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Bulgarian triticale cultivars characterized by high yield of silage mass and high stability under contrasting environmental conditions

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Abstract: The diversification of fodder production and the growing demands to provide quality raw materials for feeding farm animals is a prerequisite for continuous improvement of fodder plants. For this reason, plant breeding should be aimed at improving productivity and ensuring high quality. One of the most diverse plants in this regard is triticale. In order to establish the genotypes that provide the highest yield of silage biomass and at the same time are the most stable under contrasting environmental conditions, 12 contemporary Bulgarian winter hexaploid triticale cultivars were studied together with the adopted standards in three different growing periods. The cutting of the genotypes was carried out at milk maturity stage. The obtained results showed that cultivars Doni 52 (4170 kg/da), Avitohol (3865 kg/da) and the standard Kolorit (3768 kg/da) had the highest productivity of silage biomass. Respectively, the standards AD-7291 and Vihren and cultivar Respect had the lowest productivity. It was found out that the drought in the 2019/2020 growing period had an extremely adverse effect on the yield of silage - the average values obtained for this period were only 2322 kg/da. With the highest stability of silage mass yield were cultivars Avitohol, Akord and Lovchanets, and with the lowest - Kolorit, Doni 52 and Borislav. These results show that despite its high productivity, Doni 52 is characterized by unstable silage yields during contrasting growing periods. This makes varieties such as Avitohol significantly more suitable for silage production in different soil and climatic conditions of Bulgaria.

Keywords: silage biomass; stability; triticale

INTRODUCTION

The diversification of silage production is crucial for animal breeding, especially against the background of the increasing global population and the shortage of sufficient food and forage raw materials. The large areas sown with low-yielding forage crops and the insufficient utilization of the forage crop rotations is the reason why a large part of the food crops is used as raw materials for forage. On the other hand, obtaining quality forage within a certain period of time provides better nutrition for the animals thus contributing to animal produce of higher quality. There is a large number of crop plants, which can be used for production of both fodder and whole-plant silage but

are little known to the agricultural producers and even less to the stock breeders. In this respect, one of the highest-yielding and at the same time less known and grown silage crop is winter hexaploid triticale.

Triticale was used as green mass fodder for the first time after the registration of the hexaploid triticale AD-durumforme by Shulyndin in 1975 (according to Tsvetkov, 1989). Although its fertility is insufficient, its green mass yield is higher in comparison to wheat and rye, and this early triticale cultivar was the first in the world registered for production of green mass. Such traits of triticale as a crop plant allow a separate direction in breeding. According to Tsvetkov (1989), the use of triticale for green mass in the crop rotation en-

tures a comparatively early source of green mass and silage, as well as complementary nutrition, filling in the shortage of raw materials during the period from harvesting of rye to harvesting of alfalfa. On the other hand, triticale for green mass and silage leaves the fields free comparatively early allowing for cultivation of silage maize as a second crop.

The productivity potential of triticale for green mass and silage is exceptionally high. Gowda et al. (2011) reported 1520 kg/da mean productivity of dry mass from 111 investigated triticale lines. Similar data presented Gissen et al. (2014), showing simultaneously that in comparison to such crops as maize, the obtained yield is equal or can even be with higher values. According to Goryanina (2020), triticale is characterized by lower green mass productivity than rye, but its nutrition value is significantly greater. Gill and Omokanye (2016) reported yields from winter forms of triticale exceeding 2600 kg/da silage mass, which was largely dependent on the year conditions. Lower yields from three cultivars of spring triticale were reported by Robles Jimenez et al. (2018). According to data of Ju et al. (2010), if the crop is sown early, the green mass yield from spring triticale can reach 3900 kg/da. Cannas et al. (2005) pointed out that with regard to the obtained dry biomass, significant differences between the spring and winter forms were not observed, nor between the cultivars used in the study. Manni et al. (2021) demonstrated that significantly high silage biomass productivity can be achieved even in spring forms of triticale. Under the conditions of Bulgaria, using winter triticale forms, Tsvetkov (1989) reported maximum productivity of cultivars Belitsa 1 and Rozhen exceeding 5000 kg/da.

However, there are no thorough studies on the contemporary Bulgarian triticale cultivars with regard to their productivity for green or silage mass. An exception are the investigations of Kirchev (2020), who studied cultivars Bumerang, Respekt, and Atila, and those of Nedeva (2020) and Nedeva et al. (2016), who carried out researches on Musala and Atila and also the study of Stefanova-Dobreva et al. (2024) on 37 geno-

types including old Bulgarian cultivars Rakita, Kolorit, Vihren, Rozhen, Zaryad and Persenk. In spite of the high results the authors reported, the studies were directed towards specifying the effect of different agronomy practices or in old, but not current cultivars. From a breeding and practical point of view, it is necessary to determine both the productivity for silage mass of the contemporary triticale varieties and their stability. This is also required by the circumstance that currently in Bulgaria there are only one registered triticale cultivar for green or silage mass..

The aim of this study was to determine the yield of silage mass and its stability in contemporary Bulgaria triticale cultivars.

MATERIALS AND METHODS

Plant material

To realize this goal, 13 contemporary cultivars of winter hexaploid triticale developed at Dobrudzha Agricultural Institute were used as follows: Kolorit, Atila, Akord, Respekt, Bumerang, Irnik, Dobrudzhanets, Lovchanets, Doni 52, Blagovest, Borislav, Avitohol and Hokey. The study also included the standards AD-7291, Vihren and Rakita. The experiment was designed as a standard competitive varietal trial in five replications. Sowing was within the optimal dates for triticale, 15th – 30th October. It was performed with a plot seeder in the fields of Dobrudzha Agricultural Institute – General Toshevo.

The cultivars were cut at milk maturity. The silage mass yield was evaluated directly, without leaving the biomass to dry, drying it or applying any other thermal or chemical treatment. The silage mass yield was determined for each replication and subsequently aggregated and averaged over years, genotypes and in total.

Meteorological conditions

The experiment was carried out in three successive harvest years: 2018/2019, 2019/2020, 2020/2021. The data presented on the average monthly temperature and total monthly precipitation (Table 1) reveal the contrasting nature of

the periods included in the study. According to the long-term tendency (1960-2021), the most significant differences of the mean monthly temperatures were registered during December – March, and for precipitation – during December and May-June. These differences give sufficient ground to differentiate the growth and development of the plants over periods of vegetative growth. Clearly outlined were the separate meteorological phenomena and processes of single occurrence, which were not repeated over periods and were able to strongly influence the physiological processes in the plant organism.

Harvest year 2020/2021 is worth considering due to the extreme intensive and long rainfalls in January, a considerably long warm period in January and February and rather untypical low temperatures and snowfalls in the first two decades of March. Harvest year 2019/2020 was highly unfavorable for growing of triticale due to the rather long drought during March – April. The conditions of 2018/2019 can also be described as dry, when a lower number of negative events were observed in comparison to the other two economic years.

Nevertheless, the period 2020/2021 was the optimal for the development of the vegetative mass of triticale due to the significantly higher temperatures and precipitation. In the other two harvest years, the spring drought impeded the vegetative growth and the increase of vegetative mass was lower in comparison to the favorable period. Particularly unfavorable were the high

temperatures of June 2020, which were combined with intensive rainfalls leading to thermal stress and faster decay of the leaf mass.

Statistical processing of data

Two-way ANOVA was carried out and significant differences were found between the separate growing periods and the genotypes. Based on AMMI-analysis, the stability of the individual genotypes was determined under contrasting conditions of the environment. Software IBM SPSS Statistics, v.19 was used for the ANOVA, and for AMMI-analysis – AMMISOFT 2.7.13.1 (Gauch and Moran, 2019).

RESULTS

The contrasting nature of the separate periods of the investigation was a prerequisite for certain differences in the yield of silage mass regardless of the genotype differences. Such a tendency can be observed clearly in all studied cultivars (Table 2); the lowest results were obtained in harvest year 2019/2020, higher in 2018/2019, and the highest – in 2020/2021. This was also confirmed by the mean values of the three studied periods. The main reason for the decrease of the biomass yield were the drought effects observed during the two economic years, 2018/2019 and 2019/2020, the drought in 2019/2020 being particularly well expressed. During this period, the plants were considerably shorter in compari-

Table 1. Meteorological conditions during the investigated growing periods

Parameter	Year	Aug	Sep	Oct	Noe	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
AMT, °C	2018/2019	23,60	17,70	13,30	5,40	1,20	1,00	3,50	8,20	9,00	16,00	22,30	22,00
	2019/2020	22,80	17,90	13,40	11,70	5,20	1,80	5,10	8,00	10,00	15,40	19,60	22,30
	2020/2021	22,60	19,40	15,30	6,30	5,30	3,00	4,00	4,20	8,80	15,80	18,90	22,80
	1960/2021	21,13	16,92	11,74	6,76	2,02	-0,16	1,24	4,70	9,85	15,25	21,94	21,42
TMP, mm	2018/2019	1,10	54,70	11,70	66,20	43,80	19,20	16,30	16,10	49,40	31,70	37,50	54,00
	2019/2020	7,80	36,70	27,60	35,40	21,80	2,80	28,10	28,30	5,80	48,00	51,30	2,70
	2020/2021	3,50	34,10	52,90	26,00	74,40	109,70	13,20	22,20	44,60	63,60	162,70	29,70
	1960/2021	36,95	46,06	42,26	43,12	42,20	37,55	33,74	35,25	39,97	52,19	62,60	50,99

son to the previous and the following periods. Such effects of drought were the reason for the significant decrease of plant biomass. Actually, drought in triticale causes disturbance in the total plant development, as confirmed by the data on plant height, heading, number of productive tillers and spike morphology from our previous studies (Stoyanov, 2018). In spite of certain tendencies, however, the individual varieties did not respond identically to the contrasting growing conditions.

In 2018/2019 growing period, cultivars Akord, Doni 52 and Borislav were with the highest yield of silage biomass. Respectively, the lowest values were observed in the standard variety AD-7291 and cultivars Irnik and Lovchanets. In the standard varieties Vihren and Rakita, significant differences were not observed. Cultivar Kolorit,

which is a standard in the state varietal testing for green and silage biomass, also did not form significant differences with the other standards, with the exception of AD-7291. Higher yields than that of Kolorit were obtained only from Akord, Doni 52, Borislav and Avitohol, but the difference was significant only in Doni 52. From the 16 investigated cultivars, a half were at the level of Kolorit. Six varieties performed silage biomass yields significantly lower than Kolorit.

In 2019/2020 growing period, considerably lower values of silage mass yield were observed as compared to the previous period. This was primarily related to effect of the active soil and air drought during April – June and the strong thermal stress observed immediately prior the milk maturity stage. Highest values were registered in cultivars Dobrudzhanets, Blagovest and Avito-

Table 2. Silage biomass yield from Bulgarian triticale cultivars

Cultivar	2018/2019		2019/2020		2020/2021		Average	
	SMY kg/da	RY, %	SMY kg/da	RY, %	SMY kg/da	RY, %	SMY kg/da	RY, %
AD-7291	3278,4	79,5	2084,0	105,7	4352,0	83,6	3238,1	85,9
Vihren	4047,6	98,1	1912,0	97,0	4640,0	89,1	3533,2	93,8
Rakita	4092,4	99,2	2484,0	126,0	4568,0	87,7	3714,8	98,6
Kolorit	4124,0	100,0	1972,0	100,0	5208,0	100,0	3768,0	100,0
Atila	3627,8	88,0	2212,0	112,2	5008,0	96,2	3615,9	96,0
Akord	4228,8	102,5	2304,0	116,8	4840,0	92,9	3790,9	100,6
Respekt	3827,2	92,8	2152,0	109,1	4420,0	84,9	3466,4	92,0
Bumerang	4113,2	99,7	2196,0	111,4	4788,8	92,0	3699,3	98,2
Irnik	3671,2	89,0	2444,0	123,9	4520,0	86,8	3545,1	94,1
Dobrudzhanets	4048,8	98,2	2580,0	130,8	4576,0	87,9	3734,9	99,1
Lovchanets	3480,8	84,4	2460,0	124,7	4676,0	89,8	3538,9	93,9
Doni 52	4378,0	106,2	2432,0	123,3	5700,0	109,4	4170,0	110,7
Blagovest	3704,4	89,8	2524,0	128,0	4964,0	95,3	3730,8	99,0
Borislav	4249,6	103,0	2468,0	125,2	4296,0	82,5	3671,2	97,4
Avitohol	4129,2	100,1	2536,0	128,6	4932,0	94,7	3865,7	102,6
Hokey	4002,8	97,1	2392,0	121,3	4380,0	84,1	3591,6	95,3
Average	3937,8	95,5	2322,0	117,7	4741,8	91,0	3667,2	97,3
<i>LSD0,05</i>	150,11	3,64	102,48	5,20	179,39	3,44	98,95	2,63
<i>LSD0,01</i>	197,28	4,78	134,68	6,83	235,75	4,53	130,04	3,45
<i>LSD0,001</i>	252,02	6,11	172,05	8,72	301,17	5,78	166,13	4,41

SMY – Silage Mass Yield; RY – Relative Yield

hol, and lowest – in the standard variety Vihren, and cultivars Kolorit and Respekt. All cultivars, with the exception of Vihren, realized significantly higher yields of silage mass than Kolorit. In nine of the 16 investigated cultivars, the exceeding over Kolorit was with more than 20%. A tendency was observed of the more recent cultivars having higher silage mass yields in comparison to the older cultivars.

The highest yields of silage mass were read in the cultivars in 2020/2021 growing period. The lowest values were read in the standard variety AD-7291 and in cultivars Borislav and Hokey. Cultivar Kolorit, as well as cultivars Atila and Doni 52 gave high yields. Only Doni 52 exceeded Kolorit, the difference being significant at the highest level. All other cultivars were at the level of Kolorit and significantly below it, none of them having higher absolute yield. Averaged for the three growing periods of the investigation, the highest productivity of silage mass was registered in cultivars Kolorit, Doni 52 and Avitohol. With respective lowest yields were the standards AD-7291 and Vihren and cultivar Respekt. Above cultivar Kolorit were Akord, Doni 52 and Avitohol. A considerably high and significant difference was observed in cultivar Doni 52. In Akord, the difference was not significant, and in Avitohol, a significant difference may be noted at a level approximating 95%. Among the studied cultivars, five were at the level of Kolorit, but with lower absolute values, and all other cultivars with lower values had significantly lower average productivity for silage mass in comparison to Kolorit.

The results obtained showed that cultivars Kolorit, Doni 52 and Avitohol had the highest productivity for silage mass among the studied genotypes. However, the data over years revealed that these three cultivars were not always the most productive, while cultivars like Kolorit, for example, demonstrated rather variable response even within three growing periods. This allows searching also for parameters related to the stability and productivity of each genotype, besides their mean productivity, since such characteristics are essential for the distribution of the cultivar under different soil and climatic conditions.

The performed ANOVA (Table 3) showed that there was interaction between the genotype and the environment, which was a clear indication of genotypes with different stability with regard to their productivity of silage mass. However, the interaction was of low strength and significance in comparison to similar interactions in grain yield (e.g. Stoyanov (2024)) due to certain tendencies of this parameter, which are less influenced by the conditions of the environment. On the other hand, such an interaction is a possible indicator for greater similarity between the genotypes.

The graphic presentation of the results from the AMMI analysis carried out confirmed this hypothesis (Figure 1). The graph allows following the comparatively narrow range within which the mean productivity of the investigated cultivars varied. On the other hand, the stability expressed through the parameter IPCA1 showed that there were drastic differences in the behavior of the genotypes over growing periods. The mean values of the three individual years are positioned in

Table 3. Two way ANOVA of parameter yield of silage mass of the investigated Bulgarian triticale cultivars

Source	Sum of Squares	df	Mean Square	F	Sig.
Genotype (G)	9175925,096	15	611728,340	3,168	0,000
Environment (E)	243002581,275	2	121501290,638	629,182	0,000
G * E	11195872,192	30	373195,740	1,933	0,004
Error	37077092,000	192	193109,854		
Total	300451470,563	239			

df – degree of freedom; *F* – F-test value; *Sig.* – Significance

different quadrants of the graph at great distances from each other confirming the contrasting nature of the environments. This revealed that the three contrasting periods interacted rather differently with the genotypes, which was a prerequisite for searching of variable stability.

The genotypes to the right of the vertical axis in the AMMI1 biplot and close to the horizontal axis combined high mean productivity of biomass, having at the same time lower interaction with the conditions of the environment. Such combinations were observed in cultivars Akord, Bumerang, Blagovest and Avitohol. Respectively, the genotypes at a greater distance from the horizontal axis but also with higher than the average productivity, had stronger interaction with the environment. Among the studied genotypes, such combinations were found in cultivars Kolorit, Doni 52, Rakita, Dobrudzhanets and Borislav.

All other investigated cultivars were characterized by biomass productivity lower than the

average, but with different stability. AD-7291 and Lovchanets exhibited higher stability but lower productivity, whereas Vihren, Atila, Respekt, Irnik, and Hokey demonstrated lower stability. It should be pointed out that such cultivars as Atila, Irnik and Hokey, although having values of silage biomass yield lower than the average, are quite close to this average value, and especially to the values of the standard variety Kolorit. Concerning the specific conditions of the environment, the lowest interaction of the genotypes was that with the conditions of 2018/2019. The strongest interaction was observed according to the same period with Kolorit and Doni 52. These cultivars, on their part, were characterized by lower interaction with the conditions of 2020/2021. This highlighted their higher adaptability according to the other genotypes since they had much more favorable response to changeable environments.

At the same time, none of the genotypes had low interaction with the conditions of 2019/2020.

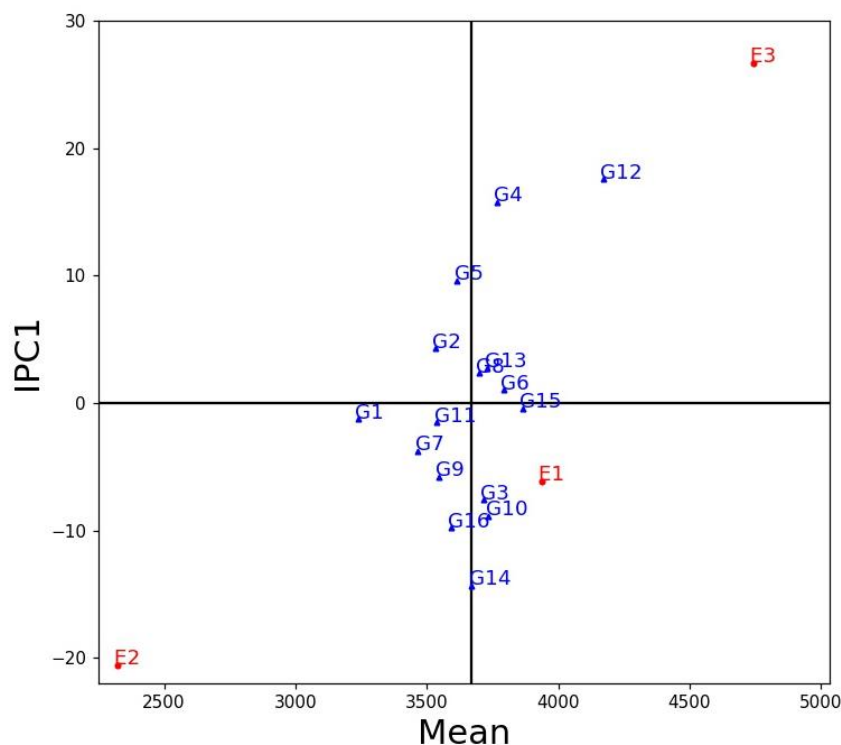


Figure 1. AMMI1 biplot of the investigated triticale cultivars for productivity of biomass

G1 – AD-7291, G2 – Vihren, G3 – Rakita, G4 – Kolorit, G5 – Atila, G6 – Akord, G7 – Respekt, G8 – Bumerang, G9 – Irnik, G10 – Dobrudzhanets, G11 – Lovchanets, G12 – Doni 52, G13 – Blagovest, G14 – Borislav, G15 – Avitohol, G16 – Hokey; E1 – 2018/2019, E2 – 2019/2020, E3 – 2020/2021

Cultivars Vihren, Kolorit, Atila, Akord, Bumerang, Doni 52, Blagovest and Avitohol interacted negatively with this economic year, while the rest of the cultivars had positive interactions, which was again rather strong. All cultivars with opposite interactions with 2019/2020 were characterized by much better drought resistance. At the same time, the conditions of the environment during this period were active soil and air drought, especially during the spring period when the biomass potential of the crop was formed. Concerning stability, IPCA1 gave sufficient information to determine the stability of the genotype since it determined over 75% of the sum of squares for the genotype $\times$ environment interaction. Most stable were the genotypes with parameter values close to 0.00. These were AD-7291, Akord, Bumerang, Lovchanets and Avitohol. At the same time, very high and positive were the values of Atila, Kolorit and Doni 52, and high and negative were the values of Dobrudzhanets, Borislav and Hokey. Such results are indicative and confirm the thesis that often the high-yielding cultivars are characterized by high plasticity but low stability.

DISCUSSION

The biomass productivity of the contemporary triticale cultivars is a little studied parameter, especially with regard to the European breeding of this crop, which has been largely directed toward higher grain yield. Grabovets and Krokhmal (2019) reported 31 developed winter hexaploid triticale cultivars, only four of which were developed for biomass. According to data provided by these authors, the triticale cultivars developed for biomass in Don region have productivity potential for biomass exceeding 8 t/da at milk maturity, the yields often being within 5 and 6 t/da, averaged for a three-year period of testing under varied environments. According to the above authors, cultivar Agraf gave a mean yield of 6.28 t/da during 2000 – 2002 and cultivar Argo was characterized by a mean biomass yield of 6.28 t/da. Cultivar Tornado gave one of the highest silage biomass yield in 2004

after previous crop black fallow – 8.9 t/da. According to data of Goryanina (2020), 4 cultivars and 3 lines of triticale gave a mean yield of 4.3 t/da at milk maturity, averaged for the period 2016 – 2018. This exceeded the yields from rye, and particularly from common wheat grown for biomass. The author also determined the same tendency at the stage between booting and heading, when rye formed higher biomass. Testing five cultivars of spring triticale, Gill and Omokanye (2016) determined a mean productivity of silage mass for the period within 2.33 – 2.43 t/da between cultivars and within 1.68 – 2.68 t/da between growing periods. Gowda et al. (2011) reported green mass yield of 1.52 t/da at 0% moisture at stage early wax maturity. Similar data on dry biomass was pointed out by Gissen et al. (2014), when growing triticale cultivar Toulouse in five fertilization variants, conceding only to maize and sugar beat by productivity. Kara et al. (2009) reported 2.28 t/da green mass yield from cultivar Karma-2000. Similar data on fresh biomass yield obtained from triticale as a single crop were published by Ju et al. (2008). According to data of Baron et al. (2015), the yield of dried biomass from winter triticale at heading stage was from 0.78 to 1.01 t/da.

There are other researches as well, which give an idea about the differences observed in the yield of green, silage and dry biomass from different genotypes and under different environments (Cannas et al., 2005; Ju et al., 2009; Ju et al., 2010; Ali et al., 2010; Kavut et al., 2012; Zannat et al., 2012; Vasylenko et al., 2015; Robles Jimenez et al., 2018; Sabirova et al., 2019; Sas and Futó, 2019; Upreti et al., 2022). The above data and the results different researches obtained show that this crop is characterized by varied productivity potential with regard to biomass, which is directly dependent on the genotype, the growing conditions, the breeding direction of the genotypes, the conditions of the environment and the used agronomy practices.

Nevertheless, the results we obtained investigating cultivars, which were not typical genotypes bred towards biomass production, showed that under the conditions of Bulgaria the produc-

tivity completely corresponds to the contemporary tendencies in this crop. This allows distributing these genotypes under the conditions of Bulgaria, though in a different direction.

Their specific expressions during the vegetative growth of the crop are well known and studied under variable contrasting conditions with regard to such vegetative growth parameters as days to heading, plant height and number of productive tillers. It should be pointed out that the breeding direction toward grain production aims at early and medium early heading, shorter stems and number of productive tillers within the range of 700 – 800 tillers/m² (Stoyanov et al., 2017; Stoyanov, 2018; Stoyanov, 2020; Stoyanov, 2021a, Stoyanov, 2021b).

The genotypes for green mass are expected to have earlier heading and be characterized by greater plant height and higher number of productive tillers (Tsvetkov, 1989). The results from the above mentioned studies with the cultivars involved in this investigation showed that these criteria are met by cultivars Atila, Respekt, Bumerang, Lovchanets, Blagovest. In this respect, the results we obtained on the productivity of silage biomass coincided with the expected ones, reading actual higher results in Atila, Bumerang and Blagovest. Cultivar Respekt, which was significantly later, and cultivars Lovchanets, characterized by a very high number of productive tillers, remained with comparatively lower productivity. On the other hand, and early cultivar such as Kolorit, as well as Doni 52 and Avitohol, which did not have a predominant grain yield-related parameter (Stoyanov, 2022), demonstrated the best results.

In Bulgaria, the studies on the productivity of green or silage mass in triticale are even scarcer. Nedeva et al. (2016) pointed out that at milk maturity stage, the green yield from cultivar Musala varied from 3.5 to 4.5 t/da within two investigated economic years and five norms of mineral nutrition, and the variation in cultivar Atila was from 3.4 to 4.7 t/da. Significant differences between the two harvest years based on the above data were observed in cultivar Musala, while in cultivar Atila these differences were considerably

lower. At the same time, the authors registered a lower yield from cultivar Musala in the first year and from cultivar Atila – in the second harvest year.

Nedeva (2020), comparing three growing periods, found the same differing tendency of the two cultivars between the second the third growing period. These results categorically confirm the thesis that the genotype x environment interaction has a significant effect on the yield of green or silage mass. This, on its part, is also related to the different stability of the individual genotypes. Kirchev (2020), investigating cultivars Lasko, Bumerang, Respekt and Atila, found rather similar data and no significant differences between the genotypes in the different variants in all three economic years of the study. Between the variants with higher and lower fertilization norms, expressly different values were observed in all cultivars during all three years. A tendency was also observed of cultivars Lasko having the lowest green mass productivity under both fertilization norms, while Bumerang was with the highest yields, although in some cases the differences with the other varieties were not significant. Nevertheless, the values under the low fertilization norm varied from 2.4 to 4.7 t/da, and under the highest – from 4.2 to 5.6 t/da. The close values and the presence of clear tendencies between the cultivars was, however, related to a lower effect of the genotype x environment interaction. These results coincided to a certain degree with the data from the present study. On the other hand, however, it should be highlighted that in Bulgaria there are practically no data from studies on larger groups of genotypes. The cited researches are oriented rather toward the agronomy practices and cannot characterize clearly the individual genotypes with regard to stability and adaptability-related traits.

In the world literature, there are insufficient studies on triticale that determine the adaptability and stability of productivity of green and silage mass. An exception is the research of Lozano del Rio et al. (2009), who studied the genotype x environment interaction in 22 genotypes of spring triticale for green mass on the productivity

at two separate cuts, and on the cumulative result from both cuts. The authors found varied genotypic expressions based on the applied AMMI1 biplot analysis, since at the different stages of cutting, as well as in the cumulative results, various combinations of productivity and stability were observed. Such wide distribution, when applying AMMI analysis, was also observed in the results we obtained, which makes them adequate enough and allows finding optimal combinations between productivity and stability.

Although cultivars Kolorit and Doni 52 were characterized by high productivity of silage biomass, they interacted rather actively with the conditions of the environment, both cultivars having higher response to the more favorable conditions. On the other hand, cultivar Avitohol, although the productivity it performed was not as high as that of Doni 52, was characterized by weak interaction with the conditions of the environment, and can be respectively described as significantly more stable than the other high-yielding cultivars. Cultivar Akord was also characterized by higher-than-the-average productivity and higher stability, but in the extremely unfavorable harvest year 2020, its values were rather low. Compromise productivity and comparatively good stability, were observed in cultivar Blagovest, but its high productivity was realized during the unfavorable period; during the two periods optimal for the development of the biomass, as well as averaged for the entire period of investigation, its productivity was with lower values in comparison to such genotypes as Doni 52, Avitohol and Kolorit.

Against the background of the contrasting meteorological conditions and the obtained results on the productivity and stability of the investigated triticale cultivars with regard to their yield and silage biomass, it can be argued with a high degree of certainty, that there is a serious lack of genetic variability in this crop. This is also confirmed by the narrow range within, which productivity varied over periods. Nevertheless, stability was rather different and allowed determining the varieties suitable for growing for silage biomass, although the main breeding direction

of the studied genotypes was triticale for grain. In this respect, worth mentioning are cultivars Doni 52 and Avitohol, which are characterized by high productivity of silage mass, but possess respectively low (Doni 52) and high (Avitohol) stability under the specific conditions of the environment. From a practical perspective, the two genotypes are suitable for growing in production, but while Doni 52 gives better results under favorable growing conditions and low ones under extremely unfavorable environments, Avitohol demonstrated a tendency towards a more balanced productivity, which under favorable environment was not as high, but under unfavorable conditions was higher than the productivity of the other cultivars. Such traits allow distributing the two genotypes besides for their productivity, also for their silage biomass under the specific soils and climate of Bulgaria.

CONCLUSIONS

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

1. The highest productivity of silage biomass was observed in cultivars Doni 52 (4170 kg/da), Avitohol (3865 kg/da) and the standard Kolorit (3768 kg/da).
2. The lowest yield of silage biomass was recorded in the standard cultivars AD-7291, and cultivar Respekt.
3. It was found that the drought during the period of vegetative growth 2019/2020 had extremely unfavorable effect on the silage yield – the mean values obtained for this period were only 2322 kg/da.
4. The highest stability of silage biomass yield was registered in cultivars Avitohol, Akord and Lovchanets, and the lowest – in Kolorit, Doni 52 and Borislav.
5. In spite of its high productivity, Doni 52 was characterized by unstable silage yields under contrasting periods of growing. This makes such cultivars as Avitohol considerably more suitable for silage production under the different soil and climatic peculiarities of Bulgaria.

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