017/2018 was more than 200 kg/dca. Although the number of productive tillers was higher, the grains formed were less, and the most affected component was 1000 kernel weight. This indicated that cultivars such as Borislav, which possesses an exceptionally high production potential, were less stable under sharp changes of the weather. Similar were the results of cultivars Presto, Akord, Atila and Irnik.

The results for the yield of the investigated cultivars confirmed the strongly contrasting nature of the two compared periods. During economic year 2014/2015, out of the investigated 16 genotypes, 10 exceeded significantly the mean standard (Rakita, Lasko, Presto, Atila, Akord, Bumerang, Irnik, Doni 52, Blagovest and Borislav). Significant differences below the mean standard were observed only in two cultivars AD-7291 and Vihren. In harvest year 2017/2018, in 12 (AD-7291, Lasco, Presto, Kolorit, Atila, Akord, Respekt, Irnik, Dobrudzhanets, Lovchanets, Blagovest and Borislav) out of the 16 investigated genotypes yields were observed, which were significantly below the mean standard. Only two cultivars, Vihren and Bumerang, exceeded significantly the mean standard.

A large number of the researches on this crop (Dhindsa et al., 2002; Cifci et al., 2010; Kirchev et al., 2014; Kirchev et al., 2016) proved that the effect of the environment on the yield formation was often above 50%. Kinaci & Gulmezoglu (2007) observed from 1.5 to 3 times lower yields under low precipitation during one of the two investigated periods. Ugarte et al. (2007) registered various effects on the yield as a result from thermal stress during different stages, its impact being especially negative in the period from booting to flag leaf. The same authors reported also significant effects of the high temperatures in the period from heading to anthesis, too. Farrer et al. (2006) observed decrease of yield in common winter wheat with up to 90 kg/dca at elongation of the period to harvesting. These researches are indicative for a significant effect of the meteorological factors and their peculiarities on the yield values during the specific period of growing.

8. Test weight

In economic year 2014/2015, the standard Vihren realized a significantly higher test weight than the standard Rakita. Simultaneously, AD-7291 was in an intermediate position between Vihren and Rakita. Cultivars Lasko, Presto, Atila, Akord, Respekt, Bumerang, Dobrudzhanets, Doni 52 and Blagovest realized significantly high test weight according to the standard Rakita. At the level of Rakita were Kolorit, Irnik, Lovchanets and Borislav. The test weight of cultivar Presto was with the highest values during this period (76 kg/100 l), followed by Lasko (75.5 kg/100 l) and Akord (75 kg/100 l), Respekt (75 kg/100 l), Bumerang (75 kg/100 l). Cultivar Kolorit was with the lowest value of test weight (72 kg/100 l).

During the unfavorable period 2017/2018, the standard Vihren (68 kg/100 l) was also with a significantly higher test weight in comparison to the standard Rakita (65.4 kg/100 l). Only cultivars Bumerang (70 kg/100 l) and Dobrudzhanets (69.2 kg/100 l) exceeded significantly the standard Vihren. Very low values were determined in cultivars Kolorit (66 kg/100 l), Irnik (66.6 kg/100 l) and Borislav (66.4 kg/100 l).

Test weight was significantly affected by the conditions of 2017/2018. The highest difference according to the period favorable for growing of triticale 2014/2015 was observed in the older cultivars AD-7291, Rakita, Lasko and Presto – over 7 kg/100 l. The test weight was respectively affected to the highest degree in the cultivars with highest values Bumerang and Dobrudzhanets, as well as cultivar in Lovchanets, which was characterized with lower test weight in principle. The effect on this parameter was very strong since the elongation of the period for harvesting strongly deteriorated the physical properties of grain.

Baychev (2013) clearly emphasized that the unfavorable period for the development of the crop decreased the values of test weight. Similar results have been reported also by Barnett et al. (2006), Kucerova (2007) and Cifci et al. (2010). Farrer et al. (2006) observed the decrease of test weight with up to 11.5 kg/100 l in common winter wheat, relating these values to the availability of rainfalls in the period from ready-to-harvest to the actual harvesting of grain. Czernacki & Evans (1986) observed the decrease of test weight to 5 kg/100 l, pointing out to differences between the studied genotypes.

9. Relative differences and Additive difference index

The results obtained as relative differences between the two observed contrasting periods allowed comparing the effects of the unfavorable conditions on each of the investigated parameters. Based on the mean relative differences, the parameter 1000 kernel weight was the least affected by the unfavorable conditions of the environment. Comparatively low was the impact on the parameters plant height and date to heading, too. Most affected were yield, weight of grains in spike and number of grains in spike. Test weight was also influenced because its values were untypically low, although the mean relative difference was not too high. Specific was the response of the parameter number of productive tillers. Its mean relative difference was below 1.00 indicating that the parameter reacted favorably to the conditions of the environment. The higher number of productive tillers, however, is often related to unfavorable values of yield (Stoyanov, 2018).

Concerning the individual genotypes, cultivar Borislav was with the highest cumulative effect of accumulated relative differences (4.87). Cultivars Presto (3.58), Atila (3.60), Akord (3.73), Respekt (4.06) and Irnik (3.89) were also with high values of ADI. The lowest values of this parameter were of cultivars Kolorit (1.22), Bumerang (1.38), Dobrudzhanets (1.31) and Lovchanets (1.59). In Bumerang and Dobrudzhanets, the lower values were related to lower differences between the parameters in the two periods. In Lovchanets, the number of productive tillers turned out to be determining for productivity. The small difference in it was related to a lower possibility for variation of the rest of the yield components. The low difference in Kolorit was related to higher seed set during the unfavorable period.

The obtained results showed that the cultivars, which required optimal conditions to realize their production potential (according to Stoyanov, 2018) such as Akord, Respekt and Irnik, reacted in an ex-

Table 5. Absolute differences between the values of the investigated parameters for the favorable and unfavorable period

Сорт	DH	PH, cm	NPT	Yield		M1000, g	TW, kg/100l	WGS, g	NGS
				kg/da	RY, %				
AD 7291	-11	9	96	48	2,8	-1,1	-7,2	-0,06	-1,5
Vihren	-11	13	77	136	15,1	-2,8	-5,5	0,08	3,3
Rakita	-10	5	110	-8	-6,1	-2,9	-7,1	-0,17	-2,4
Lasko	-10	-5	1	-134	-24,2	-3,1	-7,7	-0,16	-2,4
Presto	-10	-11	58	-153	-26,9	1,8	-7,2	-0,26	-6,9
Kolorit	-9	4	-92	-30	-9,0	0,8	-6	0,11	2,4
Atila	-6	-16	50	-154	-27,0	-1,3	-5,9	-0,3	-6
Akord	-8	-9	-30	-183	-31,1	-1,9	-6,6	-0,23	-4,2
Respekt	-6	-18	99	-141	-24,7	-1,9	-6,2	-0,32	-7
Bumerang	-7	-9	-63	-34	-10,1	-2,3	-5	0,05	2,5
Irnik	-9	-9	125	-159	-27,9	-0,5	-5,9	-0,42	-10,1
Dobrudzhanets	-9	-8	95	21	-1,4	0,9	-4,8	-0,1	-2,9
Lovchanets	-11	-7	54	-25	-8,0	0,4	-3,7	-0,09	-2,5
Doni 52	-10	-4	-23	-103	-20,0	0,8	-5,9	-0,1	-2,4
Blagovest	-10	-12	49	-111	-20,8	-0,9	-6,8	-0,2	-4,4
Borislav	-10	-3	16	-237	-39,2	-3,3	-6,6	-0,37	-5,5
Mean	-9	-5	39	-79	-16,2	-1,1	-6,1	-0,16	-3

DH – days to heading, PH – plant height, NPT – number of productive tillers, RY – relative yield, M1000 – thousand kernels weight, TW – test weight, WGS – weight of grains in spike, NGS – number of grains in spike.

Table 6. Relative differences between the values of the investigated parameters during the favorable and unfavorable period

Cultivar	DH	PH, cm	NPT	Yield		M1000, g	TW, kg/100l	WGS, g	NGS	ADI
				kg/da	RY, %					
AD 7291	1.09	0.92	0.86	0.92	0.97	1.03	1.11	1.07	1.07	1.01
Vihren	1.09	0.90	0.89	0.82	0.86	1.07	1.08	0.93	0.87	0.57
Rakita	1.08	0.96	0.85	1.01	1.06	1.07	1.11	1.18	1.10	1.47
Lasko	1.08	1.04	1.00	1.21	1.27	1.08	1.11	1.20	1.12	2.80
Presto	1.08	1.09	0.93	1.25	1.31	0.96	1.10	1.35	1.41	3.58
Kolorit	1.08	0.97	1.16	1.05	1.10	0.98	1.09	0.90	0.91	1.22
Atila	1.05	1.14	0.93	1.25	1.31	1.03	1.09	1.34	1.32	3.60
Akord	1.06	1.08	1.05	1.31	1.38	1.04	1.10	1.25	1.20	3.73
Respekt	1.05	1.17	0.87	1.25	1.31	1.05	1.09	1.44	1.41	4.06
Bumerang	1.06	1.08	1.10	1.05	1.10	1.05	1.07	0.96	0.90	1.38
Irnik	1.07	1.08	0.84	1.25	1.31	1.01	1.09	1.51	1.48	3.89
Dobrudzhanets	1.07	1.07	0.87	0.97	1.02	0.98	1.07	1.11	1.14	1.31
Lovchanets	1.09	1.06	0.93	1.04	1.09	0.99	1.05	1.11	1.13	1.59
Doni 52	1.08	1.03	1.03	1.15	1.20	0.98	1.09	1.11	1.11	2.08
Blegovest	1.08	1.11	0.94	1.17	1.23	1.02	1.10	1.25	1.22	2.78
Borislav	1.08	1.03	0.98	1.39	1.46	1.07	1.10	1.44	1.31	4.87
Mean	1.08	1.04	0.95	1.12	1.18	1.03	1.09	1.18	1.15	2.50

DH – days to heading, PH – plant height, NPT – number of productive tillers, RY – relative yield, M1000 – thousand kernels weight, TW – test weight, WGS – weight of grains in spike, NGS – number of grains in spike, ADI – Additive Difference Index.

tremely unfavorable way to the sharp changes in the conditions of the environment. Simultaneously, genotypes such as Bumerang and Dobrudzhanets, which were characterized with greater plasticity (according to Stoyanov, 2018) also reacted strongly but maintained their productivity above the average level. On the other hand, the stable cultivars such as Doni 52 and Blagovest, although their separate yield components responded weakly, realized more significant changes in the value of the yield due to the accumulation of the individual effects.

The effects of the highly unfavorable period for growing of triticale such as 2017/2018 showed that the cultivars with greater plasticity were with higher tolerance to effects of limiting and local character. At the same time, the high-yielding and stable genotypes did not manage to respond adequately to the sharp changes in the conditions of the environment. From a breeding point of view, it is necessary to look for certain cultivars that could respond to the changeable climatic conditions. This make cultivar Bumerang an exceptional genotype that can be grown under differing and variable soil and climatic conditions in Bulgaria, which is meanwhile also a valuable initial breeding material for improvement work on winter hexaploid triticale.

CONCLUSIONS

Based on the presented results, the following conclusions can be drawn:

1. Heading during the unfavorable period of triticale occurred with 9 days earlier on the average, observing smaller differences between the two compared periods in cultivars with earlier date to heading such as Atila, Akord, Respekt and Bumerang.

2. In economic year 2017/2018, plant height did not follow the typical tendency of the investigated genotypes; cultivars Atila, Bumerang and Blagovest were shorter than the typically shorter cultivars Vihren and Kolorit.

3. The considerably warmer winter period was the reason for the higher number of productive tillers in the greater part of the cultivars, with the exception of only Kolorit, Akord, Bumerang and Doni

52, in which the lower values were due to uneven emergence as a result from the autumn drought.

4. The higher air temperature during the period after heading influenced the number of grains in spike, which caused decrease of yield.

5. Late harvesting had a considerable impact on 1000 kernel weight, weight of grains in spike, yield and test weight due to the intermittent rainfalls in July of 2018.

6. Cultivar Bumerang was characterized with the highest yields and the highest plasticity, which makes it exceptionally valuable for mass growing in practice under the different soil and climatic conditions of Bulgaria.

REFERENCES

Alaru, M., Moller, B., & Hansen, A. (2004). Triticale yield formation and quality influenced by different N fertilisation regimes. *Agronomy Research, 2*(1), 3-12.

Aseeva, T. A., & Zenkina, K. V. (2019). Adaptability of Spring Triticale Varieties in the Agroecological Conditions of the Middle Amur. *Russioan Agricultural Sciences, 45*, 112-114.

Barnett, R .D., Blount, A. R., Pfahler, P. L., Bruckner, P. L., Wesenberg, D. M., & Johnson, J. W. (2006). Environmental stability and heritability estimates for grain yield and test weight in triticale. *J Appl Genet, 47*(3): 207-213.

Baychev, V. (2013). Triticale Lines and Varieties Grown under Contrasting Meteorological Conditions. Scientific Works of Instiute of Agriculture – Karnobat, 2(1), 79-86.

Baychev, V., Stoyanov, H., & Mihova, G. (2016). Borislav – new triticale cultivar with unique yield potential. Scientific works of Institute of Agriculture - Karnobat, (in press) (Bg).

Bezabih, A., Girmay, G., & Lakewu, A. (2019). Performance of triticale varieties for the marginal highlands of Wag-Lasta, Ethiopia. Cogent Food & Agriculture, 5:1, 1574109

Cifci, E.A., Bilgili, U., & Yagdi, K. (2010). Grain yield and quality of triticale lines. *Journal of Food, Agriculture & Environment, 8*(2), 558-564.

Cheshkova, A., Stepochkin, P., Aleynikov, A., Grebennikova, I., & Chanyshev, D. (2018). A comparative study of spring triticale varieties in the Western Siberian forest-steppe zone under different conditions of vegetation. *Vavilov Journal of Genetics and Breeding, 22*(3), 304-309. DOI 10.18699/VJ18.364 (Ru).

Clarke, J. M. (1981). Effect of delayed harvest on shattering losses in oats, barley and wheat. Canadian Journal of Plant Science, 61, 25-28.

Czarnecki, E., & Evans, L. E. (1986). Effect of weathering during delayed harvest on test weight, seed size, and grain hardness of wheat. Canadian Journal of Plant Science, 66, 473-482.

Derejko, A., Studnicki, M., Wojcik-Gront, E., & Gace, E. (2020). Adaptive Grain Yield Patterns of Triticale (xTriticosecale Wittmack) Cultivars in Six Regions of Poland. Agronomy, 10, 415, doi:10.3390/agronomy10030415

Dhindsa, G. S., Dosanjh, A. S., Sohn, V. S., Dhindsa, J. S., & Goyali, J. C. (2002). Genotype x Environment interaction for yield components in hexaploid triticale. Proceedings of the 5th International Triticale Symposium, Volume II, June 30 - July 5, 2002, Radzikow, Poland, 199-200.

Đekić, V., Milovanović, M., Staletić, M., Popović, V., & Branković, S. (2013). Parametri rodnosti tritikalea na zemljištu tipa vertisol. Bilten za alternativne biljne vrste, Vol. 45, No. 86, 48-54.

Dogan, R., Kacar, O., Coplu, N., & Azkan, N. (2009). Characteristics of new breeding lines of triticale. African Journal of Agricultural Research, 4(2): 133-138.

Farrer, D., Weisz, R., Heiniger, R., Murphy, J. P., & Pate, M. H. (2006). Delayed Harvest Effect on Soft Red Winter Wheat in the Southeastern USA. Agronomy Journal, 93, 3, 588-595.

Farshadfar, E., & Sutka, J. (2003). Locating QTLs controlling adaptation in wheat using AMMI model. Cereal Research Communications, 31, 3/4, 249-256.

Fox, P.N., Skovmand, B., & Thompson, B.K. (1990). Yield and adaptation of hexaploid spring triticale. Euphytica, 47(1): 57-64.

Gibson, L. R., Singer, J. W., Vos, R. J., & Blaser, B C. (2008). Optimum Stand Density of Spring Triticale for Grain Yield and Alfalfa Establishment. Agronomy Journal, 100(4): 911-916.

Giunta, F., Motzo, R., & Deidda, M. (1992). Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Res, 33(4): 399-409.

Giunta, F., & Motzo, R. (2004). Sowing rate and cultivar affect total biomass and grain yield of spring triticale (xTriticosecale Wittmack) grown in a Mediterranean-type

Giunta, F., Cadeddu, F., Mureddu, F., Virdis, A., & Motzo, R. (2020). Triticale cultivar mixtures: Productivity, resource use and resource use efficiency in a Mediterranean environment. European Journal of Agronomy, 115, 126019.

Johnson, W. H. (1959). Efficiency in combiningwheat. Agric. Eng. 40: 16-2

Kavanagh, V., & Hall, L. (2015). Biology and Biosafety. In: Eudes F. (eds) Triticale. Springer, Cham.

Kendal, E., Tekdal, S., & Karaman, M. (2019). Proficiency of biplot methods (AMMI and GGE) for appraise Triticale genotypes across multiple environments. Applied Ecolgy and Envirnmental Research, 17(3), 5995-6007.

Kinaci, E., & Gulmezoglu, N. (2007). Grain yield and yield components of triticale upon application of different foliar fertilizers. Interciencia, 32, 9, 624-628.

Kirchev, H., Delibaltova, V., Matev, A., Kolev, T., & Yanchev, I. (2014). Analysis of productivity of triticale varieties grown in Thrace and Dobrudja depending on nitrogen fertilization. *Journal of Mountain Agriculture on the Balkans, 17*(2), 328-335.

Kirchev, H., Penchev, E., & Georgieva, R. (2016). Yield plasticity and stability of triticale varieties (xTriticosecale Wittm.) under increasing nitrogen fertilization norms. *Research Journal of Agricultural Science, 48*(2), 68-68.

Kirchev, H., & Georgieva, R. (2017). Genotypic plasticity and stability of yield components in triticale (xTriticosecale Wittm.). Scientific Papers. Series A. Agronomy, Vol. LX, 285-288.

Kucerova, J. (2007). The Effect of Year, Site and Variety on the Quality Characteristics and Bioethanol Yield of Winter Triticale. *J. Inst. Brew., 113*(2), 142-146.

Larter, E. N., Shebeski, L. H., McGinnis, R. C., Evans, L. E., & Kaltskikes, P. J. (1970). Rosner, a hexaploid triticale cultivar. *Canadian Journal of Plant Science*, 50, 122-124.

Lelley, T. (2006). A low-input cereal with untapped potential. In: Singh RJ, Jauhar P (eds) Genetic resources, chromosome engineering, and crop improvement cereals (Chap. 13), vol 2. CRC

Madic, M., Paunovic, A., Durovic, D., Markovic, G., Knezevic, D., Jelic, M., & Stupar, V. (2018). Grain yield and its components in triticale grown on a pseudogley soil. *Journal of Central European Agriculture, 19*(1), 184-193.

Méndez-Espinoza, A. M., Romero-Bravo, S., Estrada, F., Garriga, M., Lobos, G. A., Castillo, D., Matus, I., Aranjuelo, I., & del Pozo, A. (2019). Exploring Agronomic and Physiological Traits Associated With the Differences in Productivity Between Triticale and Bread Wheat in Mediterranean Environments. Front. Plant Sci., 10:404. doi: 10.3389/fpls.2019.00404

Mergoum, M., Singh, P. K., Peña, R. J., Lozano-del Río, A. J., Cooper, K.V., Salmon, D. F., & Gómez Macpherson, H. (2009). Triticale: a ‘‘new’’ crop with old challenges. In: Carena M.J. (ed) Cereals. Springer, New York, pp. 267–286.

Motzo, R., Pruneddu, G., Virdis, A., & Giunta, F. (2015). Triticale vs durum wheat: A performance comparison in a Mediterranean environment. Field Crops Research, 180, 63-71.

Pool, M., Patterson, F. L., & Bode, C. E. (1958). Effect of delayed harvest on quality of softred spring wheat. Agron. J. 50, 271-275.

Racz, I., Duda, M., Braileanu, S.I., Kadar, R., & Moldovan, V. (2013). Behaviour of triticale cultivars in the yield trials at ARDS Turda (2011 and 2012). *Research Journal of Agricultural Science, 45*(3), 162-168.

Randhawa, H. S., Bona, L., & Graf, R. J. (2015). Triticale breeding – Progress and Prospect. In: Eudes, F. (ed.), Triticale, pp. 14-32.

Santiveri, F., Royo, C., & Romagosa, I. (2004). Growth and yield responses of spring and winter triticale cultivated under Mediterranean conditions. European Journal of Agronomy, 20, 281-292.

Schwarte, A. J., Gibson, L. R., Karlen, D. L., Dixon, P. M., Liebman, M., & Jannink, J. L. (2005). Planting Date Effects on Winter Triticale Grain Yield and Yield Components. *Crop Science, 46*(3), 1218-1224.

Stoyanov, H. (2016). Effect of the Environmental Factors on the Correlations in the Species Triticum ×toschevii H.P.St. *Field Crops Studies, 10*(1), 53-82 (Bg).

Stoyanov, H., & Baychev, V. (2016). Assessment of Yield Components Stability and Plasticity in Bulgarian Triticale (×Triticosecale Wittm.) Cultivars. Scientific works of Institute of Agriculture Karnobat, (in press).

Stoyanov, H., & Baychev, V. (2018). Tendencies in the yield and its components of the Bulgarian varieties of triticale, grown under contrasting conditions of the environment. Rastenievadni nauki, 55(3), 16-26 (Bg).

Stoyanov, H. (2018). Reacton of Triticale (xTriticosecale Wittm.) to Abiotic Stress. PhD Thesis, General Toshevo, Bulgaria (Bg).

Stoyanov, H. (2020). Effect of the environmental conditions and the crop density on economically important indices of Bulgarian triticale cultivars (xTriticosecale Wittm.). Journal of Mountains Agriculture in the Balkans. (in press).

Suresh, O. P. B., Behl, R. K., & Munjal, R. (2020). Study on potentials of triticale as an alternative of wheat in India. *Journal of Pharmacognosy and Phytochemistry, 9*(1), 898-901.

Szemplinski, W., & Dubis, B. (2012). Response of winter triticale cultivar Moderato to sowing time and density in North-East Poland. *Acta Scientiarum Polonorum, Agricultura, 11*(2), 73-83.

Tsenov, N., Ivanova, A., Atanasova, D., Petrova, T., & Tsenova, E. (2012). Breeding indices for assessment of drought tolerance of winter bread wheat. *Field Crops Studies, 8*(1), 65-7 (Bg).

Tsvetkov, S. (1989). Triticale. Zemizdat, p. 126 (Bg).

Tuulos, A., Turakainen, M., Kleemola, J., & Makela, P. (2015). Yield of spring cereals in mixed stands with undersown winterturnip rape. Field Crops Research, 174: 71-78.

Ugarte, C., Calderini, D. F., & Slafer, G. A. (2007). Grain weight and grain number responsiveness to pre-anthesis temperature in wheat, barley and triticale. *Field Crops Research*, 100, 240-248.

Villegas, D., Casadesus, J., Atienza, S. G., Martos, V., Maalouf, F., Karam, F., Aranjuelo, I., & Nogues, S. (2010). Tritordeum, wheat and triticale yield components under multi-local mediterranean drought conditions. *Field Crops Research*, 116, 68-74.