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AN AGRO-TECHNOLOGICAL CHARACTERIZATION OF SOUTH-EASTERN EUROPEAN BROOMCORN LANDRACES

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Comprehensive overview of the extent genetic diversity in South-East European landrace collection was estimated regard broadening of broomcorn (*Sorghum bicolor* [L]. Moench) germplasm variability. In a long-term field trials 28 accessions were analyzed to determine variability of agronomic (unthreshed panicle weight UTP, threshed panicle weight TRP, grain yield per panicle SWG and threshed panicle ratio RAN), morphological (plant height PHG, stalk height SHG, panicle length PLG, peduncle length PDL, flag leaf sheath length LSL and panicle exsertion PEX) and technological (fiber length FLG, fiber number per panicle NOP and fiber fineness FFI) traits. By all obtained results combining over univariate and multivariate analysis, the study showed significant variability over traits, so the examined landraces will be included in existing broomcorn germplasm. Accessories with valuable quantitative and qualitative characters can significantly contribute to improvement of new bred cultivars and broadening germplasm diversity. Three years field experiment showed significant positive correlations between PHG-SHG, PDL-PEX and UTP-SWG and significant negative correlations between PDL-FLG and SWG-RAN. The performance of examined landraces were generally within the ambit of broomcorn germplasm variability, but several accessions with the extreme trait profile for yield components and panicle quality will be useful as parents in the breeding process.
Keywords: Broomcorn, landraces, panicle quality, technological traits, variability.

INTRODUCTION

Sorghum is considered as one of the most important plant species worldwide based on production and utilization. It is mainly used as human food, animal feed, building material, fencing, or for brooms (Rooney and Waniska, 2000; Abubaker *et al*., 2014). Cultivated sorghum in Europe are represented by agronomic types or forms such as grain sorghum, sweet sorghum, sudan grass and broomcorn (Berenji and Dahlberg, 2004). Harlan and de Wet (1972) classified cultivated sorghum into five basic races: bicolor, caudatum, durra, guinea and kafir and ten intermediate races consisting of all combinations of the five basic races taking two at time. Based on this classification broomcorn belong to the bicolor race. Contemporary classifications consider it as *Sorghum bicolor* (L.) Moench, ssp. *bicolor*, race *bicolor*, working group *nervosum-kaoliang* (Dahlberg, 2000).

Broomcorn is a classic example of industrial use of sorghum, since its panicle has only one use as a raw material for brooms (Dahlberg and Wolfrum, 2011). Although domestication of sorghum in Africa is well documented (Dogget, 1988; Kimber, 2000), domestication of broomcorn remains rather uncertain. General opinion is the broomcorn evolved simultaneously by repeated selection for long fibers of the panicle throughout various regions worldwide. The origin of broomcorn in Europe is Mediterranean region and out of there it was spread in most of Europe (Berenji *et al.,* 2011).

The world's largest collection of sorghum germplasm includes National Plant Germplasm System (USDA) with more than 42,000 samples, International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) with over 36,000 samples, Chinese Agricultural Science Academy National Seed Bank (CASANSB) with over14,000samples (Reddy *et al.,*2008). These gene banks generally include all races and their derivatives with in *Sorghum bicolor*.

Serbia broomcorn breeding program was started more than 60 years ago in the Institute of Field and Vegetable Crops Novi Sad, and during that period collection of over 450 samples was compiled. Based on the genetic constitution and geographic origin of this collection, it can be considered as the world broomcorn germplasm collection (Sikora, 2005). The core of the 54 genotypes which include 68-100% of the basic collection variability was separated and become the base for broomcorn breeding program (Sikora and Berenji, 2008).

A successful breeding program depends on the available germplasm with wide genetic divergence. Assessment of genetic distance among genotypes is main criterion for selection of parental combinations in segregating populations (Van Becelaere *et al.*,2005) and germplasm classification into heterotic groups in hybrid creating (Menz *et al.*,2004). Genetic divergence of germplasm can be perceived in terms of pedigree, geographical origin, agro-morphological trait sand molecular markers (Melchinger, 1999). Assessment based on pedigree due to the limited information related to specific genotypes is not of ten correlated with the overall variability of the germplasm (Fufa *et al.,* 2005). Divergence of different sizes, genetic constitutions and sorghum collections geographic origins with usage of agro-morphological markers was estimate earlier (Grenier *et al.,* 2001a; Grenier *et al.,* 2001b; Geleta *et al.*,2006; Aruna and Audilakshmi, 2008; Kumar *et al.,* 2010). Although these markers are limited in number and influenced by the environmental conditions (Van Beuningen and Busch, 1997), they generally reflect genetic differences among genotypes in a good manner.

A landrace is a dynamic population(s) of a cultivated crop that has a historical origin, a distinct identity and lacks formal crop improvement. They are considered as locally adapted and environmental conditions may have a substantial impact on their main characteristics. The genetic diversity in landraces represent management processes and indigenous knowledge guiding farmer practices (Camacho Villa *et al.,* 2005; Islam *et al*., 2014). Characterization of landraces is essential for their further utilization in breeding programs.

Broomcorn is a small scale alternative crop with regionally oriented production, and experimental information about this production is rare, so some references cited in this paper was older in date. To our best knowledge, except our previous studies of world broomcorn germplasm (Berenji, 1990, 2000; Sikora, 2005; Sikora and Berenji, 2008; Ikanovic *et al.,* 2013; Glamoclija *et al.,* 2015) this is first study concerning broomcorn landraces.

The main objectives of this study was to determine quantitative traits corresponding variability of South-East European (SEE) broomcorn landraces, and association among individual traits, so the most favorable accessions with the best agro-morphological and technological traits, which was not part of existing collection, could be included in the breeding program.

MATERIALS AND METHODS

Plant material**:** The most important agro-morphological quantitative features of 28 broomcorn landraces originated from SEE were analyzed. The region of this material is located within the geographic coordinates 42°10’-48°70’N, 17º80’-24°60’E and it includes parts of the territories of Serbia, Hungary, Croatia, Romania and Bulgaria. Material includes locally adapted broomcorn landraces that has been maintained on individual farm over many years and each of them was developed under specific agro-climatic conditions and are associated with traditional farming systems (Table 1, Fig. 1).

Table 1. List of broomcorn accessions examined in the study.

Code	Description	IFVCNS[a] accession	Origin
1	NS-BP/CL-12	SO 001	Serbia
2	NS-BP/CL-4M	SO 002	Serbia
3	NS-BP/CL-6	SO 012	Serbia
4	NS-BP/CL-8	SO 019	Serbia
5	NS-BP/E-3905	SO 020	Serbia
6	Csehoszlovák	SO 025	Hungary
7	Osztrak	SO 026	Hungary
8	Torda	SO 050	Serbia
9	Mezokovacshazi	SO 074	Hungary
10	Aradac 1	SO 252	Serbia
11	Aradac 2	SO 253	Serbia
12	LP 2/89	SO 429	Hungary
13	LP 4/89	SO 431	Bulgaria
14	LP 5/89	SO 432	Bulgaria
15	LP 7/89	SO 434	Hungary
16	LP 9/89	SO 436	Croatia
17	LP 13/89	SO 440	Bulgaria
18	LP 14/89	SO 441	Croatia
19	LP 15/89	SO 442	Romania
20	LP 17/89	SO 444	Bulgaria
21	LP 19/89	SO 446	Bulgaria
22	CL-2-MM-3	SO 510	Croatia
23	CL-2K	SO 511	Croatia
24	LP 1/98	SO 586	Romania
25	Paracin	SO 594	Serbia
26	Despotovac	SO 595	Serbia
27	DBK 36	SO 699	Romania
28	VVM 131	SO 700	Romania

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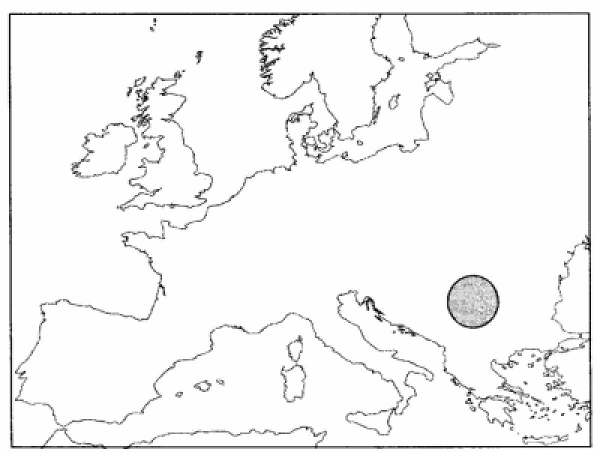


Figure 1. Region of origin of broomcorn landraces examined in the study.

Table 2. Mean precipitation (mm) and temperature (°C) for site of Backi Petrovac, BP, Serbia.

Year	Precipitation (mm)			Temperature (°C)
	X-III	IV-IX	X-IX	IV-IX
2002	157	347	504	19.7
2005	365	552	917	18.2
2006	229	445	674	19.2
1985-2010	259	352	611	19.0

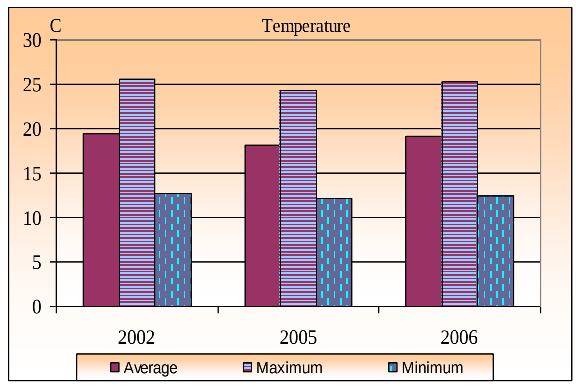
***Field trials, experimental setup and climatic conditions*:** Field trials were set up at the site of Backi Petrovac (45°20'32" N, 19°40'55" E, altitude 82 m) on molisol in 2002, 2005 and 2006 (Table 2). Elementary-two-row plots were 10 m long. Plant spacing was 0.7 m among rows and 0.1 m among plants within rows and total area of each plot was 14m^2. Plants within a plot, 10 m, served as a replications. From each plot, five plants, was selected for analysis. Manual harvest was carried out by the technology of late harvest in physiological stage of ripe grain (Berenji and Sikora, 2002, Popovic, 2010, Sikora *et al.*, 2015).

During the three year preceding crop was soybean, winter plowing was done to 30 cm soil depth in November and planting was completed between April 21st and 28th. Fertilization included application of 550 kg ha^{-1} of mineral fertilizers NPK (8:16:24) along with autumnal tillage and 250 kg ha^{-1} NPK (15:15:15) before seeding. The experiments was carried out under conventional tillage. The crops were kept free from weeds and insects according to best agricultural techniques.

The average air temperature during the growing season for the region in which the experiments were performed is 19.0°C.With average temperature19.2°C the year 2006 was equal to the long-term average, while2002 with the average of19.7°Ccan be considered as above average hot year, and 2005with the average of18.2°C as cold year (Table 2, Fig. 2a). Average winter moisture supply for the reference site amounts 259 mm and the average rainfall for the growing season 352mm, what is 611mm in total. In that respect, the 2006 with 674 mm (229 mm during winter and 445 mm for growing season) was the long-term on average level. 2002 with 157 mm of precipitation during winter and 347 mm during growing season and total of 504 mm can be considered was dry, and 2005 with total moisture supply of 917 mm (365 mm on winter and 552 mm on growing season) was wet year. Meteorological data in Table 2 and Figure 2 were obtained from official weather stations Hydro-meteorological Service of Serbia (http://www.hidmet.sr.gov.rs) located close to the experiment field.

***Measurement of agro-morphological and technological traits*:** Measurements of components of plant height was usage of the measuring stick were first performed at selected plants. Plant height (PHG) represent height from the ground to the tip of the main panicle and stalk height (SHG) from the ground to the upper node. Based on different height components Berenji (1990) distinguished the American dwarf, European dwarf and traditional tall broomcorns. Length of the panicle (PLG) was calculated as difference between PHG and SHG and included length between upper node and base of fiber or peduncle length (PDL) and length of the fiber from the base to top or fiber length (FLG). Length of the top leaf sheath (LSL), Panicle exsertion (PEX) was calculated as difference between peduncle length and flag leaf sheath length. Panicles with peduncles of 15 cm were detached by hand and dried in a dryer.

(a)



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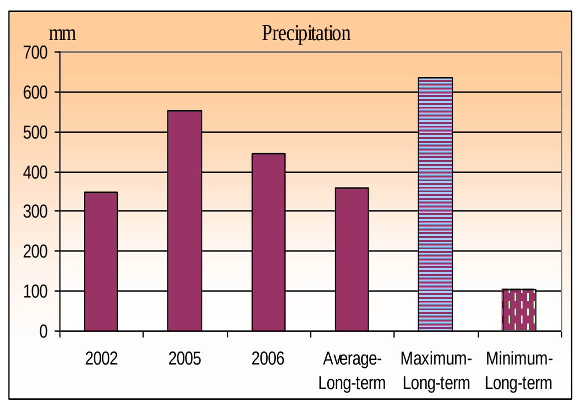

Figure 2. (a) Total precipitation (mm), and (b) average temperature (°C) for growing season.

After drying of individual panicles the certain yield components, weight of unthreshed (UPW) and threshed (TPW) panicle after threshing grain was measured in the laboratory with the technical scale. Grain weight per panicle

(GWT) was calculated as difference between UTP and TPW. Threshed panicle ratio (RAN) was calculated as the ratio of threshed panicle to the grain per panicle multiplied by 100. Broomcorn panicle quality parameters was include the number of fibers per panicle (NOP), and that was determined by counting. The coefficient of fiber fineness (FFI) was expressed as the ratio of the peduncles mass and the total peduncle length per panicle multiplied by 1000. Mijavec (1980) called peduncles the thready-like when their coefficient of fineness was below 250, thin among 250-500, thick in range of 500-1000 and rough above 1000, arguing that the technological aspect optimum is 400-600, actually 0.4-0.6g m^{-1}.

Data analysis**:** Descriptive statistical parameters such as mean value, minimum and maximum values, standard deviation (SD) and coefficient of variation (CV) were used to describe the agro-technological traits of SEE broomcorn landraces collection. The fixed effect two-way analysis of variance (ANOVA) was performed to evaluate the magnitude of main factors effect and corresponding interactions. Non-parametric correlations among test traits represented by Spearman's rank correlation coefficients were computed and displayed as heat-map diagrams. The genotype-by-trait bi-plot (Yan and Rajcan, 2002) was used for studying relationships among traits across the landraces groups. All data analysis were done with the R software (R Development Core Team, 2012).

RESULTS

Variation among accessions**:** The measures of central tendency (means and range) and dispersion (SD and CV) parameters for broomcorn quantitative traits are presented in Table 3.

Mean value for PHG was 221.8 cm with range of 115.3 to 357.8 cm, for SHG 124.2 with range of 37.8 to 269.6 cm, for PLG 97.7 cm with range of 66.2 to 118.4 cm, for PDL 30.1 cm with range of 15.4 to 46.4 cm and for FLG 67.8 cm with range of 43.1 to 86.9 cm. PEX range from -25.4 to 2.2 cm with mean value of -13.6 cm and the only one accession

Table 3. Summary table describing quantitative traits in 28 broomcorn accessions.

Trait	Code	Mean	Min	Max	SD	CV (%)
Plant height (cm)	PHG	221.8	115.3	357.8	66.0	29.8
Stalk height (cm)	SHG	124.2	37.8	269.6	68.8	55.4
Panicle length (cm)	PLG	97.7	66.2	118.4	16.1	16.5
Peduncle length (cm)	PDL	30.1	15.4	46.4	9.5	31.6
Fiber length (cm)	FLG	67.8	43.1	86.9	16.7	24.6
Flag leaf sheath length (cm)	LSL	43.5	38.7	51.9	5.7	13.2
Panicle exsertion (cm)	PEX	-13.6	-25.4	2.2	9.2	66.1
Unthreshed panicle weight (g)	UTP	71.2	50.0	97.7	23.5	32.9
Threshed panicle weight (g)	TRP	23.4	13.7	33.5	8.1	34.6
Grain yield per panicle (g)	SWG	47.8	31.0	77.4	20.4	42.7
Threshed panicle ratio (%)	RAN	34.1	20.7	48.1	10.1	29.4
Fiber number per panicle	FNO	59.3	45.1	73.5	10.4	17.6
Fiber fineness [(g m^{-1}) x 1000]	FFI	509	400	613	119.1	23.4

SD standard deviation; CV coefficient of variation;

Table 4. Two-way ANOVA of the quantitative traits for 28 broomcorn accessions. MS tested with respective mean square error term.

Trait	G	Y	GxY
Plant height (cm)	58248.7**	36112.4**	1261.1**
Stalk height (cm)	66944.1**	13758.3**	1419.2**
Panicle length (cm)	1901.1**	5522.3**	354.2**
Peduncle length (cm)	813.9**	595.1**	81.1**
Fiber length (cm)	2360.7**	3927.8**	341.8**
Flag leaf sheath length (cm)	209.2**	272.4**	24.2**
Panicle exsertion (cm)	753.9**	109.6	91.8**
Unthreshed panicle weight (g)	2107.6**	29773.3**	849.8**
Threshed panicle weight (g)	304.7**	3249.4**	113.1**
Grain yield per panicle (g)	2581.5**	14470.7**	669.0**
Threshed panicle ratio (%)	1003.1**	398.5**	187.2**
Fiber number per panicle	785.2**	192.4	170.7**
Fiber fineness [(g m^{-1}) x 1000]	43771.5**	68896.5**	1004022.3**

* $p<0.05$; ** $p<0.01$; G genotype, Y year, GxY genotype-by-year interaction

(Mezokovácsházi) with positive value. The largest variation was found for PEX and SHG with 66.1% and 55.4%. Maximum values for yield components was 2.0 to 2.5 times greater than minimum.

Yield components ranged in interval 50.0 to 97.7 g for UTP, 13.7 to 33.5 g for TRP and 31.0 to 77.4 g for SWG respectively. Average RAN were 34.1 % with ranged from 20.7 % to 48.1 %. CV for yield parameters ranged from 29.4% to 42.7% for RAN and SWG, respectively. For fiber quality parameters maximum values was 1.5 to 1.6 times greater than minimum for FNO and FFI respectively. FNO ranged from 45.1 to 73.5 with mean value of 59.3 and FFI ranged from 400 to 613 with mean value of 509 (g m^{-1}).

Combined ANOVA across years (Table 4) indicated that mean square values were highly significant (P< 0.01) for all analyzed traits, except for the environmental effect on PEX and FNO. On average, genotype main effect (G) was most important source of variation accounting for 65.1% of the total variance. Year main effect (E) averaged over all the traits accounted for 13.0%, while genotype-by-environment interaction (G×E) was 20.8% of the total variance.

***Association among quantitative traits*:** The Spearman's rank correlations calculated for quantitative traits for three experimental years was visualized by colored heat maps for 2002 (Fig. 3a), for 2005 (Fig. 3b) and for 2006 (Fig. 3c).

Positive significant (P<0.01) rank correlation in the 0.8-1.0 range for the 2002 was demonstrated between following pairs of traits: PHG-SHG, PDL-PEX and UTP-SWG. Positive significant (P<0.01) rank correlation in the 0.8-1.0 range for 2005 were observed between the PHG-SHG, SHG-SWG, PLG-FLG, PDL-PEX, FLG-TRP, FLG-RAN and UTP-SWG, and negative significant rank correlations between the SHG-RAN and SWG-RAN.

For the 2006 a positive significant (P<0.01) rank correlation in the 0.8-1.0 range was observed between the PHG-SHG, PLG-FLG, PDL-PEX and UTP-SWG. The same significant rank correlations for all three years were observed between PHG-SHG, PDL-PEX and UTP-SWG.

***Multivariate analysis of accessions quantitative traits*:** Multivariate analysis was used as a tool for relations understanding among quantitative traits and accessions. For 2002 (Fig. 4a) the PCA1 axis in the biplot explained 36.8% and PCA2 explained 23.1% of the total variation of the analyzed data. For 2005 (Fig. 4b) it was 51.1% for PCA1 and 16.5% for PCA2 and for 2006 (Fig. 4c) it was 40.7% for PCA1 and 20.7% for PCA2, respectively.

Based on the position of the traits across the 28 accessions in biplot for 2002 (Fig. 4a), for 2005 (Fig. 4b) and for 2006 (Fig. 4c), three groups of accessions could be clearly defined. Traits with shorter distance to origin not well explained in the primary (i.e., PC1 vs. PC2) biplot in all three years was LSL and FNO. Accessions generally had low variation for these traits which represents group one. Group two include PHG, SHG, PDL, PEX, SWG and PEX and group three include PLG, FLG, TRP, RAN and FFI. Group one and two was located on the upper right quadrant of PCA1 and positively correlated, while group three was situated in the positive quadrant of PCA1 and in negative correlations with groups one and two. Traits with in individual groups was in positive correlations.

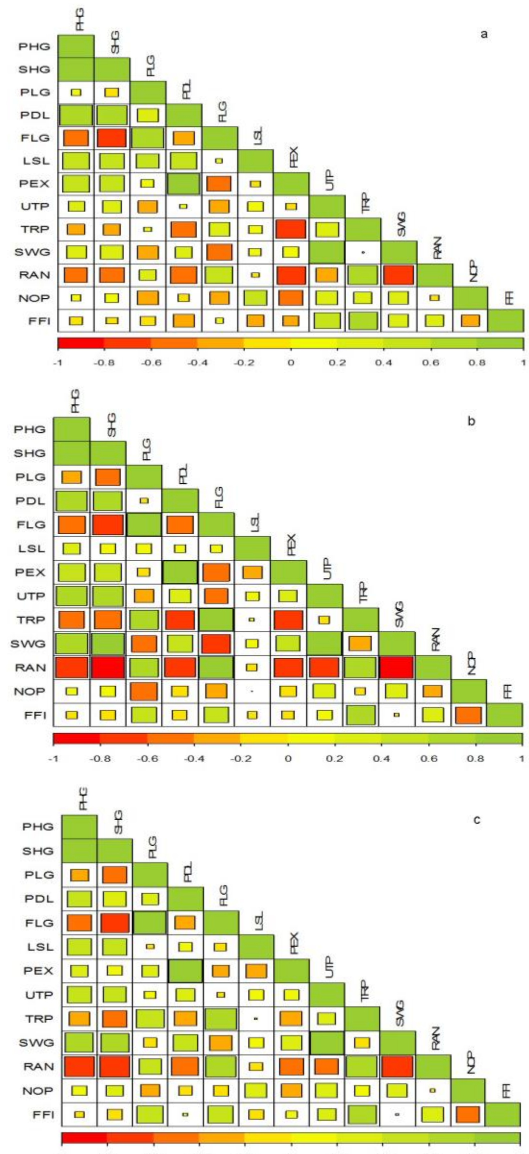

Figure 3. A heat-map of the Spearman nonparametric rank correlations for quantitative traits among 28 examined broomcorn landraces for 2002 (a), 2005 (b) and 2006 (c). The legend on the right side depicts the correlation color scale.

The details for the traits are given in Table 3.

(a)

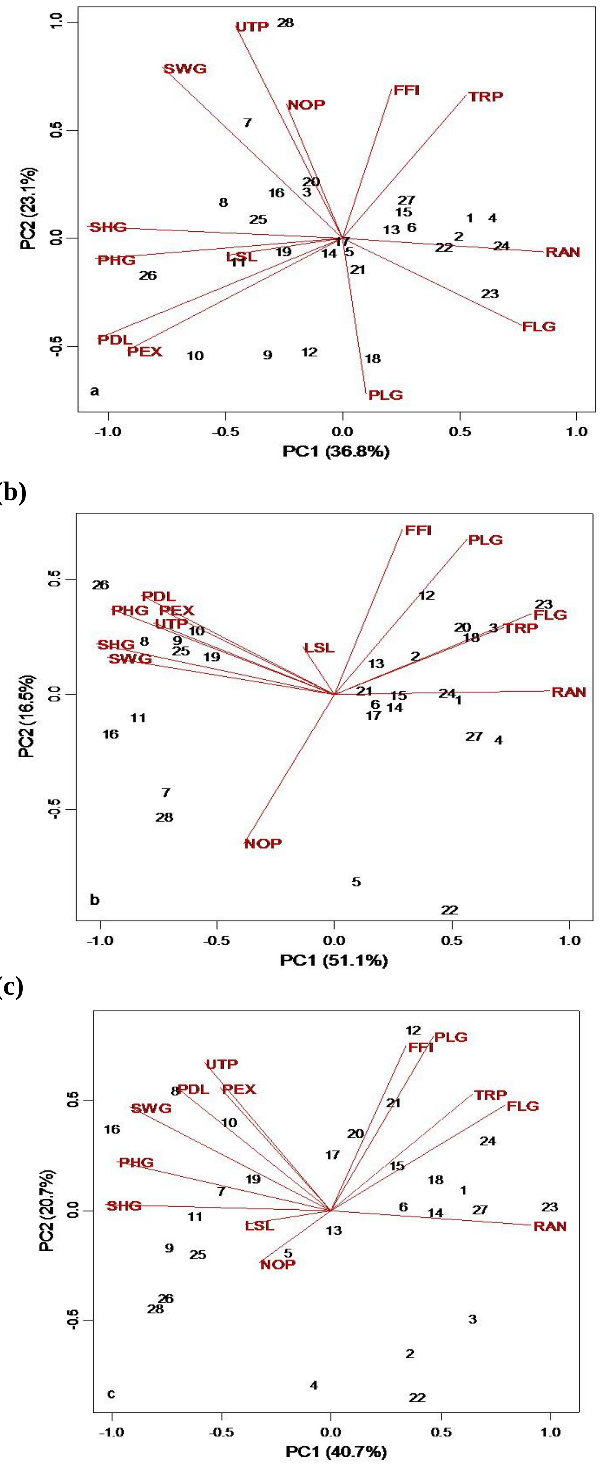

Figure 4. Biplots for 2002 (a), 2005 (b) and 2006 (c) of 28 broomcorn landraces accessions analyzed for 14 quantitative traits.

The details for the traits are given in Table 3 and the details for accessions are given in Table 1.

DISCUSSION

Biplot origin represented average values for all analyzed traits and the distance from biplot origin to the accession was a measure of how it differs from the average (Yan and Fregeu-Reid, 2008). Accession with long vectors had extreme levels for one or more quantitative traits and they may be useful in breeding program. Of 28 landraces 18 (64.3% of accession) had vector lengths shorter than 50% of the longest genotype vector for all three years, and they were less interesting as a source of useful genes for breeding program. During three years, 9 accession (4, 7, 8, 9, 11,18, 25, 26 and 28) had longer vectors and they represented 32.8% of most promising breeding material of the total 28 landraces. Four accessions 1, 2, 10 and 24 (14.3% of accession) had longer vector for 2002 and 2006, respectively. For 2005 and 2006, respectively, three accessions 16, 22 and 23 (10.7% of accessions) had vector longer than 50% of the longest genotype vector for that year. Accessions 5 and 3 had longer vectors for 2005 and accessions 12 and 27 for 2006 which represented 7.6% of the total 28 landraces (Fig. 4a-c).

The material for the trial included broomcorn landraces which were planted and maintained for long period in specific conditions of SEE sub-regions. Quantitative traits variability and association were determined to estimate possibility for including examined accessions in existing broomcorn germplasm.

According to Narkhede *et al.* (2000) and Kadam *et al.* (2001) geographic origin had no substantial influence on genetic diversity of sorghum germplasm. Early studies with broomcorn (Quesenbery and Will, 1948; Berenji, 1990) and the another types of sorghum (Showemimo, 2007, Rao *et al.,* 2011) have suggested that the influence of year and genotype by year interaction in expression of quantitative traits are significant. Although certain proportion of the total variation is due to environment and interaction, substantial proportion of the total variation for most quantitative traits due to the genotype in our trials indicate possibility for yield improving and panicle quality through implementation of accessions in the breeding programs. Favor to this refer earlier determined broad sense heritability of 98% for PHG and SHG was by Berenji (1990), and broad sense heritability for all other traits in range of 57% for LSL to 86% for FLG (Sikora, 2005).

***Variation among accessions*:** Although some earlier studies of *sorghum* sp. germplasm based on morphological characteristics suggested relative low variation in comparison with other crops (Morden *et al.,* 1989, Ollitraut *et al.,* 1989, Aldrich *et al.,* 1992); however, Hamrick and Godt (1997) reported higher variation within sorghum than in other self-pollinated species. Same authors refer about 53% divergence due to variation within forms, 14% due to variation among forms and only 11% due to variation between origin. Among all cultivated sorghum, the highest variation was found within *bicolor* race and lowest within *kafir* race (Dje *et al.,* 2000;

Grenier, 2001a; Menza *et al.*, 2004). As a main reason why only few landraces are present in existing broomcorn collection. Berenji *et al.* (2011) refers surprisingly narrow variability of SEE landraces or local forms.

Salk height (60%) and panicle length (12%) (Umakantha *et al.*, 2002) had predominant influence on plant height variation in *Sorghum* genus. Based on components of height substantial proportion (68%) of accessions belongs with dwarf type and only 32% of them represent traditional tall broomcorn. The initial material for selection of long fiber sorghum was sweet sorghum with diffuse panicles tall up to 3 m (Rothgeb, 1916). In the beginning, tall broomcorn plant were harvested by cutting the whole plant at ground level and stalks of the plant were tied together to form traditional brooms. Contemporary large scale of agronomic practices prefer dwarf broomcorn varieties from which only the panicle portion of the plant is harvested and fibers of these panicles serve as a raw material for commercial production of wooden handle brooms (Berenji *et al.*, 2011). In our trials, 9 tall accessions originated from Serbian and Hungarian sub-regions. This can be explain by the fact that broomcorn planting and old fashioned homemade brooms making in this sub-regions had longer tradition. After expansion of broomcorn broom industry in the middle of XX century and establishment of scientific programs on broomcorn technology improvement (Szeged in Hungary and Novi Sad in Serbia), dwarf material was spread to the other sub-regions, where panicles were used only for industrial brooms manufacturing (Nedelcheva *et al.*, 2007).

Broomcorn industry requires elastic fiber with length in range of 30-60 cm. Substantial proportion of accessions (71%) had fiber longer than 60 cm which is too long even for cover part of the broom and surplus parts represent waste in broom production. Handmade production of untypical brooms can be the main reason for spontaneous selection on too long fiber in landraces.

Panicle exsertion represent difference between flag leaf sheath length and peduncle length. Negative value reflect panicles that have not exerted from flag leaf so whole peduncle and part of fibers is enclosed in the flag leaf sheath. Panicle exsertion have substantial influence on manual harvesting of panicles, which is easier if panicles are exerted. Substantial proportion of accessions (71%) had extremely negative exsertion while only one (Mezökovácsházi) had the positive value and 7 others (25%) had panicles acceptably exerted up to -10 cm. Similar to the findings of Sikora (2005), flag leaf sheath length is trait with low variation which means that panicle exsertion is predominantly influenced by peduncle length. As a main reason for high variation of peduncle length within the same field Berenji (1990) suggested micro-environmental conditions. He recorded higher peduncle length variability on poor stand and for low plant emergence. In drought conditions during blooming and flowering period internodes were shorter and exsertion was extremely negative. Although Berenji *et al.*, (2011) referred that there is no or little difference between dwarf types as compared to standard broomcorns in respect to the flag leaf sheath length, in the case of this study accessions with long peduncle and exsertion close to zero is predominantly standard type.

Mann and Washburn (1930) referred that first quality broomcorn fibers must be round, straight, elastic and fully branched at the top third of their length. Almost half of accessions (43%) had a thick fibers with fineness below 0.5 gm^{-1} and fiber number per panicle over 60. Fiber number per panicle is less important trait in comparison with fiber length and its important is due influence on fiber fineness (Mijavec, 1980). Broom producers consider that higher fiber number means thinner and more elastic fibers.

For this study unthreshed panicle weight ranged from 50.0 to 97.7 g. Previous study of the broomcorn germplasm showed significantly higher variability for the yield in range of 14.8 to 114.0 g per unthreshed panicle (Sikora 2005). Main reason for this difference is that basic germplasm included low yielding genotypes with some interesting quantitative or qualitative characteristics like high fiber number or tolerance to prevalent pests. In the beginning of broomcorn breeding improvement program main goal was creation of variety with high unthreshed panicle weight. Later, higher weight of threshed panicle is pointed as a target for second breeding cycle. This was reached through increasing of threshed panicle ratio and results with few high yielding commercial varieties (Mijavec 1980). Of all accessions only one (DBK 36) had threshed panicle ratio over 30%, and for substantial proportion of the accessions (82%) threshed panicle ratio range 20-30% which was in average with the value of this trait in basic germplasm.

***Association among traits and biplot analysis*:** Correlations of broomcorn quantitative traits were observed for potential effort in obtaining desired yield and quality of panicles through breeding. Similar to our earlier findings (Berenji, 1990; Sikora, 2005), there was a significant positive correlation between PHG –SHG and PDL-PEX in examined material. Due to manual harvest of panicles, breeding strategies should be focused on dwarf type landraces with panicle exsertion close to zero. Among the studied accessions, there were several from Bulgaria with stalk height below 100 cm and panicle exsertion up to -10 cm (LP 13/89, LP 17/89 and LP 19/89), that could serve as a good start point for future breeding program. Sikora and Berenji (2000) referred that determination of LSL is due to non-additive gene effects and determination of PDL due to additive gene effects. LSL is most stable traits so positive PEX can be obtained only with long peduncle. There was a moderate negative correlations between PDL and FLG which means that first class medium length fibers were connected with medium (30-40 cm) length peduncle.

For breeding strategies the most important correlations between traits are connected with yield (Berenji and Sikora, 2002). Results of the analysis refers significant positive correlations between UTP-SWG which are in negative correlations with RAN. In broomcorn production seed is valuable by-product (Berenji *et al.*, 2011) but main product is high quality RAN. Approach to increasing TRP yield could be through increasing FNO, RAN and FFI respectively. Determination of the best accessories through a multivariate analysis for specific purposes in the aspect of yield and quality would be the most suitable approach.

While correlation matrix described only relationships between two traits biplot describe relationships among all traits (Yan and Rajcan, 2002). Variables positioning on the opposite side of the PC1 axis can be useful for determining a selection criteria. For increasing yield of TRP lower SWG and higher PLG and RAN would be desire. High value of FFI can be obtain through selection of accessions with high PLG and FNO.

If accession origin is considered, it is evident that Serbian, Croatian, Romanian and Hungarian accessions with high within group variability were distributed across the biplot, while Bulgarian accessions (LP 4/89, LP 5/89, LP 13/89, LP 17/89 and LP 19/89) were distributed close to biplot center which pointed to their low variability within the group. In this group combination of natural selection and selection performed by farmers lead to above average (> 100 cm) PLG with over 70 cm FLG.

***Conclusion*:** The examined SEE broomcorn landraces showed exceptional variability that can be exploited for improving yield and panicle quality of new varieties. All of them will be included in existing broomcorn germplasm and several accessions of different origin with exclusive trait profile for yield components (Osztrak, Torda, LP 9/89 and Despotovac) and panicle quality (NS-BP/CL-12, LP 2/89, LP 14/89, CL-2K and LP 1/98) will be useful as parents in the breeding process. High-yielding landraces had higher grain yield per panicle, but showed significantly lower threshed panicle ratio. Panicle yield was in positive correlation with amount of grain per panicle. Traits association with fiber quality was threshed panicle ratio, fiber number per panicle fiber length. Landraces with best fiber quality showed high threshed panicle ratio and had high number of medium length fibers. Fiber quality is directly correlated with fiber number per panicle. Different behavior of individual accessions in specific conditions show that further investigation of environmental influence on expression of individual traits in broomcorn germplasm should be done.

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