Science & Research

YIELD STRUCTURE AND COMPONENT ANALYSIS OF THE SPECIES ×*TRITICUM TOSCHEVII* H.P.ST.

Hristo Stoyanov[1]
M-AGRO EOOD, 9350, Stozher, Bulgaria

Abstract: The formation of yield and its components is especially important in the breeding of new amphidiploid species. In order to determine the main components of yield in the species *Triticum ×toschevii*, 12 indices of the spikes were analyzed in three successive growing periods. Componential analysis was done to determine the main components in the formation of the yield's structural elements. Based on the analyses carried out, the number of grains per spike and 1000 kernel weight were determined as the main structural elements. Indices such as number of spikelets per spike, spike length, and spike length with the awns were of secondary importance. The componential analysis clearly distinguished the structural elements of yield according to the way of their formation. The main components were four and they accounted for over 96 % of the total variation. The indices number of spikelets per spike, spike length, and awnness index were determined as typical vegetative components. The number of grains per spike and all mass indices were formed by the main component and were determined as typical generative indices. The length of spikes with awns and the number of spikelets along the length of the spike were determined by a third component. Such data outlined the high importance of the variation of the generative indices for the size of yield. This imposes the necessity to carry out purposeful selection in the species *Triticum ×toschevii*, so that it can be efficiently introduced as a cultural plant.

Key words: *Componential analysis, Yield structure, Triticum ×toschevii*

Introduction

Contemporary breeding of cereals is highly dynamic [1]. This is due to the constantly increasing demand for quality grain raw materials that would meet the requirements of the food and fodder production [2]. On the one hand, the increased consummation means increasing the yields from the cultural plants. This is related to certain restrictions, which impose the necessity of developing innovative breeding programs [1].

Modern solutions for higher yields are the use of wide hybridization, biotechnology methods and genetically modified organisms [3, 4, 5, 6]. While the biotechnology and the genetic modification of organisms give contradictory results with regard to the efficiency of the breeding process [5], the wide hybridization gives exceptional positive results [4, 6].

Wide hybridization is a conventional approach in the breeding of cultural plants, which is characterized with two-directional work toward the final goal [6]. On the one hand, the crossing of different species allows the transfer of valuable traits and properties between the cultural plants. This is evidenced in a number of researches on cereals reporting successful transfer of genes for resistance to biotic stress [6, 7], tolerance to abiotic stress [6, 8], as well as for increased quality of yield [6, 9, 10, 11].

On the other hand, wide hybridization is an efficient tool for developing of new plant species; thus the cultural plants triticale and tritordeum have been developed, which have become highly popular at this current stage of agricultural production [6]. Such plant species possess exceptional characteristics of yield, resistance to stress and adaptability to environments where the cultural plants are not able to realize their potential [12]. Apart from the above two examples, numerous amphiploid forms have been developed in the cereals plants [7, 12, 13, 14]. Often negative traits are observed resulting from certain meiotic disturbances typical for them – low fertility, shriveled grains, low germination rate [6, 7, 15]. However, other forms are characterized with high yield potential combined with resistance to economically important diseases [6, 7, 12, 13, 14]. This makes them valuable initial material for introduction as cultural plants.

[1] Corresponding author: Hristo Stoyanov, M-AGRO EOOD, 9350, Stozher, Bulgaria, hpstoyanov@abv.bg

The species *Triticum* ×*toschevii* is an amphidiploid with origin from the cross between the species *Triticum turanicum* and *Triticum timopheevii*. The aphidiploid was first reported by Spetsov and Savov [14], and was given a taxonomic description and classified as a separate species by Stoyanov [13]. The species is hexaploid as a result of reduction of the initial chromosome number. The spikes do not resemble neither of the two parental components, and are much more similar to the morphology of triticale. The plants of this species are very high and therefore are prone to lodging under unfavorable meteorological conditions. They are not attacked by diseases and resistance was found against the pathogens of powdery mildew, brown rust and septoria leaf blight [7, 16]. The spikes have a good number of seeds, with 2-3 well-developed grains per spikelet, similar to the grains of triticale.
Such amphidiploid forms, although having potential for high yield, possess variable yield structure that should be observed within the amphidiploid itself [16]. This is related to a certain degree of instability and to active occurrence of recombination processes. The investigations on the amphidiploid forms [12, 16, 17] have shown such processes. The species *Triticum* ×*toschevii*, however, is very stable. An evidence for this are previous studies on it where its productivity was analyzed in comparison to common winter wheat [18].
Such data impose the necessity to study this species in greater details with regard to its yield structure. On the other hand, the factors with highest importance for the formation and variation within the plant set should be investigated. This is related to the need for detailed clarification of the yield components with the aim to determine which ones are of highest breeding value. Thus the breeding program aimed at introduction of this species would be more efficient, which is further related to the faster introduction of the plant form as a cultural plant.
The aim of this investigation was to analyze the species *Triticum* ×*toschevii* by its morphological parameters of spike in different years in order to determine the effect of the factor year on each of these parameter and to find out which were the main components for the formation of the structural elements of yield.

Materials and Methods

An accession of the species *Triticum* ×*toschevii* with origin from the collection of Dobrudzha Agricultural Institute – General Toshevo was used. Fifteen seeds were sown in each row of a design involving 30 cm interspacing between the rows and 5 cm distance between the plants within the row. Planting was done during economic years 2012/2013, 2013/2014 and 2014/2015 on 11.11.2012, 06.11.2013 and 12.11.2014, respectively, in the fields near Stozher, Dobrich district.
Harvesting was done at stage full maturity in economic years 2012/2013, 2013/2014 and 2014/2015 on 20.07.2013, 16.07.2014 and 16.07.2015, respectively. Twenty fully mature spikes not damaged by diseases and pests were chosen randomly. The spikes from each accession were evaluated morphologically according to 6 quantitative indices: length of spike (LS), length of spike with awns (LSA), weight of spike (WS), number of spikelets per spike (NSS), weight of grains per spike (WGS), number of grains per spike (NGS), and also 5 index parameters: awness index (AI) – ratio between LSA and LS, weight distribution along the spike length (WDSL) – ratio between WS and LS, number of spikelets to the length of spike (NSLS) – ratio between NSS and LS, average weight of spike (AWS), – ratio between WS and NSS, 1000 kernel weight (M1000) – According to the Bulgarian State Standard.
In order to neutralize the effect of the factor year, and with the aim to determine the biometric relations in the amphidiploid, a specific index for elimination of the effect of the year (SEYI) was calculated – a product between the relation of WGS and NGS with LS. SEYI is based on the hypothesis that the indices WGS, NGS and LS are in a state of certain biological equilibrium regardless of the environmental conditions [19].

The data on the mean daily temperatures during the periods 01.10.2012 – 30.06.2013, 01.10.2013 – 30.06.2014 and 01.10.2014 – 30.06.2015, and on the precipitation sums for the above periods were summarized. The data on the temperature and precipitation were obtained through measurements with LaCrosse automatic weather station. Two daily measurements were made, at 07:00 and 19:00 hrs. Data means were calculated for two growth periods (vegetative – 01.10 – 31.03 and reproductive – 01.04 – 30.06), and as a total.

The mean values of the obtained data (MV) were determined and also a variation coefficient (VC, %), in total and over years. ANOVA was carried out to estimate the effects of the year and of the genotype on the amphidiploid. The significance of the obtained results was registered. Principal component analysis (PCA) was done to determine the main components in the formation of the yield structural elements. Software Microsoft Excel 2003 was used to summarize the data and to perform the variation analysis and IBM SPSS Statistics 19 was applied for the ANOVA and PCA.

Results and Discussion

The study was carried out through periods of rather contrasting nature. An evidence for this is the data on the mean monthly air temperatures and the monthly precipitation sums (Table 1). With regard to the mean monthly air temperatures, the period 2014/2015 was the coldest, while 2012/2013 was the warmest. Such data imply different course of the growth and development processes.

Regardless of this, significant differences were observed over months related to the direct effect on the yield structure of the investigated accession. The period 01.10-31.03, which is important for the tillering of cereals, was comparatively the same with regard to the temperature regime during the first two years, while in 2014/2015 it was significantly cooler. During the cooler year, the plants entered the winter considerably less developed and this was the reason for the subsequent weaker tillering and the higher effect of the stress factors. This was especially valid in 2015 when sharp cold spells occurred.

On the other hand, the high temperatures during March of 2014 were a prerequisite for the earlier development of the plants. This caused a shift in the phenological development of the investigated accession and differences in some of the studied indices. The temperature variations observed during 01.04-30.06 were related to periods of active rainfalls differing in duration and intensity, which allowed looking for differences in the number of grains per spike and in the grain filling [20, 21, 22, 23]. This was due to the temperature variations according to certain tendencies, which placed the plants under conditions of stress of different duration and intensity.

The sum values of the vegetation rainfalls during the three investigated years preconditioned the rather contrasting results with regard to the structural elements of yield [24]. This was primarily connected with the precipitation norms for the period 01.04-30.06, which differed significantly during the three years of investigation. May and June of 2014 were characterized with the occurrence of heavy intensive rainfalls, which were the reason for low fertility, considerable lodging and strongly impeded nutrition of grains. Long rainfalls were also observed in 2015 but they were of lower intensity. In spite of the fact that years 2013 and 2015 were characterized with identical sums of precipitation, it should be underlined that during 2012/2013 they were much more evenly distributed, which ensured the better development of the plants.

The variation analysis (Table 2) showed a rather variable reaction of the investigated indices during the three contrasting years. The observed differences were related to both the mean values and the variation coefficients. The indices NSS, LS, LSA, AI and NSLS were with the lowest values of variation. These parameters are linked to the vegetative development of the spikes [25]. Therefore, their variation was directly related to the conditions of the environment during 01.10-31.03 [25]. The number of productive tillers was formed in that period, as well as the potential of the spikes. Higher variation of these indices was observed during 2012/2013. Due to the higher tillering in this period, the spikes were with variable biometry. It was due to the fact that the spikes originating from the tillers which developed later were smaller than the earlier tillers and the central one. This finds strong confirmation in the values of the index LS and in the variation coefficients during the three years. The investigations of Stoyanov [25] confirm similar behavior of LS in other amphidiploid forms, as well. Similar response has been reported in common winter wheat, barley and triticale [26, 27, 28, 29, 30]. The lower variation of NSS was respectively related to the identical production potential of the spikes preconditioned at booting stage. The significantly lower variation of the indices LSA and AI was due to the absence of a significant environmental effect on the length of the awns. The previous investigations [18] confirm this. NSLS was with respective lowest variation of the indices related to the vegetative development of the spike. Since the spike length in a certain accession follows the development of a certain number of spikelets, their ratio remains comparatively stable regardless of the higher variation of LS and NSS. Such data are typical of other cereals and are referable to stability of the investigated accession with regard to its spike morphology [31].

The indices WS, WGS, NGS, WDLS, AWS and M1000 were with very high variation during the individual years of the investigation, as well as during the entire period of study. In the indices WGS, WDLS, AWS and M1000 an increased variation was observed in 2013/2014. This behavior was related to the extremely unfavorable environmental conditions, which resulted in disturbed nutrition of grains. Therefore, plants with grains of different plumpness were observed leading to higher variation of the weight indices. Identical response of the weight parameters under contrasting conditions has been reported in numerous investigations on common winter wheat, durum wheat and triticale [32, 33, 34, 35, 36, 37]. Although WS is also a weight index, the weight of the vegetative part of the spikes is included as a component in it. The absence of a clearly expressed increase in the variation of WS in 2014 can be explained by the presence of a compensatory mechanism realizing identical biological yield from the spikes. The lower variation of this index in 2015 is worth mentioning. These variation values allowed following the weaker response of a weight index such as WS to better environmental conditions. The values of NGS followed an identical tendency, which, however, was connected with lower fertility during the first two years of the investigation. Although economic year 2012/2013 was favorable for the development of the investigated accession, the lower fertility was a result from the different size of the spikes due to high tillering. In 2014, respectively, the lower fertility was due to the abundant rainfalls in May. This impeded the proper pollination and led to lower values of NGS. A peculiarity of this index was that it was highly influenced by the conditions of the environment, as confirmed by numerous researches [32, 33, 38, 39]. When high precipitation norms were not present, the number of grains per spike was respectively higher [40]. Therefore, the intermediate period 2014/2015 was characterized with highest fertility.

The data on the mean values of NGS and M1000 and their variation underlined their significance for the formation of the yield from the investigated accession. The two indices had identical importance as structural elements. It should be pointed out, however, that NGS was more sensitive to the conditions of the environment since its variation reached 36 % during the unfavorable period. At the same time, serious differences were observed with regard to the mean values during the three years of investigation. The index M1000 responded with lower variation and the decrease of the mean values during the unfavorable period was not as significant as that of NGS. Therefore, M1000 was of secondary importance for the formation of yield. Such ranking of the yield's structural elements is a peculiarity of triticale as well [41]. In common winter wheat, NGS and M1000 differ significantly in ranking. Such

relation is strictly dependent on the investigated genotype or set of genotypes [41].
The results from the ANOVA carried out (Table 3) undoubtedly confirm the contrasting nature of the investigated periods and the results from the variation analysis. The indices NSS, LS, NGS, AI, NSLS were significantly influenced by the year conditions. This behavior of the indices related to the vegetative part of the spike can be explained by the fact that significant tillering was observed during the favorable period for growing of the accession (2012/2013). This is related to the smaller spikes of the later tillers and to the lower values of NSS and LS and hence – of their derivatives AI and NSLS. Similar behavior has been reported by Mihova and Dimova [29] in barley and by Knott and Talukdar [42] in common winter wheat. The response of NSS, on the other hand, was not connected with the vegetative part of the spike but was due to the strong influence of the environmental conditions on the fertility. It is worth mentioning that the index LSA formed significant differences at the lowest level of statistical significance. The mean values for the three years of investigation showed that there was a significant difference only according to the favorable period. The lower values of LSA were due to the typical position of the awns on the spikes with sufficient number of grains [43]. The weight parameters WS, WGS, WDLS and AWS were without significant differences between the three investigated periods. This emphasized the practical lack of significant environmental effect on the spike productivity of the accession during the three investigated periods. Such behavior is untypical for most of the cereal crops under highly contrasting growing conditions [32, 33, 34, 35, 36, 37, 44, 45]. These results confirmed the considerable stability of the investigated amphidiploid accession and proved the hypothesis of a previous study [18].
The data for the index M1000 were extremely contradictory. There was a statistically significant difference between the three investigated years. On the other hand, the variation of the index was related to the simultaneous presence of plump and underdeveloped grains. In practice, the nutrition of the grains was considerably impeded during the unfavorable period 2013/2014, as well as the intermediary one – 2014/2015 as a result from lodging. Since in 2015 there was less lodging, the variation of the trait was comparatively low. Therefore it should be pointed out that M1000 was indirectly affected by the environmental conditions during the heading period as a result from lodging. Similar behavior is typical of triticale [41, 46] and of certain common winter wheat accessions [26, 47].
The dispersion analysis conditionally divided the structural elements of yield in two large groups – vegetative (NSS, LS, LSA, AI, NSLS) and generative (WS, WGS, NGS, WDLS, AWS and M1000). Such division is conditioned by the effect on the respective traits at a certain ontogenesis stage of the investigated accession – on its vegetative or generative development. Nevertheless, both main structural elements of the yield from the studied accession were of generative nature. Therefore, the contribution of each structural element should be evaluated according to their variation. This would give a general assessment as to what degree the vegetative and/or generative development were influenced in the process of productivity formation.
The data on the specific biological ratio SEYI were an additional confirmation of the results from the dispersion analyses. During the three investigated periods, this parameter varied insignificantly with regard to the mean values and did not in practice form significant differences. Such high stability allowed evaluating each of the investigated parameters on the basis of its correlation with SEYI [25]. The values of the correlation coefficients undoubtedly confirmed the different origin of the investigated indices – vegetative or generative. In the investigated accession, the generative traits were in high and positive correlation with SEYI, while the vegetative ones were in low and even negative correlation. In the group of the generative indices, only NGS was in a lower correlation with SEYI. This was so because fertility was restricted to the productivity potential of a vegetative index such as NSS.

The variation of the indices was very important for the formation of productivity. Although the variation and the dispersion analysis helped to determine the main structural elements NGS and M1000, it was especially important to find out how their variation influenced productivity together with the other investigated parameters.

The analysis of the main components (Table 5) gives an idea about the components of variation, which have significant contribution to its formation. It can be clearly determined that the first four components accounted for over 96 % of the variation in the investigated indices. The next components were related to values lower than 3 % and should be considered statistical noise and error of stochastic nature.

The first component formed 56 % of the total variation. This is connected primarily to these structural elements, which are more sensitive with regard to their expression under specific growing conditions. The second component accounted for 27 % of the total variation and its contribution was two times lower than that of the first one. The other two components accounted for about 14 % of the total variation and this is conditioned by their conservative nature. These three components were of secondary importance for the productivity of the investigated accession. This is the reason to assume that they are related to those structural elements of productivity, which have weaker reaction under specific environments.

The correlation matrix after the varimax rotation allowed following the structural elements, which were in a high correlation with a certain component of the total variation. The first component was in a high and positive correlation with the parameters WS, WGS, NGS, WDLS, AWS and M1000. Since the formed correlation was related to the group of the generative indices, the first component can be conditionally determined as a generative component of variation.

The second component of the variation was in a high correlation with the indices NSS, LS, NGS and AI. Therefore, it can be conditionally defined as a primary vegetative component. This is so since the high correlation is with indices linked to the main growth and development of the spikelets as a whole. The high correlation with NSS is impressive. It is due to the fact that NSS is a parameter formed within limits fixed by the vegetative parameters of the spikes. The distribution of this index in two main components proved the exceptional character of NSS as a main structural element of productivity dependent both on the proper vegetative development of the plants, of the spikes in particular, and on the environmental conditions.

The third component was in high correlation with LSA and NSLS. It can be conditionally named secondary vegetative component, since it is related to the general development of the spike – formation of boot, density and awns. The fourth component correlated only with LSA. Therefore, it can be conditionally designated as tertiary vegetative component. Its action is referred to the development of the spike awns and their specific effect as a compensatory mechanism.

The specific manifestation of each component according to the total variation of the indices allows defining the investigated accession as an exceptionally stable genotype. This is so because a great part of the variation of the indices was due to the first generative component. These indices, on their part, formed significant differences under the contrasting growing conditions. This can be explained by the presence of stable biological ratios in the investigated amphidiploid and active compensatory mechanisms. Such a thesis is also emphasized by the behavior of the index SEYI. On the other hand, various investigations [32, 33, 34, 35, 36, 37, 38, 39, 41] proved the importance of such indices for the formation of productivity. At the same time, Leilah and Al-Khateeb [47] reported similar results when analyzing the components in common winter wheat. These data allowed determining the investigated genotype as exceptionally stable by productivity. This opens the possibility to include it in the specialized breeding programs and introduce it as a cultural plant.

Conclusions

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

1. The weight indices WS, WGS, WDLS, AWS and M1000 were with highest variation, while the indices related to the vegetative development of the spikes were characterized with moderate and low variation – NSS, LS, LSA, AI and NSLS, both for the entire investigated period and over years.
2. The investigated indices were divided into generative and vegetative based on the results from the dispersion analysis and the correlations with the index SEYI, the vegetative indices being less stable to the conditions of the environment but more conservative in their expression under specific conditions of growing.
3. The main structural elements of the productivity of the investigated accession were NGS and M1000, which was evidenced by their variation, reaction to the environmental conditions and correlation with the biological ratio SEYI.
4. The variation of the indices was determined by four main components, which accounted for more than 96 % of the total variation.
5. The first component was the most important for the variation and it was related to the generative development of the spikes.
6. The vegetative development of the spikes was of secondary importance for the formation of the total variation as proved by the correlation of the indices from the vegetative group with the second component, and with the rest of the components.
7. NGS was the main structural element of productivity, characterized as a complex trait allowing for many-sided response with regard to its variation.
8. The investigated accession of the species was exceptionally stable with regard to its productivity based on the analyses carried out and can therefore be included in specialized breeding programs to introduce it as a cultural plant.

References

1. Chahal GS, Gosal SS. Principles and procedures of plant breeding: Biotechnological and conventional approaches. CRC Press, New York, 2000.
2. von Braun J. The world food situation: New Driving Forces and Required Actions. International Food Policy Research Institute, Washington, D.C., USA, 2007.
3. Lusser M, Parisi C, Plan D, Rodríguez-Cerezo E. New plant breeding techniques. State-of-the-art and prospects for commercial development. JRC-IPT, 220pp, 2011.
4. Jiang J, Friebe B, Gill BS. Recent advances in alien gene transfer in wheat. Euphytica, 1994; 73: 199–212.
5. Wolfenbarger LL, Phifer PR. The Ecological Risks and Benefits of Genetically Engineered Plants. Science, 2000; 290(5499): 2088-2093.
6. Stoyanov H. Status of remote hybrids in the Poaceae: problems and prospects. Agricultural science and technology, 2013; 5(1): 3-12.
7. Stoyanov H. Characteristics of amphidiploids in the Triticum-Aegilops-Haynaldia-Agropyron group. Scientific Papers. Series A. Agronomy, 2012; LV: 249-255.
8. Landjeva S, Merakchijska-Nikolova M, Ganeva G. Copper toxicity tolerance in Aegilops and Haynaldia seedlings. Biologia Plantarum, 2003; 46(3), 479-480.
9. Spetsov P, Belchev I, Plamenov D. Breeding of synthetic wheats: Crossability and production of hybrids with participation of Aegilops tauschii. Proceedings of Technical university-Varna, 2008; I, 71-76 (Bg).
10. Spetsov P, Plamenov D, Belchev I. Breeding of synthetic wheats: analysis of amphidiploid plants obtained with Aegilops tauschii Coss. Field crops studies, 2009; V-2, 207-216 (Bg).

11. Doneva S, Yordanova D, Daskalova N, Spetsov P. Polymorphism of high molecular weight glutenins in wheat advanced lines originated from crosses with D-genome derived synthetics. In: (D. Kovacevic, Ed) Book of proceedings-VI Intern Sci Agric Symp "AGROSYM 2015", Jahorina, 15-18 October 2015, 2015; 156-161.
12. Paccapelo HA, Funaro DO, Mac Cormick TB, Melis OA. Grain yield and yield components in synthetica/ cereals (tricepiros y triticales). Rev. Fac. Agronomia – UNLPam, 2004; 15(1/2): 3-8.
13. Stoyanov H. New amphidiploid wheat species (nothosp. nov.) as a result of artificial hybridisation. Scientific Papers. Series A. Agronomy, 2014; LVII: 331-338.
14. Spetsov P, Savov M. A review on amphidiploids in the Triticeae, obtained in Bulgaria during 1950-1990. Wheat Information Service, 1992; 75, 1-6.
15. Stoyanov H, Koleva M, Plamenov D, Spetsov P. Influence of wheat genome in hybrids with participation of Aegilops cylindrica Host. Field Crops Studies, 2012; VIII-1, 41-52 (Bg).
16. Stoyanov H. Analysis and assessment of amphidiploids of Triticum-Aegilops group as a source of genetic diversity. Bulgarian Journal of Agricultural Science, 2014b; 20 (Supplement 1), 173–178
17. Stoyanov H. Influence of contrast growing conditions on the amphidiploid Triticum timopheevii Zhuk. X Aegilops tauschii Coss. Proceeding of Union of Scientists – Ruse, 3, Agrarian and Veterinary Medicine Sciences, 2015; 7: 36-42.
18. Stoyanov H. Influence of environmental conditions on the species Triticum xtoschevii H.P.St. compared to common winter wheat (Triticum aestivum L.). Proceeding of Union of Scientists – Ruse, 3, Agrarian and Veterinary Medicine Sciences, 2015; 7: 29-35.
19. Stoyanov H. Effect of black (stem) rust (Puccinia graminis f.sp. tritici) to the spike characteristics in Polish wheat (Triticum polonicum L.). Agricultural science and technology, 2015; 7(1): 25-35.
20. Moragues M, Garcia del Moral LF, Moralejo M, Royo C. Yield formation strategies of durum wheat landraces withdistinct pattern of dispersal within the Mediterranean basin I: Yield components. Field Crops Research, 2006; 95: 194–205
21. Abayomi Y, Wright D. Effects of water stress on growth and yield of spring wheat (Triticum aestivum L.) cultivars. Trop. Agric., 1999; 76, 120–125.
22. Giunta F, Motzo R, Deidda M. Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. Field Crops Research, 1993; 33(4): 399-409.
23. Simane B, Struik PC, Nachit M, Peacock JM. Ontogenic analysis of yield components and yield stability of durum wheat in water-limited environments. Euphytica, 1993; 71, 211–219.
24. Campbell CA, Davidson HR, Warder FG. Effects of fertilizer N and soil moisture on yield, yield components, protein content and N accumulation in the aboveground parts of spring wheat. Can. J. Soil Sci. , 1977; 57: 311-327.
25. Stoyanov H. Spike morphology and variation in spike parameters in spesies Triticum ×savovii. Scientific Papers. Series A. Agronomy, 2015; LVIII: 315-324.
26. Kashif M, Khaliq I. Heritability, Correlation and Path Coefficient Analysis for Some Metric Traits in Wheat. International Journal of Agriculture and Biology, 2004; 6-1: 138-142
27. Fufa H, Baenziger SP, Beecher BS, Graybosch RA, Eskridge KM, Nelson LA. Genetic improvement trends in agronomic performances and end-use quality characteristics among hard red winter wheat cultivars in Nebraska. Euphytica, 2005; 144: 187-198
28. Mahmood A, Shahid M. Inheritance and inter-relationship studies of some quantitative characteristics in wheat. Pakistan Journal of Agricultural Research, 1993; 14-2/3: 121-125
29. Mihova G, Dimova D. Yield components characterization of various feed barley forms. Field Crops Studies, 2012, 8(1): 23-36.
30. Stoyanov H, Baychev V. Research on the variability in triticale (×Triticosecale Wittm.)

crosses as a source of genetic diversity. Youth Scientific Conference “Kliment’s Days”, Sofia 2016, Book of Abstracts, 2016.
31. Stoyanov H. Similarity of spike properties of tetraploid wheat species of section Dicoccoides (2n=4x=28, AABB). Field Crop Studies, 2014; IX-2: 183-202.
32. Giunta F, Motzo R, Deidda M. Grain yield analysis of a triticale (xTriticosecale Wittmack) collection grown in a Mediterranean environment. Field Crops Research, 1999; 63: 199-210.
33. Motzo R, Giunta F, Deidda M. Factors affecting the genotype × environment interaction in spring triticale grown in a Mediterranean environment. Euphytica, 2001; 121: 317-324.
34. Fischer RA, HilleRisLambers D. Effect of environment and cultivar on source limitation to grain weight in wheat. Australian Journal of Agricultural Research, 1978; 29(3): 443-458
35. Acreche MM,. Slafer GA. Grain weight response to increases in number of grains in wheat in a Mediterranean area. Field Crops Research, 2006; 98: 52-59.
36. Dencic S, Kastori R, Kobiljski B, Duggan B. Evaluation of grain yield and its components in wheat cultivars and landraces under near optimal and drought conditions. Euphytica, 2000; 113: 43-52.
37. Garcia del Moral LF, Rharrabti Y, Villegas D, Royo C. Evaluation of Grain Yield and Its Components in Durum Wheat under Mediterranean Conditions. Agron. J., 2003; 95:266-274
38. Ugarte C, Calderini DF, Slafer GA. Grain weight and grain number responsiveness to pre-anthesis temperature in wheat, barley and triticale. Field Crops Research, 2007; 100: 240-248.
39. Lopez-Castaneda C, Richards RA. Variation in temperate cereals in rainfed environments I. Grain yield, biomass and agronomic characteristics. Field Crops Research, 1994; 37: 51-62.
40. Stoyanov H, Baychev V. Response to the environmental conditions of the spike indices in second generation of triticale crosses (xTriticosecale Wittm.). Proceedings of Jubilee Scientific Conference with International Participation “135 Years Agricultural Science in Sadovo and 40 years Institute of Plant Genetic Resources – Sadovo” , 2017 (in press).
41. Stoyanov H, Baychev V. Assessment of Yield Components Stability and Plasticity in Bulgarian Triticale (×Triticosecale Wittm.) Cultivars. Scientific works of Institute of Agriculture – Karnobat, 2016 (in press)
42. Knott DR, Talukdar B. Increasing Seed Weight in Wheat and Its Effect on Yield, Yield Components, and Quality. Crop Sci., 1971; 11:280-283.
43. Elbaum R, Zaltzman L, Burgert I, Fratzl P. The Role of Wheat Awns in the Seed Dispersal Unit. Science, 2005; 316, 884-886
44. Gibson LR, Paulsen GM. Yield Components of Wheat Grown under High Temperature Stress during Reproductive Growth Contribution 97-453-J of the Kansas Agric. Exp. Stn., Manhattan. . Crop Sci., 1999; 39:1841-1846
45. Lloveras J, Manent J, Viudas J, López A, Santiveri P. Seeding Rate Influence on Yield and Yield Components of Irrigated Winter Wheat in a Mediterranean Climate. Agron. J., 2004; 96:1258-1265.
46. Kutlu I, Kinaci G. Evaluation of drought resistance indicates for yield and its components in three triticale cultivars. Journal of Tekirdag Agricultural Faculty, 2010; 7(2): 95-103.
47. Leilah AA, Al-Khateeb SA. Statistical analysis of wheat yield under drought conditions. Journal of Arid Environments, 2005; 61-3: 483-496

Tables

Table 1. Meteorological data of the investigated period

	Average monthly temperature, ºC			Total monthly precipitation, mm		
Months	2012/2013	2013/2014	2014/2015	2012/2013	2013/2014	2014/2015
Oct	16,1	12,1	11,4	73,5	79	76
Noe	9,2	9,5	5,8	41	29	54
Dec	0,9	1,8	3,0	142	10	105
Jan	1,2	2,6	2,1	47	153	40
Feb	3,6	4,7	1,7	34,5	19	101
Mar	6,2	8,7	5,6	31	56	71
Apr	13,4	11,5	11,1	39,5	39	46
May	19,7	15,6	18,5	20,5	120	27
Jun	20,9	19,2	20,1	60	234	61
Average	10,1	9,5	8,8	-	-	-
01.10-31.03	6,2	6,6	4,9	-	-	-
01.04-30.06	18	15,4	16,6	-	-	-
Total	-	-	-	489	739	581
01.10-31.03	-	-	-	369	346	447
01.04-30.06	-	-	-	120	393	134

Table 2. Variation analysis of the investigated structural elements of productivity

Parameter	Year	AV	VC, %	Parameter	Year	CC / AV	VC, %
NSS	2012/2013	20,00	17,70	AI	2012/2013	2,05	12,02
	2013/2014	23,50	11,34		2013/2014	1,71	10,44
	2014/2015	25,53	5,90		2014/2015	1,63	7,98
	Total	23,01	15,62		Total	1,79	14,76
LS	2012/2013	96,30	21,69	NSLS	2012/2013	0,210	7,58
	2013/2014	122,35	11,65		2013/2014	0,193	7,00
	2014/2015	128,80	9,09		2014/2015	0,199	4,37
	Total	115,82	18,77		Total	0,200	7,57
LSA	2012/2013	192,85	11,69	WDLS	2012/2013	0,027	21,83
	2013/2014	207,65	11,95		2013/2014	0,022	36,48
	2014/2015	209,00	7,25		2014/2015	0,024	22,26
	Total	203,17	11,16		Total	0,024	28,20
WS	2012/2013	2,70	39,82	AWS	2012/2013	0,130	26,01
	2013/2014	2,73	41,40		2013/2014	0,115	38,87
	2014/2015	3,04	23,47		2014/2015	0,119	22,01
	Total	2,82	35,84		Total	0,121	29,98
WGS	2012/2013	1,96	41,78	M1000	2012/2013	48,95	13,24
	2013/2014	1,64	61,53		2013/2014	41,48	34,88
	2014/2015	2,10	29,93		2014/2015	38,41	19,38
	Total	1,90	45,52		Total	42,95	25,55
NGS	2012/2013	38,90	33,72	SEYI	2012/2013	4,81	31,73
	2013/2014	36,75	35,99		2013/2014	5,11	38,80
	2014/2015	54,47	20,13		2014/2015	4,94	19,68
	Total	43,37	34,21		Total	4,95	31,72

Table 3. ANOVA of the investigated structural elements of productivity

Parameter		SS	F	Sig.	Parameter		SS	F	Sig.
NSS	Between groups	278,648	17,900	0,000	AI	Between groups	1,863	24,316	0,000
	Within groups	404,733				Within groups	1,992		
	Total	683,382				Total	3,856		
LS	Between groups	10923,577	20,181	0,000	NSLS	Between groups	0,0031	8,666	0,001
	Within groups	14073,150				Within groups	0,0093		
	Total	24996,727				Total	0,0124		
LSA	Between groups	3025,627	3,201	0,049	WDLS	Between groups	0,0003	2,941	0,062
	Within groups	24573,100				Within groups	0,0023		
	Total	27598,727				Total	0,0025		
WS	Between groups	1,190	0,581	0,563	AWS	Between groups	0,0024	0,920	0,405
	Within groups	53,250				Within groups	0,0692		
	Total	54,440				Total	0,0716		
WGS	Between groups	2,028	1,403	0,255	M1000	Between groups	1073,910	5,031	0,010
	Within groups	37,589				Within groups	5549,881		
	Total	39,617				Total	6623,791		
NGS	Between groups	3067,444	9,635	0,000	SEYI	Between groups	0,968	0,191	0,827
	Within groups	8277,283				Within groups	132,089		
	Total	11344,727				Total	133,057		

Table 4. Correlations of the investigated structural elements of productivity with the parameter SEYI

Parameter	PC	Parameter	PC
NSS	0,470**	WS	0,887**
LS	0,504**	WGS	0,863**
LSA	0,407**	WDLS	0,789**
AI	-0,439**	AWS	0,851**
NSLS	-0,348**	M1000	0,801**
NGS	0,583**	SEYI	1

Table 5. Principal component analysis in the investigated accession

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6,162	56,014	56,014	6,162	56,014	56,014	4,741	43,099	43,099
2	3,014	27,403	83,418	3,014	27,403	83,418	3,287	29,885	72,984
3	0,937	8,518	91,936	0,937	8,518	91,936	1,690	15,360	88,344
4	0,529	4,813	96,749	0,529	4,813	96,749	0,925	8,405	96,749
5	0,274	2,491	99,241						
6	0,049	0,443	99,684						
7	0,018	0,164	99,848						
8	0,011	0,104	99,951						
9	0,002	0,019	99,971						
10	0,002	0,019	99,989						
11	0,001	0,011	100,000						

Table 6. Correlation matrix of the principal components and structural elements of productivity.

	Component			
	1	2	3	4
NSS	0,131	***0,913***	0,170	0,287
LS	0,118	***0,832***	0,474	0,236
LSA	0,200	0,307	***0,663***	**0,616**
WS	***0,854***	0,417	0,211	0,211
WGS	***0,932***	0,296	0,054	0,160
NGS	***0,610***	***0,599***	-0,035	0,424
AI	-0,048	***-0,962***	-0,214	0,136
NSLS	-0,038	-0,290	***-0,931***	0,001
WDLS	***0,984***	0,029	-0,033	0,130
AWS	***0,968***	0,087	0,181	0,109
M1000	***0,890***	-0,170	-0,018	-0,331