

Comparative Evaluation of Einkorn Accessions (*Triticum monococcum* L.) of Some Main Agricultural Characters

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Abstract

A set of 15 landraces was estimated by seven agronomical characters. The analysis of variance showed that the most relative variable character during the period of study was the grain yield, followed by the spike length and the thousand kernel weight. The accessions with the shortest stem were B3000126 (90 cm) and B3000128 (95 cm), while B4E0040 and B3000130 had dense and long spikes. The highest thousand kernel weight was observed in B3E0024 (37.66 g), followed by B3000126 (36.60 g). B3000024 and B3000082 possessed high production potential. PC-analysis was applied to arrange accessions by their similarity. The first two factors explained 68.533 % of total variation. The first factor had an important role to justify alteration of length of vegetative growth phase, number of spikelets per spike, plant height and the thousand kernel weight. The second factor justified 27.603 % of total variance. Cluster analysis based on the two factors grouped the landraces into six groups.

Key words: einkorn, agronomical characters, PCA, cluster analysis

Introduction

Triticum monococcum L. is one of the earliest cultivated wheat forms. Grains from wild forms are found in excavations, dating from the epipaleolithic era in the Middle East known as the Fertile Crescent. It is accepted that *T. monococcum* has been cultivated for the first time about 7500 years b.c. near Kardag, a region in Southeast Turkey (Heun et al., 1997; Weiss and Zohary, 2011). Vavilov (1926) suggests that the formation center of *T. monococcum* L. is Asia Minor and neighboring countries.

According to Zhukovskiy (1957) ancient remnants of such a culture are found in many places in Russia. Later on, during the Bronze Age, its cultivation gradually decreased at the expense of other crops and was gradually reduced to its present state of relic - almost forgotten plant, almost of no economic significance grown as a regional kind in Morocco, Turkey, Albania, Romania, Spain, Italy Greece, Kurdistan, Syria, Palestine, the countries of former Yugoslavia and some mountainous regions of France. In these places it was used for the production of manna croup and feed for livestock (Stallknecht et al., 1996). In Bulgaria it has been grown in Haskovo, Stara Zagora, Jambol, Pernik, Sofia and Kustendil regions and has been known as “yasa”. According to Stansky (1929, 1934) and Arnaudov (1936) *T. monococcum* was brought by proto-Bulgarians in former Volgo-Camska Bulgaria from the Balkan Peninsula. Schiemann (1932) divides a branch of the way of *T. monococcum* starting from our country and goes towards Volga – Cama – Ural.

The plant was grown later in larger areas, during the early stages of the New Era, when Slavic tribes invaded the Balkan Peninsula and formed the basis for the current Bulgarians. They continued to grow this plant and gave it the name of “lemec”, which originates from the way of its usage by hammering in stone containers to dispose of weed class. Stranski (1929, 1934), who studied *T. monococcum* in Bulgaria, found 4 wild and 11 cultural varieties, some of them endemic (*var. bulgaricum*, *var. sofianum*) and described a great diversity. According to him the following are spread in our county: *var. vulgare*, *var. symphaeropolitanum*, *var. atriaristatum*, *var. nigricultum*, *var. pseudomacedonicum*, *var. macedonicum*, *var. flavescens*, *var. sofianum*, *var. hornemannii* (Fig.1).

The rich diversity of wild and cultural variations and forms, found in Bulgaria, is a sure sign that our country is in the center of its formation. That also shows that *T. monococcum* is an ancient crop, grown in Bulgaria from where it spread throughout Europe (Popov and Dimitrov, 1979).

In Bulgaria the interest in einkorn has increased during the past few years. Today farmers practicing organic agriculture initiate the testing of various varieties of einkorn applicable to organic or low-input farming (Fig.1- a, b, c). A lot of practical questions come from difficulties with sowing norms and terms, unknown growth type, no possibilities and/or problems with threshing and de-hulling, or relatively low yield in relation to cultivated wheat (Desheva et al., 2014).



Fig. 1. a - *Tr. monococcum* var. *atriastatum*; b - *Tr. monococcum* var. *sofianum*; c - *Tr. monococcum* var. *macedonicum*.

Triticum monococcum L. collection is maintained in a long-term and medium-term ex situ storage in the national genebank in IPGR – Sadovo. For long-term storage, seeds are kept in hermetical packs at -18°C , after drying to a suitable level (Stoyanova, 1998; 2001). The collection comprises 83 accessions, 68 of which are in base collection under -18°C (Odshakova et al., 2007; Desheva et al., 2013).

The evaluation, identification and description of the genetic variation of einkorn accessions stored in germplasm collections is of utmost importance for the prevention of genetic erosion and for the promotion of its use in breeding programs (Butnaru et al., 2003).

The aim of the study is to evaluate the economic value of original *T. monococcum* geneplasm, stored for over 20 years in long-term storage in a genebank.

Material and Methods

15 accessions of einkorn (*Triticum monococcum* L.) were reproduced during the period from 2014-2015 in the experimental field of the Institute of Plant Genetic Resources-Sadovo (Table 1).

The landraces were sown in harvest plots each of 10 m^2 in three replications, in the randomized block design. Normal agronomic and cultural practices were applied to the experiment throughout the growing seasons.

The agronomic characters were taken after harvesting the plants. From each variety, 10 plants were collected for biometrical measurements. Data were registered for plant height (cm), spike length with awns (cm), number of spikelets per spike, number of grains per spike, grain yield (kg ha⁻¹). Length of vegetative growth phase (days) is presented as a number of days from the 1st January to the date of heading. The thousand kernel weight (g) was determined according to the methods described in BDS ISO 520 (2003). The mean data from all six characters were used to analyze the variance according to Lydansky (1988). LSD test was carried out to explore the significance of differences between mean standard and respective accession in the data set. PC-analysis was applied to group accessions according to similarity on the basis of all six traits in two components in the factor plane by using SPSS 13 software and the related clusters were plotted based on the main components.

Tab. 1. List of einkorn landraces included in the study

Списак локалних популација једнозрне пшенице коришених у истраживању

Accession № <i>Бр. принове</i>	Species <i>Врста</i>	Subspecies <i>Подврста</i>	Country of origin <i>Земља поријекла</i>
B3000023	Triticum monococcum L.	var.hornemannii	SYR
B3000024	Triticum monococcum L.	var.macedonicum	BGR
B3000025	Triticum monococcum L.	var.macedonicum	TUR
B3000026	Triticum monococcum L.	var.macedonicum	AZE
B3000082	Triticum monococcum L.	-	AUT
B3000084	Triticum monococcum L.	-	AUT
B3000126	Triticum monococcum L.	var. monococcum	TUR
B3000128	Triticum monococcum L.	var.mansfeldii	TUR
B3000129	Triticum monococcum L.	var.clusii	-
B3000130	Triticum monococcum L.	var.pseudohornemannii	-
B2BM0148	Triticum monococcum L.	-	BGR
B2E0417	Triticum monococcum L.	-	BGR
B3E0024	Triticum monococcum L.	-	BGR
B3E0025	Triticum monococcum L.	-	BGR
B4E0040	Triticum monococcum L.	-	BGR

Results and Discussion

The evaluated set of the einkorn includes 15 landraces. Einkorn has a long growth cycle, compared to other cultivated wheat species (Dorofeev et al., 1979; Zaharieva and Philippe Monneveux, 2014.). The results of our study showed that mean length of vegetative growth phase was 152.54 days.

A limited variation was noted ($CV = 2.66\%$). The shortest phase was calculated for Bulgarian landraces - B2E0417 (145.33 days) and B2BM0148 (147.67 days), while the longest was for B3000084 (161 days). The accessions with the shortest stem were B3000126 (90 cm) and B3000128 (95 cm) from Turkey, while B2BM0148 had the tallest stems (123 cm), respectively. Results are in agreement with Sharma et al. (1981), Castagna et al. (1992) and Butnaru et al. (2003) which described a broad variation for plant height. The number of spikelets per spike varied between 21 and 41. Seven accessions showed significant differences with the check mean standard for this trait. The accessions B4E0040 and B3000130 had dense and long spikes (Table 2).

The thousand kernel weight is a useful tool for the assessment of the potential milling yield. The kernel size contributes directly towards the improvement of grain yield as well as milling yield. Khan et al. (2009) indicated that the wheat varieties possessing a higher grain weight present a better potential for grinding and flour extraction. The einkorn landraces are characterized with low thousand grains weight (Empilli et al., 2000; Konvalina et al., 2010; Desheva et al., 2014). Frégeau-Reid and Abdel-Aal (2005) refer to the fact that the small grain of the einkorn may cause serious losses during the peeling of the grains. In our study the thousand kernel weight showed significant variation among different einkorn landraces. It ranged from 20.33 g to 37.66 g. The highest thousand kernel weight confirmed statistically was observed in B3E0024 (37.66 g), followed by B3000126 (36.60 g) (Table 2).

The einkorn landraces are characterized by low grain yield potential which is only around 40 to 60% of grain yield of common and durum wheat (Stallknecht et al, 1996; Honermeier, 2006). In our study grain yield ranged from 1480.50 to 3410.16 kg ha⁻¹.

Four of einkorn wheat accessions (B3000082, B3000024, B3000084 and B3000026) surpassed significantly the mean standard by this trait. The Bulgarian landraces showed significantly lower grain yield. The values of coefficient of variation ($CV\%$) was from 2.66 to 30.59%. The analysis showed that the most relative variable character during the period of study was the grain yield (30.59%), followed by spike length with awns (22.09%) and the thousand kernel weight (16.13%).

The values of these coefficients confirm that these traits were more susceptible to change under the influence of different factors. Relatively the least variable for the period of study indicated the length of vegetative growth phase (Table 2).

Tab. 2. Characteristics of einkorn wheat landraces (2014-2015)
Особине локалних популација једнозрне пшенице

№ Бр	Accession number <i>Бр. принове</i>	Length of vegetative growth phase, days <i>Дужина вег. фазе (дани)</i>	Plant height, (cm) <i>Висина биљке (cm)</i>	Number of spikelets per spike <i>Број класића у класу</i>	Spike length with awns, (cm) <i>Дужина класа са осјем (cm)</i>	Thousand kernel weight, (g) <i>Маса 1000 зрна (g)</i>	Grain yield, (kg ha ⁻¹) <i>Принос зрна (kg/ha)</i>
1	Mean St.	152.54	108.04	32.67	15.92	29.00	2060.48
2	B300023	156.00*	115.00*	36.00*	18.00*	20.33***	1510.33***
3	B300024	153.00	110.00	32.00	14.00	35.33***	3270.00***
4	B300025	152.00	105.00	32.00	14.00	30.33**	1980.50
5	B300026	152.00	100.00*	30.00	16.00	29.67	2640.16***
6	B300082	154.00	105.00	34.00	12.00***	25.33***	3410.16***
7	B300084	161.00***	115.00*	34.00	14.00	24.66***	2690.66***
8	B3000126	148.00**	90.00***	36.00*	13.00**	35.66***	1720.66***
9	B3000128	149.00*	95.00***	28.00**	13.00**	28.33	1740.00***
10	B3000129	158.00***	115.00*	36.00*	15.00	24.33***	1810.16***
11	B3000130	154.00	115.00*	38.00***	22.00***	28.33	1740.16***
12	B4E0040	154.00	115.00*	42.00***	21.00***	30.33**	1480.50***
13	B3E0024	152.00	105.00	30.00	13.00**	37.66***	1630.00***
14	B3E0025	152.00	110.00	30.00	16.00	30.66**	2030.83
15	B2E0417	145.33***	102.53	21.00***	14.67	28.00*	1640.66***
16	B2BM0148	147.67***	123.00***	31.02	23.10***	26.00***	1630.33***
	LSD 5%	2.73	6.90	3.02	1.96	0.97	130.57
	LSD 1%	3.64	9.18	4.02	2.60	1.29	180.05
	LSD 0.1%	4.73	11.94	5.23	3.39	1.68	230.48
	CV, %	2.66	8.17	14.98	22.09	16.13	30.59

Principal component analysis (PC-analysis)

PC-analysis was applied to arrange accessions by their similarity. The values of the two components to each of the studied characters were calculated empirically. The first two factors explained 68.533 % of total variation. The first factor determining 40.930% of the variation had an important role to justify alteration of length of vegetative growth phase, number of spikelets per spike, plant height and thousand kernel weight (Table 3). The second factor had justified 27.603% of total variance.

Tab. 3. Factor analysis of traits using principal components analysis in 15 einkorn wheat genotypes

Факторска анализа особина уз помоћ анализе главних компонената за 15 принова једносрне пшенице

Rotated Component Matrix / Ротирана матрица компоненти		
Characteristic / Особина	Factor 1 / Фактор 1	Factors 2 / Фактор 2
Length of vegetative growth phase (LVGPh) / Дужина вегетативне фазе (LVGPh)	0.822	
Plant height (PH) / Висина биљке (PH)	0.807	
Number of spikelets per spike (NSS) / Број класића у класу (NSS)	0.701	
Spike length with awns (SL) / Дужина класа са осјем		-0.79
Thousand kernel weight (TKW) / Маса 1000 зрна (TKW)	-0.624	
Grain yield (GY) / Принос зрна (GY)		0.84
Eigen values / Својствене вриједности	2.55	1.562
Proportional variance, % / Пропорционално одступање, %	40.93	27.603
Cumulative variance, % / Кумулативно одступање, %	40.93	68.533

The factorial coefficient of spike length with awns was high and negative, while the factorial coefficients of grain yield was also high but positive (Table 3, Fig. 2).

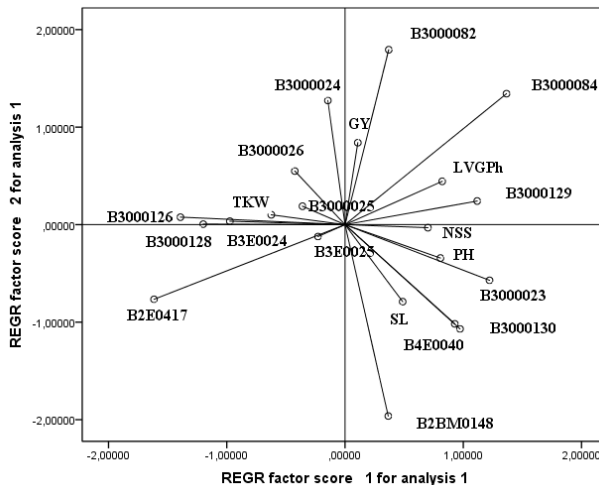


Fig. 2 Projection of the investigated characters and accessions on the factor plane (1 x 2)

Пројекција истраживаних особина и принова на фактор-плану (1x2)

Cluster analysis based on the two factors grouped the landraces into six groups at 5% linkage distance (Fig. 3).

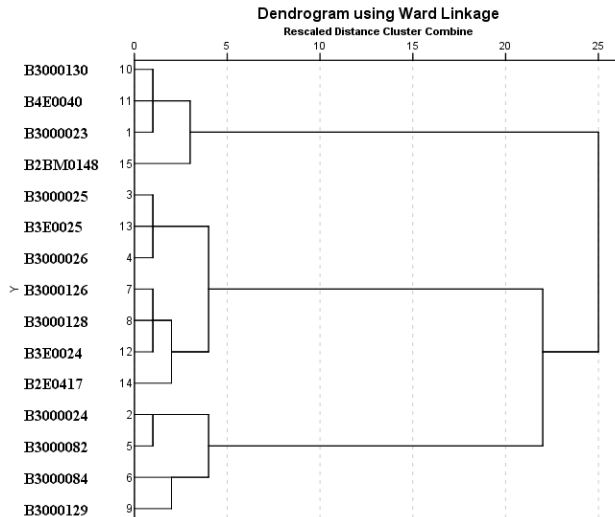


Fig. 3 Tree diagram of 15 einkorn genotypes for 2 extracted factors using hierarchical cluster analysis (Ward’s method and Square Euclidean distance).

Приказ гранања за 15 генотипова једнозрне пшенице и два изолована фактора, према хијерархијској кластер анализи (Ward-ов метод и Еуклидска дистанца)

Average of factors for each cluster is shown in Table 4.

Tab. 4. The average of traits for achieved groups from cluster analysis based on factor analysis in 15 einkorn wheat genotypes

Вриједности особина за дате групе према кластер анализи (просјек) на бази факторске анализе за 15 генотипова једнозрне пшенице

Cluster <i>Кластер</i>	Factor 1 <i>Фактор 1</i>	Factor 2 <i>Фактор 2</i>
Cluster 1	1.198	-0.796
Cluster 2	0.342	-1.855
Cluster 3	-0.292	0.152
Cluster 4	-1.251	0.298
Cluster 5	-0.087	1.550
Cluster 6	1.058	0.940

In the first cluster, three accessions (B3000130, B4E0040 and B3000023) were classified including 20% of total genotypes. Landraces in this

cluster were in the highest rate with respect to the first factor and are characterized with the highest number of spikelets per spike and long spike. B2BM0148 was separated in single cluster. This Bulgarian landrace was with the tallest stem and the longest spike.

The third group comprised 3 accessions (B3000025, B3E0025 and B3000026). The genotypes in this cluster had the thousand kernel weight about 30 g and a 156-day length of vegetative growth phase. In the fourth group, 2 genotypes from Bulgaria and 2 from Turkey (B3000126, B3E0024, B3000128 and B2E0417) were classified including 26.66% of total accessions. They had the shortest plant height and large kernels. The fifth group included 2 landraces (B3000024 and B3000082). They had the highest rate with respect to the second factors. Genotypes in this cluster had the highest grain yield. The genotypes from Austria (B3000084 and B3000129) were grouped in the last cluster. They had a tall stem and the longest vegetation period.

Conclusion

Considerable diversity of agronomical characters was found in einkorn. The most relative variable character during the period of study was the grain yield (30.59 %), followed by spike length with awns (22.09 %) and thousand kernel weight (16.13 %). Relatively the least variable indicated the length of vegetative growth phase.

Principal Component Analysis illustrated the grouping of accessions by two components in the factor plane, where they explain the total of 68.533% variation in the experiment. The first factor had an important role to justify alteration of duration of vegetative growth phase, number of spikelets per spike, plant height and thousand kernel weights. The second factor was associated with spike length and grain yield.

B3000024 and B3000082 possessed high production potential.

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Упоредна евалуација принова једнозрне пшенице (*Triticum monocossum* L.) у погледу најважнијих агрономских особина

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Сажетак

Укупно 15 локалних популација је оцијењено за седам агрономских особина. Анализа варијансе је показала да је релативно најваријабилнија особина током истраживања била принос зрна, а затим дужина класа и маса 1000 зрна. Најкраће стабло су имале принове В3000126 (90 cm) и В3000128 (95 cm), док су принове В4Е0040 и В3000130 имале бујне и дуге класове. Највеће вриједности тежине 1000 зрна уочене су код принове В3Е0024 (37,66 g), те код принове В3000126 (36,60 g). Принове В3000024 и В3000082 су имале висок продуктивни потенцијал. РСА-анализа је споведена у циљу сврставања принова на основу сличности. Прва два фактора су објаснила 68,533 % укупне варијације. Први фактор је имао значајну улогу у објашњењу промјена у дужини фазе вегетативног раста, број класића у класу, висини биљака и маси 1000 зрна. Други фактор је објаснио 27,603 % укупне варијације. Кластер анализа на основу ова два фактора је показала груписање локалних популација у шест група.

Кључне ријечи: једнозрнац, агрономске особине, РСА анализа, кластер анализа

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