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Influence of drought on the heading in Bulgarian triticale cultivars

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Abstract
In order to study how the heading changes in exposure under the influence of natural drought processes and whether such a change affects crop productivity, 17 cultivars of winter hexaploid triticale were studied during 7 contrast growing periods. The results show that the latest heading is observed in the 2016/2017 growing period, and the earliest in the 2015/2016. During the period with the most pronounced soil and atmospheric drought - 2019/2020, the heading was earlier than the other periods. There is a tendency for the varieties AD-7291 and Vihren the heading to be earlier than the others, regardless of the environmental conditions. A tendency to later heading than the other cultivars is observed in Respect. On the other hand, early-heading cultivars have a positive effect on productivity, especially in periods of severe drought. Despite the differences observed in the heading period under the influence of drought, productivity of the cultivar Bumerang remains high. This shows that the cultivar has a high tolerance to soil drought, which makes it extremely suitable for growing in various soil and climatic conditions of Bulgaria.

Key words: triticale; Bulgarian cultivars; drought; heading

INTRODUCTION

One of the factors with highest effect on the production of agricultural crops is drought during active growth. Since water is a significant resource, which ensures the vegetative and generative development, the deficiency of soil moisture causes extremely high levels of stress. According to data by (Blum, 2014), drought is the reason for over 30% decrease of the yield from the cultivated plants. It is one of the most complex phenomena and processes, which, during the separate periods of vegetative growth, are characterized by rather varied occurrence intensity and duration. Therefore, it is necessary to study in detail a large number of physiological, anatomic and morphological parameters related to drought as a process under changeable conditions of the environment.

One of the cereal crops with comparatively good tolerance to various types of drought is triticale. There are numerous researches aimed at demonstrating the physiological tolerance of this crop to drought (Bączek-Kwinta et al., 2006; Hura et al., 2013; Shanazari et al., 2018; Saed-Moucheshi et al., 2019). One of the most studied traits in relation to the effect of drought is yield. The complex expressions of productivity under insufficient soil moisture have been thoroughly investigated by Kutlu & Kinaci (2010), Lonbani & Arzani (2011), Stoyanov (2018), Riasat et al. (2019), Stoyanov (2021). Depending on the occurrence, intensity and duration of drought, and also on the genotype used, various responses are observed with regard to both the yield and its related traits.

According to Arseniuk (2015), the higher tolerance of triticale to drought is related to the earlier heading and the greater ability of the roots to extract water from soil. Dhindsa et al. (1998) found out that under conditions of natural drought on the territory of India, the late cultivars possessing higher drought resistance were able to realize higher yields in comparison to the early ones. Martyniak (2002) pointed out that triticale was affected by drought to a highest degree during the stages heading and milk maturity, when the decrease of grain yield were highest. Stankova & Stankov (2002) reported that drought to permanent wilting at heading stage caused significant deviations in such traits as number of grains in spike and grain weight in spike. Stirmanova et al. (2021) pointed out that the main problem with the processes of drought can be solved by decreasing of the vegetative growth duration to avoid unfavourable events. Such results show that drought at the stages critical for the development of the crop, such as heading, has high effects on its productivity.

Heading in triticale is a parameter, which is little studied as a yield related trait in the modern cultivars. Although there are researches on the heading of a certain group of genotypes and their behaviour according to the conditions of the environment (Urazaliev & Ainebekova, 2012; Krokhmal et al., 2021), the impact of this trait on yield has seldom been pointed out. Yurchenko et al. (2012) wrote that the period from heading to wax maturity in triticale determined the temperature and water regime of the plant, and thus the varietal specificity as well. Han et al. (2019) purposefully selected earlier heading cultivars characterized by higher productivity of green biomass. Skatova (2021) studied the heading in hybrid populations of triticale and during 2018, when there was strong drought, there were almost insignificant differences between the separate hybrid combinations and cultivars. Kendal et al. (2016) pointed out that the presence of stress factors (low temperatures) significantly influenced the parameter days to heading. These authors also reported that cultivar Karma, which was with the latest cultivar heading, was most affected by the drought. The data of Ramazani et al. (2017) showed that there was a low but significant correlation of yield with the days to heading, as well as a positive direct effect. These authors also noticed high indirect effect of heading on the yield through 1000 kernel weight. The results from these studies show that heading was largely depended on the conditions of the environment and was important for the formation of the value of the yield. Since both yield and heading respond to drought, it is necessary to study in detail the correlations between the two traits.

The aim of this study was to evaluate the effect of the natural processes of drought on the heading of triticale and to find out what is the relation of heading with yield under conditions of intensive water deficiency in the region of Dobrudzha.

MATERIALS AND METHODS

Plant material and biometrical analysis

To accomplish the above aim, eleven Bulgarian triticale cultivars were used (Table 1). They were grown as a whole area crop in trial plots of 10 m^2, in four replications according to a standard block design, within a competitive varietal trial. Sowing was mechanized, within the standard dates for triticale, at density 550 seeds per m^2.

Besides the above cultivars, the competitive variety trial also included the standard triticale cultivars AD-7291, Vihren and Rakita, as well as the world standards Lasko and Presto.In each experimental plot, days to heading from 1st January of the respective period till entering of 50 % of the plants into heading stage were read. The plots were harvested at full maturity, reading the yield from each of them separately.

Table 1. Cultivars used during the period of study

No	Name	Year of registration
1	Kolorit	2005
2	Atila	2007
3	Akord	2007
4	Respekt	2008
5	Bumerang	2009
6	Irnik	2011
7	Dobrudzhanets	2012
8	Lovchanets	2013
9	Doni 52	2014
10	Blagovest	2015
11	Borislav	2016

Conditions of growing

The experiment was carried out in seven consecutive harvest years: 2014/2015, 2015/2016, 2016/2017, 2017/2018, 2018/2019, 2019/2020, 2020/2021. The data presented on the mean monthly temperature and the sum of monthly precipitation (Table 2) reveal the contrasting nature of the studied periods. The highest differences according to the long-term tendency with regard to temperature were observed during December – March, and with regard to precipitation – in December and May. The differences in these periods were sufficient to conclude that the vegetative growth over years occurred in different ways. Clearly outlined are certain meteorological phenomena and processes, which were of single occurrence, were not repeated over periods and were

Table 2. Mean monthly temperature and sum of precipitation during the period of study

Parameter	Year	Aug	Sep	Oct	Noe	Dec	Jan
Mean monthly air temperature, °C	2014/2015	22,70	17,50	11,20	5,60	3,10	1,40
	2015/2016	22,80	19,50	10,90	9,30	3,40	-0,80
	2016/2017	22,20	18,10	10,60	6,50	-0,60	-4,10
	2017/2018	22,50	19,00	11,80	7,50	4,70	1,70
	2018/2019	23,60	17,70	13,30	5,40	1,20	1,00
	2019/2020	22,80	17,90	13,40	11,70	5,20	1,80
	2020/2021	22,60	19,40	15,30	6,30	5,30	3,00
	1960/2021	21,13	16,92	11,74	6,76	2,02	-0,16
Sum of precipitation, mm	2014/2015	19,30	31,40	57,90	33,20	87,00	33,20
	2015/2016	42,00	20,80	78,30	55,10	0,40	86,30
	2016/2017	5,00	35,80	72,20	43,30	12,50	48,40
	2017/2018	12,40	69,90	50,50	57,20	55,80	75,40
	2018/2019	1,10	54,70	11,70	66,20	43,80	19,20
	2019/2020	7,80	36,70	27,60	35,40	21,80	2,80
	2020/2021	3,50	34,10	52,90	26,00	74,40	109,70
	1960/2021	36,95	46,06	42,26	43,12	42,20	37,55
Parameter	Year	Feb	Mar	Apr	May	Jun	Jul
Mean monthly air temperature, °C	2014/2015	2,00	5,00	10,10	16,40	19,40	22,40
	2015/2016	7,30	6,80	13,20	14,70	20,90	22,80
	2016/2017	2,00	7,30	8,70	15,00	20,20	21,80
	2017/2018	1,10	4,60	13,40	17,70	20,40	22,20
	2018/2019	3,50	8,20	9,00	16,00	22,30	22,00
	2020/2021	5,10	8,00	10,00	15,40	19,60	22,30
	2020/2021	4,00	4,20	8,80	15,80	18,90	22,80
	1960/2020	1,24	4,70	9,85	15,25	21,94	21,42
Sum of precipitation, mm	2014/2015	79,50	67,70	8,50	12,90	31,30	27,20
	2015/2016	40,70	52,70	20,80	117,10	55,70	2,80
	2016/2017	27,40	48,90	38,40	29,00	87,70	66,30
	2017/2018	48,80	4,90	30,90	90,80	59,60	59,60
	2018/2019	16,30	16,10	49,40	31,70	37,50	54,00
	2019/2020	28,10	28,30	5,80	48,00	51,30	2,70
	2020/2021	13,20	22,20	44,60	63,60	162,70	29,70
	1960/2021	33,74	35,25	39,97	52,19	62,60	50,99

able to strongly influence the physiological processes in the plant organism.

Worth mentioning are 2018/2019 and 2019/2020 growing periods, when extremely intensive spring drought was observed. Highly unfavorable for growing of triticale was 2019/2020 due to the rather long drought during March-April. At the same time, favorable for growing of triticale were the conditions of 2014/2015, 2016/2017 and 2020/2021, when smaller number of negative events during vegetative growth were observed.

Developing a model

Similar to any other stress factor, drought leads to quantitative and qualitative changes in physiological, anatomic and morphological aspects. Since, however, it is impossible to differentiate under natural conditions the effect of a given stressor on such complex parameters as yield and its related traits, it is possible to observe identical phenotypic response under the influence of various expressions of the weather. That raises the question how to determine the effect of drought on such a trait as heading and respectively on the value of yield.

One of the most important stages in determining the effect of drought on a given trait is evaluating the intensity and duration of drought for each specific period of the investigation. This is necessary because drought as a factor is not possible to control under natural conditions. One of the most common methods is using the aridity index of De Martonne, which is based on the ratio of the sum of precipitation of the period to the mean temperature of the period (Formula 1) (Croitoru et al., 2012). The original index gives an idea about drought during the entire calendar or growing period (12 months).

Since heading is not related to all processes in a given growing period, a period from the beginning of the plant development to the end of heading is to be chosen. Under the conditions of Bulgaria, this period includes the months from October to May, since sowing of triticale is most often in October, and the mass heading of the winter triticale forms encompasses the period between 20th April and 30th May, which, however, is strictly dependent on the set of genotypes and the specific conditions of the environment. The aridity index of De Martonne could be calculated for this period – October-May (8 months) and could satisfy Formula 2.

$$I_{DMY} = \frac{P_Y}{T_Y + 10} \quad (1)$$

$$I_{DMHP} = \frac{1,5 P_{HP}}{T_{HP} + 10} \quad (2),$$

where

I_{DMY} –De Martonne index of the growing period

P_Y – Sum of precipitation of the growing period

T_Y – Mean air temperature of the growing period

I_{DMHP} –De Martonne index of the period to heading

P_{HP} – Sum of precipitation of the period to heading

T_{HP} – Mean air temperature of the period to heading

At the next stage, it is necessary to evaluate in a long-term perspective if the region is a dry one as a whole, i.e. based on the De Martonne index, to determine the long-term tendency. In this case, the index is calculated for the same period but based on the long-term mean values of temperature and precipitation. Such data are necessary to determine to what extent the stress conditions in a specific period differ from the long-term tendency and if conditions different from the normal ones cause a certain effect on a given trait.

The phenotypic expression triggered by a stressor on a specific trait can be identical to a phenotypical expression resulting from a different stressor. Thus, for example, heading in triticale may occur earlier if the winter is warmer or if there are good moisture reserves in soil, but it may also be triggered by intensive drought. In this respect, the calculated De Martonne aridity index allows determining those processes and phenomena, which are not related to drought as a complex process.

To evaluate, however, its effect on a specific trait, it is necessary to model the trait itself in such a way as to be able to isolate the effect of all other possible causes. This is possible only by additionally increasing the contrast between the values of the studied parameter. The mathematical interpretation of such a model in presented in Formula 3.

$$X_{DMA} = X . \frac{I_{DMHPi}}{I_{DMHPb}} \quad (3)$$

X_{DMA} – De Martonne adjusted (model) value of the studied parameter X

X – Real values of the studied parameter X

I_{DMHPi} – De Martonne aridity index of the period to heading during vegetative growth period i

I_{DMHPb} – De Martonne aridity index of the period to heading based on long term values

If we assume that a given trait decreases under the effect of a stress factor, the model values based on the De Martonne index should be comparatively the same for all expressions of the stress effect, with the exception of those caused by drought. If, however, a given trait increases under drought, the model values of the period with active drought will decrease it. In this case, the model values of the periods without occurrence of drought will be higher. Regardless of drought causing higher or lower values, this model allows differentiating the effects of drought from the effects of other stress factors.

Application of the model and statistical analysis

The obtained results on the days to heading and the yield from the studied triticale cultivars were summarized and averaged by genotype and period of study. The De Martonne aridity index was calculated for each investigated period separately based on 8-month period to heading (October – May). Drought was analyzed over the years of the study and the periods with intensive drought were determined. The model (De Martonne adjusted) values of the days to heading were calculated based on Formula 3, and were applied according to Formulae 4 and 5.

$$DMADH = DH.\frac{I_{DMHPi}}{I_{DMHPb}} \quad (4),$$

where

DMADH – De Martonne adjusted (model) value of parameter days to heading

DH – Real values of parameter days to heading

$$DMAY = Y.\frac{I_{DMHPi}}{I_{DMHPb}} \quad (5),$$

where

DMAY – De Martonne adjusted (model) values of yield

Y – Real values of yield

The calculations were performed over cultivars, years and replications. The results from the model values were also summarized and averaged over cultivar and year. A correlation analysis was carried out between days to heading and yield, as well as between the DMADH and yield and DMAY. The effect of drought on days to heading was determined. A thorough analysis was done with regard to the effect of drought on yield through the effect of drought on heading. For summarizing of results MS Office Excel, 2003 was used, and for the correlation analysis - IBM SPSS Statistics, v.19.

RESULTS AND DISCUSSIONS

Effect of drought on heading

The data on the weather during the studied periods (Table 2) show the rather contrasting nature of the growing conditions of triticale. Especially clearly outlined is the absence of rainfalls during the two growing periods 2018/2019 and 2019/2020. The results on the aridity index of De Martonne (Table 3) confirmed the high degree of drought in these two periods, especially in 2019/2020. In this respect, up to the beginning of and during heading, low winter moisture reserves were registered besides the insufficient precipitation, as well as considerably higher air temperatures. This was the reason for the comparatively earlier occurrence of heading in these two periods (Table 4). On the other hand, early heading was observed also in 2015/2016, although this period was considerably more humid, especially during heading stage (Table 2). In comparison to the long-term tendency, all other economic periods were characterized as moderately humid or considerably humid. Closest to the long-term values was the De Martonne index in 2016/2017.

Both between the individual periods and between the studied genotypes, significant differences

Table 3. De Martonne index of the period to heading over years of study

Year	I_{DMDH}
2014/2015	33,82
2015/2016	37,41
2016/2017	30,63
2017/2018	34,89
2018/2019	22,19
2019/2020	15,76
2020/2021	34,19
1960/2021	29,80

were observed over periods. Differences of up to 20 days were registered between the mean values of the seven vegetative growth periods. Nevertheless, there was a certain tendency in the separate cultivars their heading to be close to the mean values.

In 2014/2015, with earliest heading were cultivars Kolorit (130 days) and Dobrudzhanets (130 days), at the level of the early standard cultivar AD-7291. The standard cultivars Vihren and Rakita differed significantly with one day, by days to heading (131 and 132 days). At the level of the standard cultivar Rakita were cultivars Atila, Akord, Lovchanets, Doni 52 and Blagovest. Significantly later is the heading of the cultivar Respekt.

In harvest year 2015/2016, again the early was standard cultivar AD-7291, which started heading in 117 days. Vihren and Rakita differed significantly, their heading being in 118 and 120 days, respectively. Cultivar Kolorit was at the level of AD-7291. At the level of the late standard cultivar Rakita were cultivars Lasko, Presto, Irnik, Dobrudzhanets, Lovchantes, Blagovest and Borislav. Considerably later were cultivars Atila, Akord, Respect and Bumerang.

In the third growing period (2016/2017), the early standard cultivar AD-7291 (139 day) was almost equal to the standard cultivar Rakita (140 days), and the latest of the three standard cultivars was Vihren (141). Kolorit was also equal to Rakita by heading. At the level of Vihren were cultivars Presto, Bumerang, Irnik, Dobrudzhanets, Doni 52 and Blagovest. The heading of cultivar Borislav was the earliest of all cultivars, averagely for 138 days. Significantly later were cultivars Atila, Akord, Respekt and Lovchanets.

Growing period 2017/2018 was characterized by significantly earlier heading according to the previous period. Again, the earliest standard cultivar was AD-7291 (119 days), later was Vihren (120 days), and latest – Rakita (122 days). The heading of the world standard cultivars Lasko and Presto was between Vihren and Rakita. At the level of Vihren was only Kolorit. Cultivars Irnik, Dobrudzhanets, Doni 52 and Blagovest were equal to Rakita by heading. At the level of Lasko were Lovchanets and Borislav, and significantly later than all standard cultivars were Atila, Akord, Respekt and Bumerang.

Table 4. Days to heading of the investigated triticale cultivars

Cultivar	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Average
AD-7291	130	117	139	119	127	122	133	127
Vihren	131	118	141	120	128	124	132	128
Rakita	132	120	140	122	129	126	133	129
Lasko	131	120	142	121	128	129	133	129
Presto	131	120	141	121	129	122	133	128
Kolorit	130	117	140	120	126	125	132	127
Atila	132	128	143	125	128	126	135	131
Akord	132	123	142	124	129	126	134	130
Respekt	133	129	144	126	133	129	135	133
Bumerang	131	127	141	124	131	127	133	131
Irnik	131	120	141	122	130	127	133	129
Dobrudzhanets	130	119	141	122	129	127	133	129
Lovchanets	132	120	144	121	129	126	133	129
Doni 52	132	121	141	122	128	124	132	129
Blagovest	132	120	141	122	128	126	133	129
Borislav	131	119	138	121	127	126	133	128
Average	131	121	141	122	129	126	133	129
LSD 0,05	*0,4*	*1,8*	*0,7*	*0,9*	*0,8*	*1,0*	*0,4*	*0,7*
LSD 0,01	*0,5*	*2,4*	*1,0*	*1,2*	*1,1*	*1,3*	*0,6*	*1,0*
LSD 0,001	*0,6*	*3,1*	*1,2*	*1,6*	*1,4*	*1,6*	*0,7*	*1,2*

In 2018/2019, heading was similar to 2015 by average value of the investigated set of cultivars. Among the studied cultivars, the standard cultivar AD-7291 was again the earliest (127 days), which was equal to cultivar Borislav by heading. Vihren and Rakita were later and their heading period is 128 and 129 days, respectively. Lasko was equal to Vihren, and Presto – to Rakita. Kolorit was earliest than all standard cultivars (126 days). Atila, Doni 52 and Blagovest were equal to Vihren, and Akord, Dobrudzhanets and Lovchanets – to Rakita. With later heading were Respekt, Bumerang and Irnik.

In economic year 2019/2020, when strong drought occurred, the average heading period of the studied cultivars was 126 days. The earliest to heading was observed in the standard cultivar AD-7291 (122 days) but it was equal to the usually late world standard cultivar Presto. Vihren heading period was 124 days, Doni 52 being at its level. Rakita was later (126 days), and Atila, Akord, Lovchanets, Blagovest and Borislav were equal to it. Bumerang, Irnik and Dobrudzhanets had later heading period – 127 days, and Respekt was the latest, being equal to Lasko (129 days).

In the period 2020/2021, which was the most unfavorable for growing of triticale, the heading of the cultivars differed insignificantly. Thirteen out of the sixteen investigated cultivars had heading period of 132-133 days. Later were only Atila, Akord and Respekt – 134-135 days.

The results on the investigated periods showed that comparatively narrower range of heading was observed in years, when the conditions were considerably more favorable for growing of triticale – 2014/2015, 2016/2017 and 2020/2021. In periods with serious deviations from the long-term tendency with regard to both temperature and precipitation, heading was much longer.

This tendency can be followed in Figure 1. Considerably wide was the range of heading in 2015/2016, and in the two periods with clearly expressed drought – 2018/2019 and 2019/2020. Nevertheless, in absolute values heading was influenced to a much higher degree and was significantly earlier in economic years 2015/2016 and 2017/2018 in comparison to the mean values of the separate periods

Such behavior does not allow determining the effect of drought, since it is not possible to determine if the earlier heading in these periods related to the wormer winters or to the insufficient moisture.

The use of the developed model based on the adjusted values of the days to heading through the De Martonne index allowed making more clear the effect on heading. This was related to the fact that in the more humid periods the values of heading will

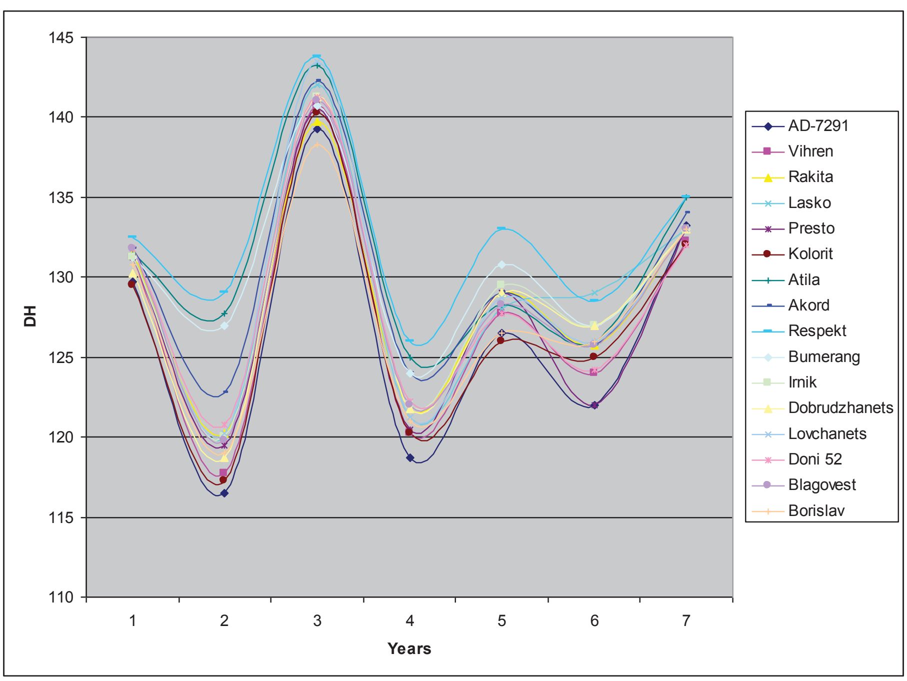

Figure 1. Dynamics of trait days to heading

increase due to the higher De Martonne index, and in periods with active drought, the days to heading will decrease due to the lower De Martonne index. The effect on the separate genotypes can be followed in Table 5 and on Figure 2.

Most prominent are two periods, 2018/2019 and 2019/202, when the two lowest declines in the graph were observed. Respectively, in the other periods when effects of the meteorological phenomena and processes on heading were observed, they were equal to the rest of the periods. This indicated not only that drought affected heading of triticale, but that it was also affected to a high degree.

The results we obtained on the days to heading entirely correspond to those of other researches in winter triticale. Krokhmal et al. (2021) pointed out that the 20 accessions they tested for an average of five years began heading between 12th May and 2nd June depending on the conditions of the environment and the genotype. Sechnyak & Sulima (1984) pointed up that a serious shortcoming of the early triticale forms was their late maturation. Nevertheless, a large part of the breeding programs direct the breeding process toward earlier forms as evidenced by Ittu & Saulescu (1998), Medvedev et al. (2012), Urazaliev & Aynebekova (2012) and Yurchenko et al. (2012). In this respect, as emphasized by Arseniuk (2015), the early forms have a significant advantage with regard to drought. According to Liu et al. (2017), wheat starts heading earlier under the effect of drought, this mechanism, in the opinion of Shavrukov et al. (2017) leading to avoidance of the unfavorable effects of the environment. Kumar et al. (2014) demonstrated that the heading of accessions from crosses of triticale with wheat was with an average of two days earlier under drought. Lagrou (2014) noticed an insignificant difference between the mean values of heading in the eight triticale forms they studied under three regimes of drought.

Significance of the effect of drought on heading for formation of yield

Since days to heading are one of the most important yield related trait in triticale, the effect of drought on it would be significant for the yield

Table 5. Values of DMADH in the studied triticale cultivars

Cultivar	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Average
AD-7291	147	146	143	139	94	65	153	127
Vihren	149	148	145	141	95	66	152	128
Rakita	149	151	144	143	96	67	153	129
Lasko	149	151	146	142	95	68	153	129
Presto	149	150	144	141	96	65	153	128
Kolorit	147	147	144	141	94	66	151	127
Atila	149	160	147	146	95	67	155	131
Akord	150	154	146	145	96	67	154	130
Respekt	150	162	148	148	99	68	155	133
Bumerang	149	159	145	145	97	67	153	131
Irnik	149	151	145	143	96	67	153	129
Dobrudzhanets	148	149	145	143	96	67	153	129
Lovchanets	150	151	148	142	96	67	153	129
Doni 52	150	152	145	143	95	66	151	129
Blagovest	150	150	145	143	95	67	153	129
Borislav	148	149	142	142	94	67	153	128
Average	149	152	145	143	96	66	153	129
LSD 0,05	*0,4*	*2,3*	*0,8*	*1,1*	*0,6*	*0,5*	*0,5*	*0,8*
LSD 0,01	*0,6*	*3,0*	*1,0*	*1,4*	*0,8*	*0,7*	*0,6*	*1,0*
LSD 0,001	*0,7*	*3,9*	*1,3*	*1,8*	*1,0*	*0,8*	*0,8*	*1,3*

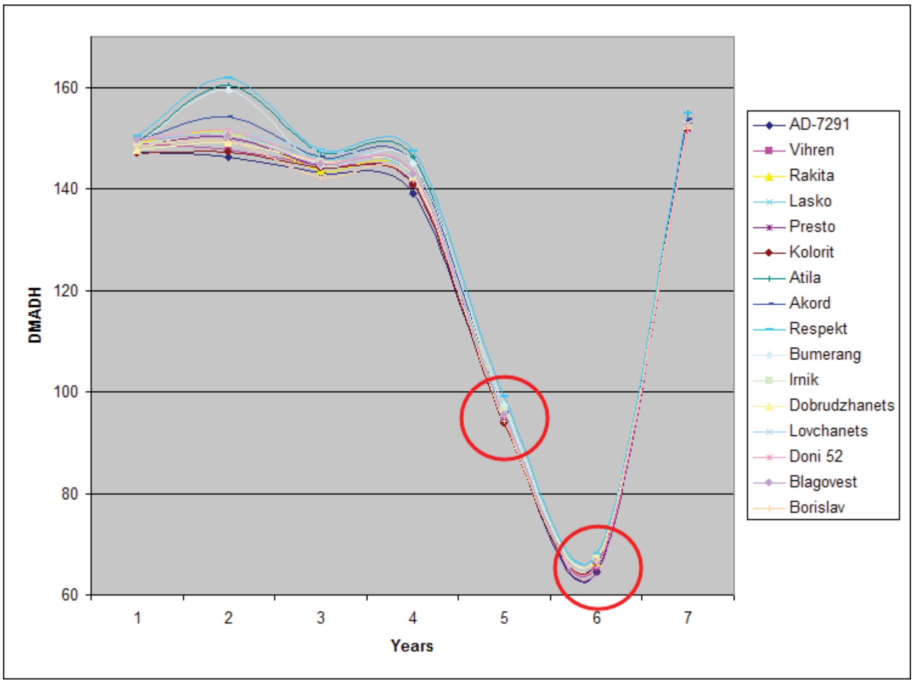

Figure 2. Dynamics of parameter DMADH

from the investigated genotypes, too. According to Shavrukov et al. (2017), the early heading is one of the best mechanisms to avoid the effect of drought on the formation of productivity in common wheat. Giunta et al. (1992) pointed up, that the early heading was the reason why triticale was significantly more drought resistant and the difference between the variant with drought and the watered check was considerably lower in comparison to the same difference in wheat.

Under natural conditions, however, it is very difficult to determine to what degree heading influences productivity, particularly under conditions of long and intensive drought. This can be determined from Table 6, which presents the results on the yield from the studied cultivars. In the two periods with active drought, productivity was actually much lower, but it was nevertheless higher in comparison to the productivity in economic year 2015/2016, which was characterized as extremely humid, especially during the heading stage.

Such results show that not only drought but the extremely high precipitation norms also cause stress in triticale, and lead to lower productivity, respectively. Similar to heading, however, with regard to productivity it should also be emphasized that the actual data on yield and their referring to a certain meteorological characteristics do not give sufficient ground to assume that the decrease of productivity is unambiguously related to the effects of drought.

The application of the developed model to the values of the yield supports this thesis by underlying the rather strong effects of the insufficient moisture reserves on the formation of productivity in triticale. The values of DMAY in 2018/2019 and 2019/2020 show that in the second of the two years the intensive drought had much higher effect on the plants, as supported by the values of heading, too.

The dynamics of the model values of yield largely approximated the values of heading (Figure 3). Although the yield values varied within a much wider range, a tendency was observed both the days to heading and productivity to demonstrate extremely contrasting model values for both periods of intensive drought in comparison to the rest of the periods. Therefore, it can be assumed that heading is highly important for yield and that the effect of drought on heading is rather significant for productivity.

These assumptions are confirmed by the values of the correlation coefficients between the days to heading and the yield, between the DMADH and the yield, and between DMADH and DMAY.

The values of the correlation coefficients between days to heading and yield revealed the degree

Table 6. Yield from the studied triticale cultivars

Cultivar	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	Average
AD-7291	589	596	602	637	507	483	806	603
Vihren	609	540	631	745	513	477	741	608
Rakita	725	529	735	717	608	570	747	662
Lasko	765	455	614	631	561	547	779	622
Presto	777	436	681	624	612	596	806	647
Kolorit	691	543	644	661	504	531	768	620
Atila	763	632	757	609	476	564	644	635
Akord	767	552	691	584	549	568	730	634
Respekt	704	320	679	563	406	478	698	549
Bumerang	779	424	776	745	608	631	859	689
Irnik	793	521	603	634	495	556	776	625
Dobrudzhanets	643	469	770	664	579	468	830	632
Lovchanets	649	378	564	624	476	490	686	552
Doni 52	803	611	745	700	603	574	770	687
Blagovest	747	543	713	636	532	567	767	643
Borislav	839	605	711	602	601	572	831	680
Average	728	509	682	649	539	542	765	631
LSD 0,05	*35,8*	*43,5*	*32,5*	*26,4*	*29,8*	*23,9*	*27,9*	*19,8*
LSD 0,01	*47,1*	*57,1*	*42,8*	*34,7*	*39,1*	*31,4*	*36,7*	*26,1*
LSD 0,001	*60,2*	*73,0*	*54,6*	*44,4*	*50,0*	*40,1*	*46,9*	*33,3*

Table 7. Values of DMAY in the studied triticale cultivars

Cultivar	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	Average
AD-7291	669	749	619	746	377	255	925	620
Vihren	691	678	649	872	382	252	850	625
Rakita	823	663	756	840	453	301	857	670
Lasko	868	571	631	739	418	289	894	630
Presto	882	547	700	731	456	315	925	651
Kolorit	785	681	662	773	376	281	881	634
Atila	865	793	778	713	355	298	739	649
Akord	870	693	710	684	409	300	838	643
Respekt	799	401	698	659	302	253	801	559
Bumerang	884	532	798	873	452	334	986	694
Irnik	899	653	620	742	369	294	890	638
Dobrudzhanets	729	588	792	777	431	248	953	645
Lovchanets	737	475	580	731	355	259	787	560
Doni 52	911	767	766	820	449	304	884	700
Blagovest	848	681	732	745	396	300	879	655
Borislav	952	760	730	705	447	303	954	693
Average	826	640	701	759	402	287	878	642
LSD 0,05	*40,7*	*54,6*	*33,4*	*30,9*	*22,2*	*12,6*	*32,1*	*19,7*
LSD 0,01	*53,5*	*71,7*	*43,9*	*40,7*	*29,1*	*16,6*	*42,1*	*25,9*
LSD 0,001	*68,3*	*91,6*	*56,1*	*52,0*	*37,2*	*21,2*	*53,8*	*33,1*

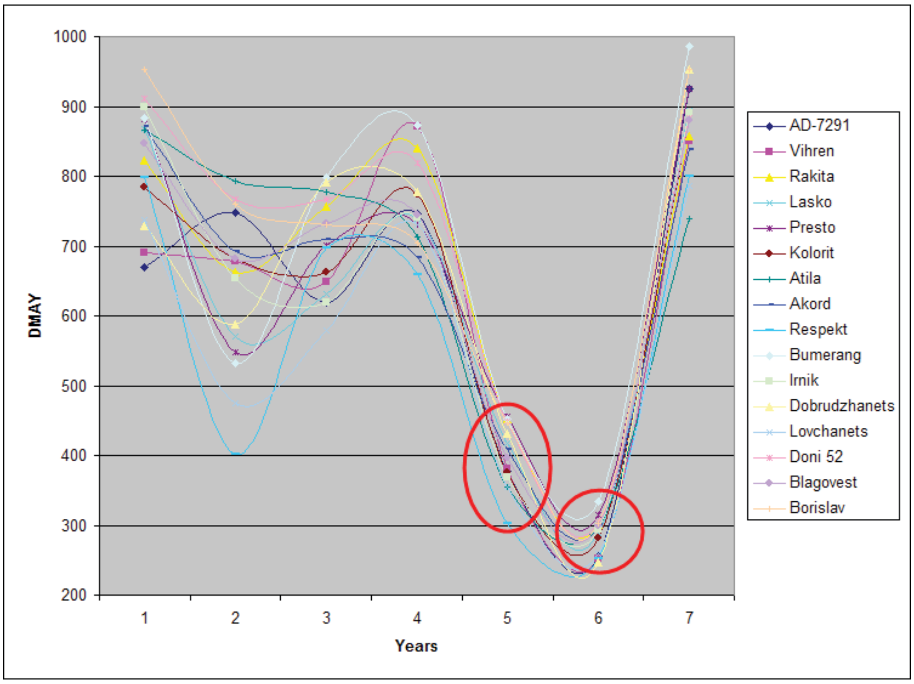

Figure 3. Dynamics of parameter DMAY

to which heading itself was important for productivity. In the greater part of the cultivars, a moderate or comparatively low but significant correlation of the two parameters was observed. It was highest in cultivars Presto, Akord and Dobrudzhanets, and lowest in AD-7291, Vihren and Irnik. These results showed that heading was of comparatively low importance for AD-7291, Vihren and Irnik, but considerably more important for Presto, Akord and Dobrudzhanets.

The correlations between DMADH and yield, on their part, revealed the importance of drought on heading for the values of yield. The correlation of the entire set of cultivars was similar to the previous correlation. On the other hand, however, the cultivars had entirely different values. Presto, Respect, Bumerang and Lovchanets were with the lowest correlation coefficients. With the highest correlation coefficients were AD-7291, Vihren, Kolorit and Doni 52. In the cultivars with high values, the yield was influenced to a higher degree by drought effects on heading. This means that the stronger the effect of drought on the heading of a cultivar, the stronger the reaction of the yield will be.

The correlation between the two model values (DMADH and DMAY), on its part, gives an idea about how the effects of drought on heading influence the effects of drought on yield. In practice, the correlation between the two parameters reveals if both parameters respond identically to drought. All correlation coefficients over cultivars were high and significant. They were highest in cultivars AD-7291, Vihren, Rakita, Kolorit, Doni 52, Blagovest and Borislav. Lowest were in Respekt and Bumerang. The lower correlation in the latter two cultivars shows that although their heading was affected by drought, yield did not respond to the same degree. This is also emphasized by the absence of a high and significant correlation of DMADH with yield.

On the other hand, both heading and drought were important for the formation of the value of yield. In this respect, in cultivars, in which higher correlation of DMADH with yield was observed than of days to heading with yield, the drought and its effect on yield was more important for the total effect on productivity. Furthermore, if the correlation of the days to heading with yield was higher than the correlation of DMADH with yield, this was an indication that the process of heading itself was more significant for the formation of productivity. Such correlations were observed in Rakita, Lasko, Presto, Atila, Akord, Respekt, Bumerang, Dobrudzhanets, Lovchanets, Blagovest and Borislav. In practice, in the early cultivars such as AD-7291,

Table 8. Correlations between actual and model values of the studied parameters

Correlation	DH-Y		DMADH-Y		DMADH-DMAY	
	r	R^2, %	r	R^2, %	r	R^2, %
AD-7291	0,284	8,07	0,681**	46,38	0,907**	82,26
Vihren	0,184	3,39	0,647**	41,86	0,895**	80,10
Rakita	0,542**	29,38	0,450*	20,25	0,910**	82,81
Lasko	0,420*	17,64	0,380*	14,44	0,848**	71,91
Presto	0,630**	39,69	0,243	5,90	0,823**	67,73
Kolorit	0,392*	15,37	0,610**	37,21	0,925**	85,56
Atila	0,575**	33,06	0,573**	32,83	0,926**	85,75
Akord	0,632**	39,94	0,490**	24,01	0,927**	85,93
Respekt	0,480**	23,04	0,322	10,37	0,730**	53,29
Bumerang	0,411*	16,89	0,189	3,57	0,744**	55,35
Irnik	0,294	8,64	0,485**	23,52	0,866**	75,00
Dobrudzhanets	0,606**	36,72	0,506**	25,60	0,859**	73,79
Lovchanets	0,376*	14,14	0,363	13,18	0,815**	66,42
Doni 52	0,540**	29,16	0,616**	37,95	0,937**	87,80
Blagovest	0,574**	32,95	0,529**	27,98	0,919**	84,46
Borislav	0,594**	35,28	0,552**	30,47	0,917**	84,09
Whole set	0,409**	16,73	0,432**	18,66	0,852**	72,59

DH – Days to heading; Y – Yield.

Vihren and Kolorit, the effect of drought was more important both for heading and productivity. This demonstrated that early heading is an active mechanism of high importance for yield formation. On the other hand, in the later cultivars, in which heading itself had higher effect on productivity, such a mechanism was absent or was not so significant for the productivity of the respective genotype.

The results we obtained completely correspond to the correlations in triticale described by Ghandorah (1987) for wheat and triticale. According to the author, with the increase of the percent content of soil moisture, the investigated genotypes started heading later and gave higher yields. The regression equations obtained by the same author corresponded to our results because the days to heading and the yield did not follow identical tendencies when the moisture reserves in soil increased. Gupta et al. (2007) demonstrated, investigating 22 derivative lines of a triticale x common wheat cross, that in practice there was no correlation between yield and days to heading although the studied set did not include genotypes preliminary determined for drought resistance. Kalbarczyk (2010) emphasized the significance of drought in the period from heading to milk maturity as the most critical for the formation of productivity. The data of Kheirizadeh Arough et al. (2016) showed that the content of water and chlorophyll in the leaves of triticale in heading stage under regime of extremely high water stress was considerably lower in comparison to the other regimes of watering at the same stage.

The results from the cultivars we studied under contrasting environments and highly contrasting conditions during the separate periods at heading stage showed that heading as a process was largely affected by the insufficient moisture reserves in soil. This influenced the formation of the crop's productivity, which was directly dependent on the intensity of drought. The separate studied genotypes responded differently; in some of them heading itself was more important for productivity, while in others the effect of drought on heading influenced to a higher degree the values of yield.

Among the studied genotypes, the heading of cultivars Bumerang and Respekt was with lowest importance for productivity. While Bumerang is a genotype comparatively tolerant to drought, the genotypically determined later heading of Respekt had in practice no effect on productivity since in this cultivar the entire vegetative growth period was later in comparison to the rest of the studied cultivars. On the other hand, cultivars such as Doni 52 and Kolorit had earlier heading periods under drought revealing a mechanism for avoidance of the negative effects of drought. Nevertheless, Bumerang and Doni 52, although possessing different strategies for minimizing the effect of drought on the growth and development of the plant, were characterized as highly productive even under intensive conditions of drought, which makes them valuable for growing under varied conditions of the environment.

CONCLUSIONS

Based on the results presented above, the following conclusions can be made:

1. Among the studied contrasting periods of growing, 2018/2019 and 2019/2020 were characterized by intensive spring drought, which significantly influenced the trait days to heading in all investigated genotypes.

2. The obtained model values of the parameter DMADH showed that the effect of drought on heading in 2019/2020 was much higher than in 2018/2019.

3. The model values of the parameter DMAY showed a tendency of yield similar to the tendency of days to heading.

4. Based on the correlation analysis carried out, it can be assumed that drought, through heading, had a significant effect on the productivity of the studied triticale genotypes.

5. Cultivar Bumerang demonstrated absence of drought effects on heading and on productivity, respectively, while in Doni 52 high effect of drought on heading and on yield, respectively, was observed. This indicated that in the highly productive genotypes drought tolerance was triggered by different mechanisms.

6. Regardless of the different strategies for minimizing the effect of drought on the growth and development of cultivars Bumerang and Doni 52, they were characterized as highly productive even under intensive drought, which makes them highly suitable for growing under various environments.

REFERENCES

Arseniuk, E. (2015). Triticale abiotic stresses – an overview. In: Eudes, F. (ed.), *Triticale*, pp. 68-81.

Baczek-Kwinta, R., Filek, W., Grzesiak, S., & Hura, T. (2006). The effect of soil drought and rehydration on growth and antioxidative activity in flag leaves of triticale. *Biologia plantarum*, *50*(1), 55-60.

Blum, A. (2014). The Abiotic Stress Response and Adaptation of Triticale – A Review. *Cereal Research Communications*, *42*(3), 359-375.

Croitoru, A. E., Piticar, A., Mircea, A., Doina, I., & Burada, C. (2012). Spatiotemporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania. *Theor Appl Climatol*. 10.1007/s00704-012-0755-2.

Dhindsa, G. S., Dosanjh, A. S., Singh, G., & Nanda, G. S. (1998). Variation and adaptation of triticale varieties for heat tolerance in North India. *Proceedings of the 4-th International Triticale Symposium*, Volume 2 – Poster Presentations, pp. 314-316.

Ghandorah, M. O. (1987). Response of wheat and triticale cultivars to water stress. *J. Coll. Agric. King Saud Univ*, 9, 59-72.

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.

Gupta, D., Mittal, R. K., Kant, A., & Singh, M. (2007). Association studies for agro-physiological and quality traits of triticale X bread wheat derivatives in relation to drought and cold stress. *Journal of Environmental Biology*, *28*(2), 265.

Han, O. K., Park, H. H., Park, T. I., Oh, Y. J., Ahn, J. W., & Ku, J. H. (2019). 'Choyoung', Triticale Cultivar for Forage of Early Heading, Resistance to Lodging and High Seed Production. *Journal of the Korean Society of Grassland and Forage Science*, 39(2), 68-74 (Kr).

Hura, T., Hura, K., Ostrowska, A., Grzesiak, M., & Dziurka, K. (2013). The cell wall-bound phenolic as a biochemical indicator of soil drought resistance in winter triticale. *Plant, Soil and Environment*, 59(5), 189-195.

Ittu, G. & Saulescu, N. (1998). Advances in triticale breeding in Romania. *Proceeding of 4-th International Triticale Symposium, Red Deer, Alberta, Canada*, 26-31 July, 1998. Vol. 1, Oral Presentations, pp 65-70.

Kalbarczyk, E. (2010). Variability of grain yield of spring triticale in Poland in the different conditions of atmospheric drought. *Scientific Review Engineering and Environmental Sciences*, 2010(1)), 20-33.

Kendal, E., Sayar, M. S., Tekdal, S., Aktas, H., & Karaman, M. (2016). Assessment of the impact of ecological factors on yield and quality parameters in triticale using GGE biplot and AMMI analysis. *Pak. J. Bot*, 48(5), 1903-1913.

Kheirizadeh Arough, Y., Seyed Sharifi, R., & Seyed Sharifi, R. (2016). Bio fertilizers and zinc effects on some physiological parameters of triticale under water-limitation condition. *Journal of Plant Interactions*, 11(1), 167-177.

Krokhmal, A.V., Grabovets, A. I., Gordinskaya, E. A. & Barulina, N. I. (2021). Ecological testing of winter varieties triticale in the conditions of the northwestern zone Rostov region. *Triticale. Proceedings of the meeting of the OSKhN triticale section RAS - online. (June 9, 2020): – Triticale. Breeding, genetics, agrotechnicks and technology of raw materials processing"*, 66-75.

Kumar, S., Mittal, R. K., Dhiman, R., & Gupta, D. (2014). Assessment of Triticale (*Triticosecale*) X Bread Wheat (*Triticum Aestivum*) Genotypes for Drought tolerance based on morpho-physiological, grain yield and drought tolerance indices under non-irrigated and irrigated environments. Int. J. Food Sci. Nutr. Diet, 3(5), 1115-121.

Kutlu, İ., & Kinaci, G. (2010). Evaluation of drought resistance indicates for yield and its components in three triticale cultivars. *Journal of Tekirdag Agricultural Faculty*, 7(2), 95-103

Lagrou, J. (2014). *Drought resistance of eight triticale genotypes in South Africa*. Masterproef voorgedragen tot het behalen van de graad van Master of Science in de biowetenschappen: land-en tuinbouwkunde

Liu, Y., Bowman, B.C., Hu, Y.-G., Liang, X., Zhao, W., Wheeler, J., Klassen, N., Bockelman, H., Bonman, J.M. & Chen, J. (2017). Evaluation of Agronomic Traits and Drought Tolerance of Winter Wheat Accessions from the USDA-ARS National Small Grains Collection. *Agronomy*, 7(3): 51.

Lonbani, M., & Arzani, A. (2011). Morpho-physiological traits associated with terminal drought stress tolerance in triticale and wheat. *Agronomy Research*, 9(1-2), 315-329.

Martyniak, L. (2002). Grain yield and yield components of spring triticale as affected by simulated drought stress applied at different growth stages. *Proceedings of the 5th International Triticale Symposium*, I – Oral presentations, IHAR, Radzikow, Poland, 143-148.

Medvedev, A. M., Postovaja, O. V., Lavrinova, V. A. & Zeleneva, Y. V. (2012). Ecological studying to winter triticale in the conditions of the Tambov region. *The proceedings of international scientifically-practical conference "Triticale and its role in conditions of increase aridity of climate" and section triticale of department of plant growing of Russian Academy of Agricultural Science, Rostov on Don*, 2012, pp 69-75. (Ru)

Ramazani, S. H. R., Tajjali, H., & Ghaderi, M. G. (2017). Correlation and path coefficient analysis for determining interrelationships among grain yield and related characters in Iranian genotypes of triticale. *Bulgarian Journal of Crop Science*, 54(1), 35-39.

Riasat, M., Kiani, S., Saed-Mouchehsi, A., & Pessarakli, M. (2019). Oxidant related biochemical traits are significant indices in triticale grain yield under drought stress condition. *Journal of Plant Nutrition*, 42(2), 111-126.

Saed-Moucheshi, A., Razi, H., Dadkhodaie, A., Ghodsi, M., & Dastfal, M. (2019). Association of biochemical traits with grain yield in triticale genotypes under normal irrigation and drought stress conditions. *Australian Journal of Crop Science*, 13(2), 272-281.

Sechnyak, L. K. & Sulima, Y. G. (1984). *Triticale*. Moscow, Kolos.

Shanazari, M., Golkar, P., & Mirmohammady Maibody, A. M. (2018). Effects of drought stress on some agronomic and bio-physiological traits of *Triticum aestivum*, Triticale, and Tritipyrum genotypes. *Archives of Agronomy and Soil Science*, 64(14), 2005-2018.

Shavrukov, Y., Kurishbayev, A., Jatayev, S., Shvidchenko, V., Zotova, L., Koekemoer, F., de Groot, S., Soole, K., & Langridge, P. (2017). Early Flowering as a Drought Escape Mechanism in Plants: How Can It Aid Wheat Production? Front. Plant Sci. 8:1950. doi: 10.3389/fpls.2017.01950

Skatova, S. E. (2021). Characteristics of the first and second generations winter-spring hybrids of triticale in spring sowing. *Triticale. Proceedings of the meeting of the OSKhN triticale section RAS - online. (June 9, 2020): – Triticale. Breeding, genetics, agrotechnicks and technology of raw materials processing"*, 102-115 (Ru).

Stankova, P., & Stankov, I. (2002). Relationship between economic and biological yield in some cereals in soil drought. *Proc of the Jubilee Sci Session Selection and Agrotechnics of Field Crops*, 1, 168-173 (Bg).

Stirmanova, E.Yu., Chernousov, E.V., & Grabovets, A.I. (2021). Morphological properties of F1 hybrids when crossing spring forms with winter ones. *Triticale. Proceedings of the meeting of the OSKhN triticale section RAS - online. (June 9, 2020): – Triticale. Breeding, genetics, agrotechnicks and technology of raw materials processing"*, 134-141.

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

Stoyanov, H. (2021). Effect of drought on yield and yield components of triticale in the conditions of South Dobrudzha. *Scientific Papers. Series A. Agronomy*, LXIV, 1, 556-568.

Urazaliev, R. A., & Ainebekova, B. A. (2012). Selection and biological evaluation of winter triticale in Kazakstan. *The proceedings of international scientifically-practical conference "Triticale and its role in conditions of increase aridity of climate"and section triticale of department of plant growing of Russian Academy of Agricultural Science, Rostov on Don*, 2012, pp 103-109 (Ru).

Yurchenko, T. A., Krohmal, F. V., Grabovets, A. I. & Mihalenko, P. V. (2012). World collection VIR – initial stocks for breeding spring triticale. *The proceedings of international scientifically-practical conference "Triticale and its role in conditions of increase aridity of climate"and section triticale of department of plant growing of Russian Academy of Agricultural Science, Rostov on Don*, 2012, pp 136-140 (Ru).

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