ISSN 1313 - 8820
Volume 7, Number 2
June 2015

AGRICULTURAL SCIENCE AND TECHNOLOGY

2015

An International Journal Published by Faculty of Agriculture,
Trakia University, Stara Zagora, Bulgaria

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The articles appearing in this journal are indexed and abstracted in: EBSCO Publishing, Inc. and AGRIS (FAO).

The journal is accepted to be indexed with the support of a project № BG051PO001-3.3.05-0001 "Science and business" financed by Operational Programme "Human Resources Development" of EU.

The title has been suggested to be included in SCOPUS (Elsevier) and Electronic Journals Submission Form (Thomson Reuters).

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Exploring the yield potential and spike characteristics of Tritordeum (×*Tritordeum* Ascherson et Graebner) accessions under the conditions of South Dobrudzha

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Abstract. *For the conditions of Europe the artificially created amphidiploid tritordeum (xTritordeum) could be a promising crop. In order to study its suitability for the conditions of Southern Dobrudzha, Bulgaria, 10 tritordeum accessions were tested for their morphological and physiological characteristics. The winter resistance of plants in two successive crop periods is recorded. The indicators length of spike, length of spike with awns, number of spikelets, weight of spike, weight of grains per spike, number of grains per spike, awness index, number of spikelets along the length of spike, weight distribution along the length of spike, weight of single spikelet, weight of 1000 grains and grain index are reported. The average number of tillers per plant, the time of heading, flowering and full maturity for the economic 2012/2013 is determined. During the same period the attack of pathogens of powdery mildew, brown rust and septoria leaf blight was also recorded. All accessions tested were completely resistant to powdery mildew and septoria leaf blight but susceptible to brown rust. The highest winter resistance in both financial years exhibits accession HT621 (100% survival of plants), and the worst – HTC1324 (40%). Relatively short growing period for accession HT621 was reported, which entered into maturity before the others. With the highest values of yield components (weight of grains per spike, average number of tillers) are HTC1331, HT31-2 and HT119. The accessions with the highest yield potential and the highest winter resistance appear to be promising for future studies on the introduction of the new grain crop into South Dobrudzha.*

Keywords: spike morphology, *Tritordeum*, winter tolerance, yield potential

Introduction

Grain cereal production is one of the main sectors of the world economy, which provides much of the food supply of the population (von Braun, 2007). The importance of grain cereals becomes greater due to the continuously increasing demand for quality food and feed (Crosson and Anderson, 1992). This necessitates seeking and creating high yielding varieties of plants from the group of cereals, that combine yield opportunities, but also resistance to biotic and abiotic environmental factors (Hazell and Wood, 2008). The restrictions that imposed by certain plant species in terms of their yield abilities are the reason not only for improving the existing grain cereals (Ayala and Kiger, 1984) but also to seek new species suitable for introduction, as well as artificially created hybrids characterized by greater productive capacity and resistance to higher levels of biotic and abiotic stress (Stoyanov, 2013). This requires detailed studies on the biology of different hybrid accessions in order to choose the most suitable ones that are to be used as crop plants.

Wide hybridization as part of the classical breeding is the primary method for creation of new crops species in family *Poaceae* (Stoyanov et al., 2010). Particularly great is the diversity of hybrid and amphidiploid accessions in tribus *Triticae*, and especially in the group *Triticum-Aegilops* (Stoyanov, 2013). The challenge to create hybrid plant species that combine important economic qualities of their parental forms begins with hybridization between common wheat and rye (Kolev, 1978). Only after the discovery of the effects of colchicine (Kostoff, 1938), it is possible to overcome the sterility of wheat-rye hybrids and to create stable amphidiploid plants with high yield potential and high resistance to economically important diseases of wheat and rye. Subsequently, a large number of amphidiploid forms that combine the genomes of their parents are created (Stoyanov, 2013). These are perennial wheatgrass-wheat hybrids (Tsitsin, 1978), synthetic hexaploid wheat forms (Spetsov et al., 2008; Spetsov et al., 2009; Stoyanov et al., 2010), x*Senaldia* (Ksiazczyk et al., 2011), and others.

The ability to create an amphidiploid between bread wheat (*Triticum aestivum*) and cultural barley (*Hordeum vulgare*) is a prerequisite many crosses to be made at the beginning of the last century but a stable hybrid not to be created (Kruse, 1973; Chu et al., 1984; Sethi et al., 1986). This directs the efforts of researchers to use other species of the genus *Hordeum* to participate in the wide hybrids. The South American species *Hordeum chilense* appears to be promising for the creation of amphidiploid forms and in 1973 Martin (in Atienza et al., 2000) created successfully the amphidiploid x*Tritordeum* ($2n = 6x = 42$, $AABBH^{ch}H^{ch}$) combining the genomes of durum wheat (*Triticum durum* ($2n = 4x = 28$, AABB)) and wild species *Hordeum chilense* ($2n = 2x = 14$, $H^{ch}H^{ch}$).

Tritordeum is an amphidiploid crop plant (Knuepffer, 2009) which features resistance to economically important diseases such as brown rust, septoria leaf blight, common bunt, yellow rust, transferred from diploid paternal component (Rubiales et al., 1991; Rubiales et al., 2000; Martin et al., 2000). The grain is rich in carotenoids, lutein, fibers, antioxidants (Alvarez and Martin, 1996; Martin et al., 1996) and balanced amount of monosaccharides (Mikulikova et al., 2006). The plants are distinguished by a high drought tolerance due to the presence of the genome of wild species (Martin et al., 1996). Yields are close to those of bread wheat and triticale (Ballesteros et al., 1994; Ballesteros et al., 2005; Rodriguez-Suarez et al., 2009). Martin and Alvarez (1996) reported minor differences in the yields of wheat and tritordeum but significant differences in protein content determined tritordeum as a source of genes for selection in the direction of protein. Cubero et al. (2000) reported a protein content of 25%, which greatly exceeds that of

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common winter wheat and triticale. Gallardo and Fereres (1993) on the other hand indicate a negative correlation between the yield of the crop and its protein content. Despite their negative qualities *Tritordeum* is promising cereal, which is the reason to be tested in different agro-climatic regions.

As Martin et al. (1996) reported increased drought resistance and thermotolerance of *Tritordeum*, it could be assumed that this new crop would be suitable for growing under the conditions of South Dobrudzha. The region is characterized by a precipitation rate below the national average and high temperatures between May and June (Kiryakov et al., 1971; Raev et al., 2003) when heading and flowering occurs in most grain cereals, leading to a reduction in yield and quality properties. Therefore, interesting to overcome the unfavorable conditions of climate of the region are different accessions of *Tritordeum*.

The purpose of this study is to test accessions of *Tritordeum* on their morphological and physiological properties and evaluation of their suitability for the conditions of South Dobrudzha to be made.

Material and methods

Ten accessions of x*Tritordeum* were used, as nine originate from the collection of the Plant Production Research Center Piešťany, Research Institute of Plant Production Piešťany, Gene bank of Slovak Republic, and one (HT621) was derived from the National Small Grains Collection, GRIN-ARS, USDA, the USA. Fifteen seeds of each accession were sown with a spacing 30 cm between rows and 5 cm inside the rows. Sowing was carried out on 28.11.2012, under field conditions in the area of Stozher, Dobrich region.

The number of emerged plants (NGP) and field germination (FG) per accessions are reported. Data for complex winter tolerance is reported by number of frosted (NF) and pulled-out (NPO) plants. The influence of winter conditions (IWC) is presented as the ratio of the sum of the number of frosted and pulled-out plants to the number of germinated plants (NGP). The number of overwintered plants (NP) is reported.

Winter tolerance is monitored during the next growing season as sowing has been conducted on the same schedule of 08.11.2013. The seeds used are obtained as reproduction of the previous period, and accessions HT621, for comparison, which is obtained by Prof. Antonio Martin, Spain.

The determination of the attack by phytopathogens is performed under field conditions; for powdery mildew (EG) according to methodology of Stoilova and Spetsov (2006); for brown rust (PR) according to the methodology of Ivanova (2012); for septoria leaf blight (ST) according to the methodology of Eyal et al. (1987). Assessment was carried out in phase lactic maturity as established resistant (R), medium resistant (M) and susceptible (S) accessions.

At the same scheme are sown and reported data for standard wheat varieties for frost tolerance – Mironovska 808, Bezostaya 1, Rusalka, №301, San Pastore and standards for susceptibility to powdery mildew (*Erysiphe graminis*) – Sadovska ranozreyka; brown rust (*Puccinia recondita*) – Michigan Amber; septoria leaf blight (*Septoria tritici*) – Enola. A comparative analysis of winter tolerance and susceptibility to infection of phytopathogens of the amfidiploid accessions compared to those wheat varieties are done.

Data for average daily temperatures during the periods 01.10.2012 – 31.03.2013 and 10.01.2013 – 03.31.2014, for the amount of precipitation during 31.10.2012 –30. 06.2013 and 31.10.2013 – 30.04.2014, and the snow cover in the same period were summarized. The data for temperature and precipitation are derived from measurements with an automatic weather station LaCrosse. Measurements were taken twice daily at 07:00 and 19:00. Data of snow cover are determined using standard snow-meter with accuracy 0.5 cm.

During the growing season in the grain filling phase the average number of tillers per plant (ANT) is reported. Harvesting is done in phase full maturity between 12 and 20.07.2013. Of each sample were randomly selected 10 fully matured spikes with no established existence of attack by pests. A morphological evaluation of the spikes of each accession was made by 6 quantitative traits: length of spike (LS), length of spike with awns (LSA), weight of spike (WS), number of spikelets per spike (NSS), weight of grains in a spike (WGS), number of grains in a spike (NGS) and 6 index properties: awness index (AI) – ratio of LSA and LS, weight distribution along the spike (WDLS) – ratio of WS and LS, number of spikelets to the length of spike (NSLS) – ratio of NSS and LS, average weight of spike (WSS) – ratio of WS and LS, weight of 1000 grains (M1000) – set according to standard methodology of BDS, percentage of grains in weight of spike (GI) – ratio of WGS and WS. The yield of each accessions equivalent to 1 ha is reported.

The obtained data is averaged and the standard deviation (SD) is reported, per accession and in general. The total variation coefficient (VC) and the significance of the results are calculated. ANOVA is derived, and significant differences are established. A cluster analysis for grouping of accessions according to their productivity and winter tolerance is made. For summarizing the data and for analysis of variance software Microsoft Excel 2003 was used, for ANOVA (Statistica 7) and for cluster analysis (IBM SPSS Statistics 19).

For the purpose of this study hypothetical calculable yield is defined as an area corrected product of the reported indicators – ANT and WGS.

$$HPY = \frac{ANT.WGS.p.d}{k} \quad (1)$$

where HPY is hypothetical potential yield, ANT is average number of tillers, WGS is Weight of grains in a spike, p is sowing rate per square meter (=80), d is coefficient of equivalence to 1 ha (=10000), k is coefficient of equivalence to 1 kg (=1000).

The comparison of real yield is made per accessions and the suitability of the accessions for the specific growing conditions was reported. Phenological observations were carried out during the growing season. Date of heading (DH), full flowering (DF), full maturity (DFM) are reported.

Results and discussion

The data about the studied morphological parameters are presented in Tables 1, 2 and 3. From the tables the slight variations in indicators NSS, LS, LSA and M1000 and the high variability in WS, WGS and NGS can be traced. The slight variation in the first four indicators is due to a similar external morphology, which is accentuated by the genetic proximity of the accessions. In the second group of parameters high variation is caused by the uneven seedset of spikes in different accessions, which is indicative of the reduced fertility in some of them. Lack of stability in the yield components is a typical feature in most amphidiploids and hybrids.

Table 1. Morphological characteristics of the studied x*Tritordeum* accessions by properties NSS, LS, LSA and WS.

Accession	NSS		LS		LSA		WS	
	AV	SD	AV	SD	AV	SD	AV	SD
HT 119	18.8000	1.31656	83.2000	7.19259	132.2000	7.61285	2.1140	.41045
HT 129	21.0000	.81650	98.0000	4.16333	155.2000	7.06792	2.4720	.29664
HT 31-1	22.4286	2.14920	93.5714	7.11471	150.4286	7.48013	2.9686	.97686
HT 31-2	24.1000	1.37032	100.9000	5.68526	154.2000	9.63558	3.5450	.83967
HT 31-4	20.0000	1.76383	83.7000	8.34066	130.3000	14.41488	1.8630	.89864
HT 621	21.1000	1.52388	83.8000	6.21468	125.5000	3.89444	2.5420	.54328
HTC 1323	19.3000	2.83039	76.3000	13.16603	117.3000	17.95086	2.4700	1.03136
HTC 1324	18.7000	1.94651	65.2000	8.02496	104.1000	10.19204	2.0160	.63460
HTC 1331	20.4000	1.26491	81.7000	7.30373	123.5000	5.42115	3.2290	.44921
HTC 1380	17.0000	3.41565	60.2857	11.82813	99.7143	12.67168	1.3471	.62869
Total	20.3191	2.59947	83.0319	14.34704	129.5106	20.66983	2.4757	.90775
CV, %	12.7932		17.2790		15.9599		36.6659	

NSS – number of spikelets per spike; LS – length of spike; LSA – length of spike with awns; WS – weight of spike; AV – average value; SD – standard deviation

Table 2. Morphological characteristics of the studied x*Tritordeum* accessions by properties WGS, NGS, AI and NSLS.

Accession	WGS		NGS		AI		NSLS	
	AV	SD	AV	SD	AV	SD	AV	SD
HT 119	1.5590	.28564	34.7000	4.11096	1.5941	.08121	.2265	.01130
HT 129	1.7990	.19846	48.8000	4.49197	1.5849	.06906	.2144	.00486
HT 31-1	2.0029	.82643	38.2857	14.15055	1.6125	.09575	.2397	.01550
HT 31-2	2.4450	.77426	52.2000	10.88118	1.5287	.05894	.2391	.01042
HT 31-4	1.1390	.70229	28.6000	11.73977	1.5578	.10251	.2398	.01829
HT 621	1.7620	.49418	48.9000	12.06878	1.5038	.10115	.2521	.01304
HTC 1323	1.8200	.85066	43.3000	17.78295	1.5444	.09439	.2540	.00950
HTC 1324	1.5240	.50029	38.9000	9.99389	1.6029	.08400	.2877	.01521
HTC 1331	2.3650	.35296	53.7000	6.56675	1.5202	.11759	.2506	.01477
HTC 1380	.9243	.47212	25.0000	11.73314	1.6864	.25659	.2824	.02057
Total	1.7513	.71058	41.8511	13.91909	1.5687	.11631	.2478	.02502
CV, %	40.5752		33.2586		7.4146		10.0954	

WGS – weight of grains in a spike; NGS – number of grains in a spike; AI – awness index; NSLA – number of spikelets to the length of spike; AV – average value; SD – standard deviation

Similar data have been reported for other *Triticum* amphidiploids (Spetsov and Savov, 1992; Lalkova et al., 2004; Spetsov 2004), synthetic hexaploid wheats (Plamenov et al., 2011; Spetsov et al., 2009; Spetsov et al., 2008) and intergeneric hybrids and amphidiploids (Naskidashvili, 1984; Spetsov and Savov, 1992; Rehman et al., 2006; Stoyanov et al., 2011, Stoyanov, 2013). In the majority of accessions unequal variance in the separate accessions is observed indicating differences in size and seedset of spikes. On the one hand, this could be due to differences in nutrition of additional tillers and on the other hand – to the heterogeneity in the plant population.

The slight variation in the indicator NSLS highlights the high degree of similarity between the accessions in relation to the density of the spike (Figure 1). They do not differ significantly by the two components of the index (NSS and LS) and the values offset each other. A simultaneously slight variation in the GI of spikes emphasizes their equal seedset in a percentage view of the biomass of the spikes. This defines the normal distribution of nutrients during the growing season compared to spike formation. Despite the differences in characteristics WS and WGS, their ratio expressed by GI showed a similar response to environmental conditions expressed by the formation of plant biomass. The mean and similar variance in the indicators WDLS and WSS on the other hand is indicative for lack of uniformity in fertility in the individual accessions, to form heavier spikelets. Thus, differences in variability in individual accessions of parameters NSLS and WDLS highlight the number of formed florets and the adaptability of the accessions to the environmental conditions.

The studied *Tritordeum* accessions in similar experiments on the territory of Central Europe (Martinek et al., 2000) demonstrate similar values of the indicator M1000 in range between 33.1 and 40.3g. The established standard deviation is similar, in the range of 4

Table 3. Morphological characteristics of the studied x*Tritordeum* accessions by properties WDLS, WSS, M1000 and GI

Accession	WDLS		WSS		M1000		GI	
	AV	SD	AV	SD	AV	SD	AV	SD
HT 119	.0252	.00335	.1119	.01691	44.6905	4.26791	73.9471	2.70931
HT 129	.0252	.00266	.1176	.01286	36.8349	1.44881	72.8843	2.69474
HT 31-1	.0313	.00840	.1315	.03831	51.6231	4.83382	65.5331	7.76625
HT 31-2	.0349	.00727	.1466	.03194	45.8154	7.38765	67.5994	8.15781
HT 31-4	.0218	.00898	.0922	.04092	37.8997	9.79765	58.1550	12.14616
HT 621	.0301	.00448	.1197	.01947	36.1432	4.59055	69.1517	10.02669
HTC 1323	.0313	.00931	.1240	.03826	41.2598	4.24365	70.9954	12.85743
HTC 1324	.0305	.00653	.1063	.02498	38.5546	3.18429	75.2271	3.00998
HTC 1331	.0394	.00322	.1582	.01950	43.9754	3.05657	73.1996	3.64124
HTC 1380	.0215	.00715	.0768	.02675	37.2650	8.79302	67.3475	4.05785
Total	.0293	.00822	.1194	.03488	41.2123	7.01387	69.5932	8.90695
CV, %	28.0636		29.2159		17.0189		12.7986	

WDLS – weight distribution along the length of spike; WSS – weight of a single spikelet; M1000 – weight of 1000 grains; GI – percentage of grains in weight of spike; AV – average value; SD – standard deviation

–5g. This gives grounds to seek broad adaptive capacity of the crop to the agroclimatic conditions of the European continent. Differences were obtained for spring sowing in which this indicator is significantly lower – 28 –30g. The lack of a large variability in growing in different climatic areas is indicative of the broad genetic limits set by the hybrid genome (Lima-Brito et al., 1996).

Tritordeum is derived from single crosses (Ballesteros et al., 2005), combined with embrioresque technique and colchicine treatment. Such techniques are involved in the obtaining of plants, which are aligned in relation to genetic point of view and the expression of phenotypic differences related to the performance and the characteristics of the spikes is not so great, especially in lines derived from a single cross. The studied accessions HT31-1, HT31-2 and HT31-4 are identical (within established limits) and in most of the examined indicators there are no significant differences. Differences in standard deviation between the characteristics of the three accessions are not very high, which indicates low variability of the accessions. These characteristics are due to the common origin of the three lines (Ballesteros et al., 2005). On the other hand, the possibility for identical crosses to exhibit similarities of their properties is not excluded, but phytohormones and colchicine solution used in the creation of amphdiploids could cause mutagenic effect, which would have established the occurrence of variability in the plant population (Ayala and Kiger, 1987). The easy occurrence of mutations leading to a large percentage of plants resistant to herbicides highlights the variation-inducing ability in *Tritordeum* (Rodriguez-Suarez et al., 2009).

The weather conditions during the growing of *Tritordeum* significantly affect its productivity. This is due to the fact that plants are mostly spring forms and this is determined by the participation of spring forms of durum wheat and wild southern species such as Chilean barley (*Hordeum chilense*). During two different vegetative seasons which are distinguished in average monthly temperatures (AMT) in the winter period and in precipitation (TMP) during the growing season (Table 4), differences in the number of overwintered plants are established. In season 2012/2013 most *Tritordeum*

Table 4. Data for climate conditions in 2012/2013 and 2013/2014 growing seasons

Months	AMT, °C		TMP, mm		TSC, cm	
	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
October	16.1	12.1	73.5	79.0	-	-
November	9.2	9.5	41.0	29.0	-	9
December	0.9	1.8	142.0	10.0	43	5
January	1.2	2.6	47.0	153.0	15	71
February	3.6	4.7	34.5	19.0	7	11
March	6.2	8.7	31.0	56.0	15	2
April	-	-	39.5	39.0	-	-
May	-	-	20.5	120.0	-	-
June	-	-	60.0	N/A	-	-
Average	6.2	6.6	-	-	-	-
Total	-	-	489.0	505.0	80	98

AMT – average monthly temperature; TMP – total monthly precipitation; TSC – total snow cover

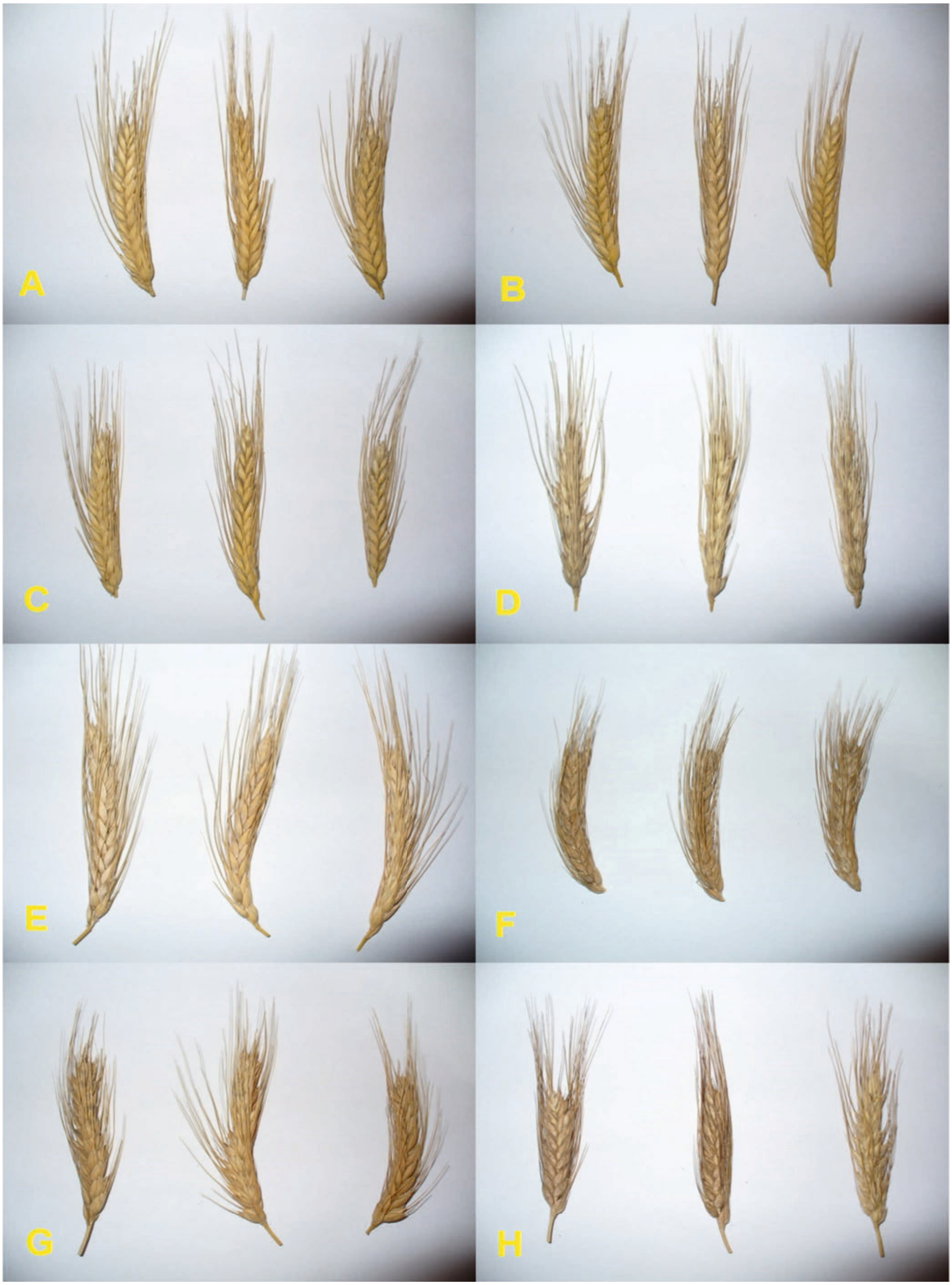

Figure 1. x*Tritordeum* accessions: HT31-1 (A); HT31-2 (B); HT31-4 (C); HT119 (D); HT129 (E); HT621 (F); HTC1331 (G); HTC1380 (H).

accessions showed bad winter tolerance, as there are a large number of frozen and pulled-out plants (Table 5). Accessions HTC1380, HT119 and HT621 feature better winter tolerance compared to others, but the first two are susceptible to the effects of winter conditions compared to the most susceptible standard wheat variety for frost tolerance – San Pastore. In the next growing season (Table 6) defeats were observed only in accessions HT119, due to poorly developed plants that form only two leaves before the onset of a prolonged cold period. From the weather data in both vegetative seasons (Figure 2, 3 and 4) it is clear that economic 2013/2014 is characterized as warmer and with more rainfall. In 2012/2013 autumn is moist but colder, which prevents germination and sprouting of accessions in time, which is probably the reason for the large damage due to the lack of hardening. Economic year 2013/2014 was characterized by greater rainfall during spring (Figure 3), unlike the previous year, which is a reason for more rapid start of vegetation and intensive growth. Similar data have been reported for *Tritordeum* winter tolerance under conditions of warmer

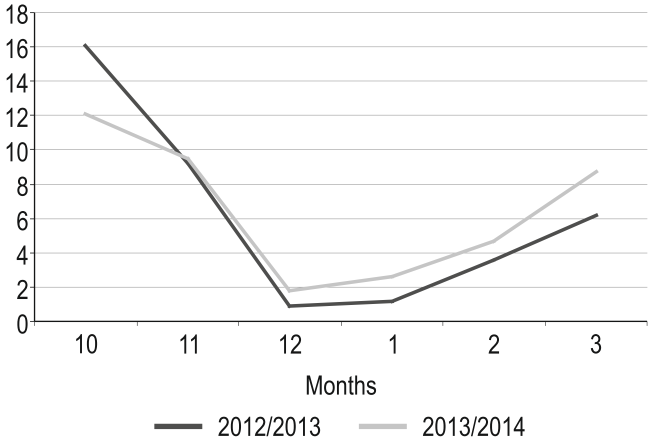

Figure 2. Average monthly temperatures (AMT, °C) during 2012/2013 and 2013/2014 winter periods

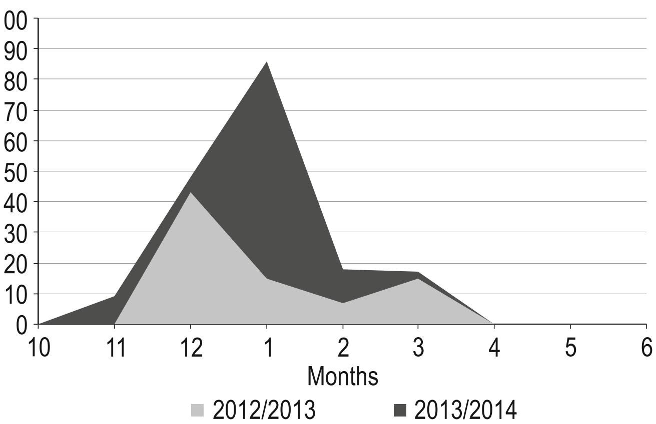

Figure 4. Total snow cover (TSC, cm) during 2012/2013 and 2013/2014 growing seasons

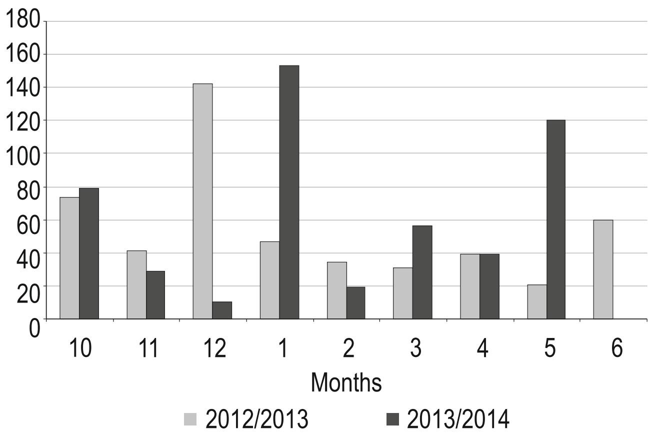

Figure 3. Total monthly precipitation (TMP, mm) during 2012/2013 and 2013/2014 growing seasons

Table 5. Data of field germination and influence of the winter conditions of x*Tritordeum* accessions for 2012/2013 growing season

Accession	NP	NSSG	NGP	NF	NPO	FG, %	IWC, %
HT 119	4	20	10	3	1	50.00	40.00
HT 129	6	20	12	3	3	60.00	50.00
HT 31-1	3	20	8	2	3	40.00	62.50
HT 31-2	4	20	10	4	2	50.00	60.00
HT 31-4	3	20	11	3	5	55.00	72.73
HT 621	20	20	20	0	0	100.00	0.00
HTC 1323	6	20	15	3	6	75.00	60.00
HTC 1324	2	20	6	3	1	30.00	66.67
HTC 1331	5	20	15	8	2	75.00	66.67
HTC 1380	6	20	10	0	4	50.00	40.00
MIR 808	20	20	20	0	0	100.00	0.00
BEZ 1	20	20	20	0	0	100.00	0.00
RUS	20	20	20	0	0	100.00	0.00
N301	19	20	20	1	0	100.00	5.00
SP	17	20	20	3	0	100.00	15.00

NP – number of overwintered plants; NSSG – number of seeds set for germination; NGP – number of geminated plants; NF – number of frosted plants; NPO – number of pulled-out plants; FG – field germination; IWC – influence of winter conditions; MIR 808 – Mironovskaya 808; BEZ 1 – Bezostaya 1; RUS – Rusalka; N301 – No301; SP – San Pastore.

Table 6. Field germination and influence of the winter conditions of x*Tritordeum* accessions for 2013/2014 growing season

Accession	NP	NSSG	NGP	NF	NPO	FG, %	IWC, %
HT 119	6	20	8	2	0	40.00	25.00
HT 129	8	20	8	0	0	40.00	0.00
HT 31-1	12	20	12	0	0	60.00	0.00
HT 31-2	9	20	9	0	0	45.00	0.00
HT 31-4	15	20	15	0	0	75.00	0.00
HT 621	20	20	20	0	0	100.00	0.00
HTC 1323	10	20	10	0	0	50.00	0.00
HTC 1324	11	20	11	0	0	55.00	0.00
HTC 1331	10	20	10	0	0	50.00	0.00
HTC 1380	10	20	10	0	0	50.00	0.00
HT 621 AM*	15	20	15	0	0	75.00	0.00
MIR 808	20	20	20	0	0	100.00	0.00
BEZ 1	20	20	20	0	0	100.00	0.00
RUS	20	20	20	0	0	100.00	0.00
N301	20	20	20	0	0	100.00	0.00
SP	19	20	20	1	0	100.00	5.00

NP – number of overwintered plants; NSSG – number of seeds set for germination; NGP – number of geminated plants; NF – number of frosted plants; NPO – number of pulled-out plants; FG – field germination; IWC – influence of winter conditions; MIR 808 – Mironovskaya 808; BEZ 1 – Bezostaya 1; RUS – Rusalka; N301 – No301; SP – San Pastore.
*Accessions HT 621 AM is the same as HT 621, but it is obtained from Prof. Antonio Martin.

Table 7. Phenology and pathogens resistance data of the studied x*Tritordeum* accessions in 2012/2013 growing season

Accession	DH	DF	DFM	EG	PR	ST
HT 119	10-12.05	15-20.05	11-15.07	R(0)	S(8)	R(0)
HT 129	10-12.05	15-22.05	11-15.07	R(0)	S(9)	R(0)
HT 31-1	08-12.05	16-20.05	11-15.07	R(0)	S(8)	R(0)
HT 31-2	09-12.05	17-21.05	11-15.07	R(0)	S(8)	R(0)
HT 31-4	08-12.05	15-23.05	11-15.07	R(0)	S(8)	R(0)
HT 621	01-05.05	09-12.05	08-11.07	R(0)	M(5)	R(0)
HTC 1323	09-12.05	16-19.05	11-15.07	R(0)	S(8)	R(0)
HTC 1324	10-13.05	15-18.05	11-15.07	R(0)	S(8)	R(0)
HTC 1331	11-16.05	17-24.05	11-15.07	R(0)	S(8)	R(0)
HTC 1380	11-15.05	15-23.05	11-15.07	R(0)	S(9)	R(0)

DH – date of heading; DF – date of flowering; DFM – date of full maturity; EG – Erysiphe graminis; PR – Puccinia recondita; ST – Septoria tritici.

winter period on the territory of Central Europe (Martinek et al., 2000). The same authors indicate significantly higher yield over the three monitored periods in autumn sowing of the crop. Accession HT621 features higher field germination than accessions HT621AM. Since both accessions come from common initial plants, the differences in germination despite identical conditions are probably due to the great diversity of *Tritordeum* and as a new crop were not subjected to active breeding pressure. During the two growing seasons, the low field germination in other accessions is probably due to the amphidiploid nature of the lines defining greater heterogeneity combined with spring-type crop character.

In terms of disease, there was no established attack by powdery mildew and septoria leaf blight (Table 7). All studied accessions, however, are attacked at late stages of development by the pathogens of brown and black rust. Especially strong is the attack of black rust in secondary appeared tillers and it reaches the spikes. In similar experiments of establishing resistance to pathogens, other authors (Martinek et al., 2000; Rubiales et al., 1991) indicate strong attack by powdery mildew, brown rust, septoria leaf blight, and *Stagonospora nodorum* blotch. The lack of an attack by powdery mildew and septoria leaf blight in the conditions of the country is probably due to the high specialization of pathogens to local wheat genotypes. This is evidenced by a strong attack by powdery mildew of standard wheat varieties used in the experiment (Stoyanov, personal communication).

In the studied *Tritordeum* accessions significant differences in the number of productive tillers are observed (Table 8). In spite of the equal distances between the rows and lack of competition associated with the nutrition area, some accessions are characterized by too low tillering and this determines their low total productivity (HTC1331). Yield capacity is limited by the low values of the indicator WGS in some of the accessions (HTC1380). As with

Table 8. Productivity and yield of the studied x*Tritordeum* accessions

Accession	ANT	HPY, kg/ha	Y, kg/ha	P, %
HT 119	9.00	14031.00	2400.00	17.10
HT 129	5.50	9894.50	3200.00	32.34
HT 31-1	2.33	4673.43	2600.00	55.63
HT 31-2	5.75	14058.75	3800.00	27.03
HT 31-4	3.33	3796.67	3250.00	85.60
HT 621	5.55	9779.10	6400.00	65.45
HTC 1323	2.67	4853.33	2400.00	49.45
HTC 1324	5.00	7620.00	2950,00	38.71
HTC 1331	6.60	15609.00	2750.00	17.62
HTC 1380	1.17	1078.35	1000.00	92.73

ANT – average number of tillers; HPY – hypothetical potential yield; Y – yield; P – potential

ANT they determine the productivity of the studied accessions, even small deviations (e.g. in HT31-4) lead to a significant change in the yield. This is emphasized by the values of HPY, which vary within a broad range (Table 8). Despite the slight variations and the great value of WGS in the lines of HT31-X group, there are large differences in HPY and Y, which is defined on the one hand by the uneven seedset in some spikes, and on the other – by a different response to environmental conditions, which determines their lower productive tillering. Low spike productivity in the current growing conditions for accessions HTC1323, HTC1324 and HTC1380 highlights their weak adaptability, which is complemented by their limited tillering, regardless of the larger sowing distances. The highest values of productivity shows accession HT621. Upon registration of the line in the conditions of Spain, the values of yield averaged 4000 kg/ha (Ballesteros et al., 2005). In the other lines in the conditions of Central Europe yields are similar to those obtained for the conditions of the country – 2000 –3500kg/ha (Martinek et al., 2000). Differences between HT621 and the other accessions are mainly due to its phenology. The tillering, stem-elongation, heading and flowering of the accession is 5-8 days earlier than the others (Table 7). This is a reason for the accession to avoid the adverse effects of some factors such as high temperatures, prevailing south and hot winds and low precipitation rates. Such accumulation of earlier periods in the specified phase ensures higher productivity due to the native drought in mid-May, which is unfavourable for pollination, grain formation and grain filling.

The differentiation of the lines as to their productivity and winter tolerance could be traced from the dendrogam in the displayed cluster analysis (Figure 5). The highly productive and winter-tolerant accessions form separate clusters, which enables us to make a selection in a future breeding work. Despite some of its negative characteristics, some of the accessions (e.g. HTC1380) realize more of its potential yield in excess of this indicator of highly productive accessions. Such a valuable feature enables these samples to be included in the hybridization programs, as they may possess genes that also control adaptation in high levels of stress factors which reduce their propagation coefficient, in order to obtain even fewer, but well formed seeds, with greater uniformity. The combination of these genotypes with high-performance accessions would allow to improve the quality of the crop in the conditions of South Dobrudzha.

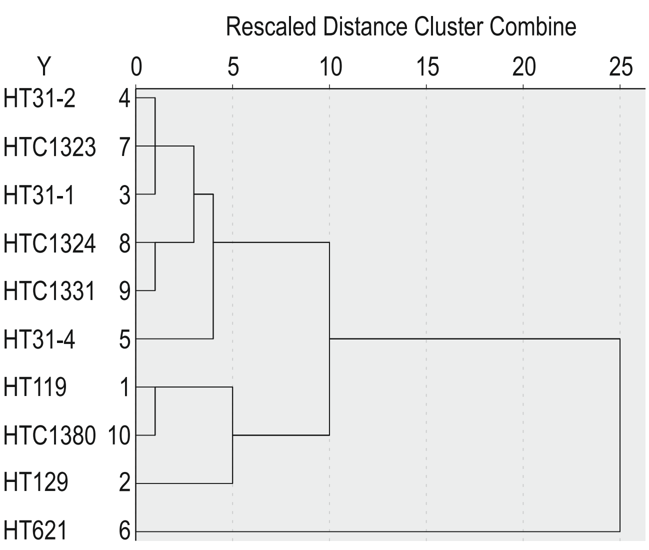

Figure 5. Dendrogram of cluster analysis by the productivity (WGS) and winter tolerance (IWC) of the studied xTritordeum accessions

Conclusions

The studied x*Tritordeum* accessions under the conditions of the country demonstrated a slight to moderate variation in indicators NSS, LS, LSA, GI, NSLS, M1000, but high variation in indicators WS, WGS and NGS due to heterogeneous seedset and differences in fertility and also the amphidiploid nature of the accessions. With the earliest heading, flowering, and maturity periods and high productivity of tritordeum forms is accession HT621, with the lowest performance to their productivity are accessions HTC1324 and HTC1380, and with the highest performance in spike productivity are accessions HT31-1, HT31-2 and HTC1331. Regarding winter resistance in current growing conditions, as winter tolerant but below the values of standard wheat varieties are accessions HT119 and HT1380, but accession HT621, in two-year results showed no signs of frost damages. All studied accessions are resistant to the pathogens of powdery mildew and septoria leaf blight, but susceptible to subsequent infections with brown rust. Despite their negative characteristics, the studied tritordeum accessions are promising for further experimental work on the introduction of the crop in the territory of the country.

Acknowledgement

The present study was performed with support of the Plant Production Research Center Piešťany, Research Institute of Plant Production Piešťany, Gene bank of Slovak Republic, and also the National Small Grains Collection, GRIN-ARS, USDA, the USA and also Professor Antonio Martin from Institute for Sustainable Agriculture, Cordoba, Spain, from where the seeds of the studied tritordeum accessions were kindly provided.

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AGRICULTURAL
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Volume 7, Number 2
June 2015

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