UDC 575.630
https://doi.org/10.2298/GENSR1801045L
Original scientific paper

GENETIC VARIABILITY FOR YIELD AND YIELD COMPONENTS IN JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.)

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Lakić Ž., I. Balalić, M. Nožinić (2018): *Genetic variability for yield and yield components in jerusalem artichoke* (*Helianthus tuberosus* L.).- Genetika, Vol 50, No.1, 45-57.

Investigation of quantitative traits of Jerusalem artichoke populations was conducted on the experimental field of the Agricultural Institute of the Republic of Srpska in Banja Luka, during 2013 and 2014. The material was collected in the wider area of Republic of Srpska. The following populations were analyzed: Srbac, Modriča, Pivara, Lazarevo, Bosna, Vrbas, Gradiška and Aleksići. The trial was arranged in a randomized complete block design with three replications. The following parameters were analyzed: tuber weight (g), plant height (cm), stem number/plant, average stem thickness (cm), green mass yield/plant (kg), and dry mass yield/plant (kg). Average tuber weight ranged from 36.7 g (Bosna) to 61.0 g (Lazarevo). Plant height ranged from 1.55 m (Lazarevo) to 2.20 m (Aleksići). Stem number/plant varied from 2.2 (Aleksici) to 5.3 (Modrica). Stem thicknesswas between 1.24 cm (Bosna) and 2.11 cm (Aleksići). The population Bosna had the lowest average yield of green mass and dry mass yield/plant, while the highest mean value had population Aleksići. Broad sense heritability varied from 34.66% (plant height) to 50.99% (dry mass yield/plant). Highly significant positive correlations between plant height and stem thickness (r = 0.874), stem thickness and green mass yield (r = 0.919), stem thickness and dry mass yield (r = 0.902) were established. Jerusalem artichoke populations were clustered into two groups, and the first group was composed of two sub-groups.The results of these studies will allow choice of Jerusalem

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artichoke populations with better quantitative traits, and their inclusion in the program of creating new varieties.

Keywords: correlation, heritability, interaction, quantitative traits, topinambour

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) is a hexaploid Angiospem plant species (2n = 102), of Asteraceae family, and it is native to temperate regions of North America (TASSONI *et al.*, 2010; PUTTHA *et al.*, 2013). *Helianthus tuberosus* L., called also topinambour, apple-to-earth, carrots, pork, pear-wintry, sunshoke, is a perennial plant, well-adapted to humid and cold climats, not demanding to soil and with good yield increase (ROPCIUC *et al.*, 2014).

High yield potential, and wide possibilities of using, as chemicals, pharmaceuticals and industrial applications, have caused an increase of interest in this species. This crop is one of the most important crops for industrial inulin production because its carbohydrate-rich tubers contain 75% inulin on a dry-weight basis (KAYS and NOTTINGHAM, 2008; LIU *et al.*, 2012). Low fat content and high mineral composition along with the presence of inulin as dietary fiber, makes Jerusalem artichoke nutritionally valuable food product for human consumption. Its protein has high food value due to the presence of almost all essential amino acids, but also due to their good balance (RADOVANOVIĆ, 2013)**.** Jerusalem artichole possesses prophylactic and medicinal properties for diabetic patients, and act as a biogenetic factor for the development of natural intestinal microflora after disbacteriosis (RAKHIMOV *et al.*, 2003). Fresh above-ground mass of Jerusalem artichokecontains a lot of vitamins (carotene, ascorbic acid, riboflavin, nicotinic acid, etc.) and mineral salts (IZSÁKI and NÉMETH KÁDI, 2013; SAWICKA *et al.*, 2015). The leaves of Jerusalem artichoke might be a potential source of natural antioxidants (YUAN *et al.*, 2012). It is a suitablelivestock feed (SEILER and CAMPBELL, 2006; HAFEZ, 2013). Jerusalem artichoke has potential as a bioenergy crop for bioethanol production, because it has a rapid growth rate, high biomass productivity, and limited cultivation requirements (JOHANNSON *et al.*, 2015; LONG *et al.*, 2016; SONG *et al.*, 2016). It is also successfully used in sunflower (*Helianthus annuus* L.) breeding programs as a source of disease resistance genes (ATLAGIĆ and TERZIĆ, 2006; ŠKORIĆ, 2014). It has became an interesting research topic, and it is even labeled as a new cultivated crop (TERZIĆ and ATLAGIĆ, 2009).

In Bosnia and Herzegovina, Jerusalem artichoke is one of the invasive plant species. It grows on arable land, like a weed, and it can make a serious problem. It grows as a wild plant along roads, forest edges, in forest clearings, along the embankments and abandoned lands. It is frequently located along rivers and streams, and often is decoration in gardens. In our country, Jerusalem artichoke is propagated by tubers. It is similar to sunflower. The people usually call it wild or sweet potatoe. Interest in Jerusalem artichoke as the crop varies throughout history, and often increasis in periods of food shortage (KAYS and NOTTINGHAM, 2008). As Bosnia and Herzegovina is a hilly and mountainous country the importance of Jerusalem artichoke is that it can be successfully grown in mountainous areas, where other fodder crops are not best suited for the production of green fodder, silage or tubers as fodder.

For successful breeding and the creation of new varieties, one of the conditions is that there is variability in the starting material (LAKIC *et al.*, 2013). To evaluate the potential usefulness of the genetic material used in breeding programs, aimed at improving the quality of the vegetative parts of the feed and human consumption, it is also desirable to analyze the concentration of essential elements in the leaves and tubers of Jerusalem artichoke (TERZIĆ *et al.*, 2012).

The aim of this study was to investigate the genetic variability,heritability and correlations of yield components and green mass yield/plant, and dry mass yield/plant of the selected Jerusalem artichoke populations. On the basis of the results it will be possible to choose genotypes which could be used as parents in the process of breeding new varieties of this species.

MATERIALS AND METHODS

Plant materials and field experiments

Analyzis of quantitative traits were conducted during two consecutive growing seasons (2013 and 2014) at the experimental field of the Agricultual Institute of Republic of Srpska in Banja Luka. The populations of Jerusalem artichoke were collected in the wider region of Republic of Srpska. The following populations were used: Srbac, Modriča, Pivara, Lazarevo, Bosna, Vrbas, Gradiška and Aleksići. Populations of Jerusalem artichoke were vegetative transferred and propagated. All tested populations had white tubers. The trial was arranged in a randomized complete block design with three replications. Before planting the tubers were weighed, and then planted one tuber in the space provided. Tubers were planted in rows at distance of 70 cm x 50 cm. Planting in both years was carried out manually in late autumn last year. In the time of trial establishment 300 kg ha^{-1} NPK (8:24:24) was applied. For top fertilization in both years 100 kg ha^{-1} KAN (27% N), when plant height amounted 35-40 cm, was used.

The following quantitative traits were analyzed: tuber weight (g), plant height (cm), number of stems per plant, average stem thickness (cm), green mass yield per plant (kg), and dry mass yield per plant (kg).

Soil conditions

On the experimental field of Agricultural Institute of Republic of Srpska in Banja Luka, where the trials were carried out, dominating soil type was determined as a valley-brown soil on alluvial substrate of the river Vrbas. According to mechanical constitution this soil belongs to the group of clay-loam, and according to the raw clay it is classified as moderate to strong colloidal soil. The tillage layer of the soil has crumb structure. Soil capacity for water is medium, while the air capacity of the soil is unfavorable. Soil color is dark brown to 40 cm depth.

The results of the chemical analysis of tillage layer, on which the experiment with the Jerusalem artichoke populations was carried out, are presented in Table 1.

Table 1. Results of chemical analysis of soil tillage layer

Depth (cm)	Humus (%)	pH in		mg/100g/soil	
		H_2O	KCl	P_2O_5	K_2O
0-30	2.7	7.7	6.9	18.3	14.5

In terms of pH, the soil is neutral, with low humus content (2.7%). Supply with easy available phosphorus is good (18.3 mg / 100g), while the presence of potassium in the soil is medium (14.5 mg / 100 of soil).

Based on the results of chemical analysis of tillage layer it can be concluded that the brown-valley soil is suitable for the cultivation of Jerusalem artichoke.

Meteorological conditions

For the analysis of weather conditions, the data of meteorological station in Banja Luka were used (Table 2).

Table2. Mean temperatures (°C) and precipitation (l/m²) in Banja Luka (2013 and 2014)

Year	Temperature/ Precipitation	Month												Average/ Sum
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2013	Temperature (°C)	2.8	2.3	6.1	13.4	16.6	20.4	23.0	23.5	16.7	13.1	7.4	2.5	12.3
	Precipitation (l/m^2)	94	116	89	63	120	54	27	36	70	68	7	0	893
2014	Temperature (°C)	5.6	6.5	9.6	13.1	15.8	20.3	21.7	20.6	16.4	13.5	8.9	4.0	13.0
	Precipitation (l/m^2)	52	74	91	214	218	97	139	276	284	117	42	83	1 687
1961-2014	Temperature (°C)	0.2	2.0	6.7	11.3	16.1	19.6	21.3	20.8	16.3	11.3	6.4	1.5	11.1
	Precipitation (l/m^2)	70	64	78	90	98	110	91	86	96	80	93	91	1 043

The winter period in both years was warmer than the multi-annual average. The average temperature was 11.1°C, and during the vegetation period 17.6°C. The total amount of precipitation in the vegetation period (IV-IX) for the period 1961-2014 year was 571.01 l/m^2. During both investigated periods, average temperatures in the vegetation period were higher than the multi-annual average. In the first year of investigation amount of precipitation during the growing season, compared to the long term average, was lower by 201.0 l/m^2. During the vegetation period in 2014 fell 1228.0 l/m^2, which is 657.0 l/m^2 more precipitation in relation to multi-annual average. The higher amount of precipitation than the average in the second year of the trial showed significant influence on the results of this research.

Statistical analysis

Obtained results were processed with statistical methods of analysis of variance (ANOVA). The mean values were compared using least significant difference test (LSD) with significance of 0.05 and 0.01. Evaluation of ecological effects were done by the separation of the total variance on the variance affected by: population (genotype), σ^2g, population × year interaction (σ^2g/σ^2y), and phenotype (σ^2f). Heritability in broad sense was calculated by the formula: $h^2 = \sigma^2g/\sigma^2f$. The relationships among the studied traits of selected populations were calculated by Pearson's correlation coefficient (r) of yield components, green matter yield and dry matter yield. Hierarchical cluster analysis based on Ward's method and squared Euclidian distance was performed and the dendrogram was constructed.

Statistical analyzis was performed using the program STATISTICA 12.0.

RESULTS

The average values of the two-year experiment of yield components and yield of green and dry mass per plant of eight selected population of Jerusalem artichoke are shown in Table 3. Analysis of the results of tuber weight, indicated that there were highly significant differences in the mean values between studied populations of Jerusalem artichoke. Tuber weight varied between 36.7 g (Bosna) and 61.0 g (Lazarevo).

Table 3. Mean values of yield components, green mass yield, and dry mass yield of Jerusalem artichoke populations (2013-2014)

Population	Tuber weight (g)	Plant height (m)	Stem thickness (cm)	Stem number/plant	Green mass yield/plant (kg)	Dry mass yield/plant (kg)
Srbac	41.3	2.02	1.51	4.7	1.58	0.57
Modriča	57.5	1.61	1.35	5.3	1.16	0.38
Pivara	50.1	1.90	1.49	2.6	1.28	0.41
Lazarevo	61.0	1.55	1.29	3.2	1.13	0.40
Bosna	36.7	1.83	1.24	4.1	0.98	0.32
Vrbas	38.9	2.00	1.97	2.8	1.38	0.44
Gradiška	37.0	1.91	1.54	2.9	1.22	0.39
Aleksići	42.0	2.20	2.11	2.2	1.86	0.63
X of populations	45.6	1.88	1.56	3.5	1.32	0.44
LSD 0,05	14.0	0.26	0.26	1.3	0.30	0.10
0,01	18.7	0.35	0.34	1.7	0.40	0.13

Plant height is one of the most important traits on which, except genetic factors, great influence have environmental factors, the way of cultivation and exploitation of Jerusalem artichoke. This trait is also the most important component of green and dry biomass yield, and also of the quality of nutrients. The average plant height of Jerusalem artichoke populations amounted to 1.88 m, and the differences between populations were statistically significant. Population Lazaraevo had lowest plant height (1.55 m), and population Aleksići highest plant height (2.20 m).

Stem thickness has significant impact on the biomass yield but also affects the quality of the biomass. The average stem thickness in the investigated populations of Jerusalem artichoke was 1.56 cm, and the determined differences in thickness between the tested populations were statistically highly significant. Stem thickness in the populations ranged from 1.24 cm (Bosna) to 2.11 cm (Aleksići). The maximum stem thickness was found in two populations, Aleksići (2.11 cm) and Vrbas (1.97 cm).

There were significant differences between mean values for stem number per plant in Jerusalem artichoke populations. Average stem number was 3.5. Larger number of stems per plant in relation to average, was found in populations of Modriča (5.3), Srbac (4.7) and Bosna (4.1). Lowest stem number was stated in the population of Aleksići (2.2).

In the green mass yield per plant significant differences between populations were found. The average yield of green mass per plant in populations ranged from 0.98 kg (Bosna) to 1.86 kg (Aleksići). The average green mass yield/plant in the Jerusalem artichoke populations was 1.32 kg. There were significant differences between the studied populations in dry mass yield per plant. On the basis of realized average yield of dry mass per plant was achieved by populatons from Aleksići (0.63 kg) and Srbac (0.57 kg).

Table 4. ANOVA, variance components, and heritability of quantitative traits in Jerusaleme artichoke populations

Traits Variability parameters	Tuber weight	Plant height	Stem thickness	Stem number/plant	Green matter yield/plant	Dry matter yield/plant
MS genotype	720.59*	0.37*	0.80**	9.71**	0.63**	0.09**
MS year	12020.38**	3.50**	17.88**	9.77*	45.40**	4.95**
MS interaction	997.98**	0.55**	0.87**	12.84**	0.59**	0.07**
Genotypic variance σ^2_g	578.02	0.29	0.67	7.88	0.54	0.08
Phenotypic varince σ^2_f	1576.01	0.83	1.54	20.72	1.14	0.15
Heritability h^2 (%)	36.68	34.66	43.70	38.03	47.84	50.99

For all investigated traits main effects (genotype, year) and interaction (genotype × year) were highly significant (Table 4). There were significant variations between all traits. Rather high variations between years for investigated traits indicated that these traits were non consistent between years. The variations caused by genotype × year interaction were greater than that caused by genotypes for tuber weight, plant height and stem number/plant. Highly significant year and genotype × year effects pointed to the importance of the environmental factors in the inheritance of these traits in Jerusalem artichoke.

Heritability for tuber weight, plant height and number of stems per plant were medium heritable, while the stem thickness, the green mass yield and dry mass yield per plant were higher heritable traits. The largest proportion of genotypic variance was found for dry mass yield per plant (50.99%), while the contribution of environmental variance in the total, phenotypic variance accounted for 49.01%. Tuber weight was caused by the higher proportion of the environmental variance in total phenotypic variance (63.31%), while the proportion of genotypic variance accounted for 36.69% (Table 4).

Values of correlation coefficients among traits of Jerusalem artichoke selected populations under investigation are presented in Table 5. The intension was to explore which traits are well associated and meaningful for breeding.

Highly significant positive correlation between plant height and stem thickness ($r = 0.874$), stem thickness and green mass yield ($r = 0.919$), stem thickness and dry mass yield /per plant ($r = 0.902$) were observed. The results indicated that to the greatest extent green and dry mass yield were determined by the stem thickness. A significant positive correlation was found between plant height and green mass yield (r = 0.759), plant height and dry mass yield (r = 0.744). This indicated that inreased plant height caused higher green mass and dry mass yield per plant. Negative and significant correlation of tuber weight with plant height, stem thickness, green mass yield/plant and dry matter yield/plant showed that inreased plant height, stem thicknes, green mass/plant and dry matter yield/plant are at the expence of tuber weight.

Table 5. Correlation coefficients among quantitative traits of Jerusalem artichoke populations

Traits	Plant height	Stem thickness	Stem number/plant	Green mass yield/plant	Dry mass yield/plant
Tuber weight	-0.689*	-0.671*	0.073	-0.679*	-0.660*
Plant height		0.874**	-0.285	0.759*	0.744*
Stem thickness			-0.150	0.919**	0.902**
Stem number/plant				0.120	0.147

* p> 0.95 ** p> 0.99

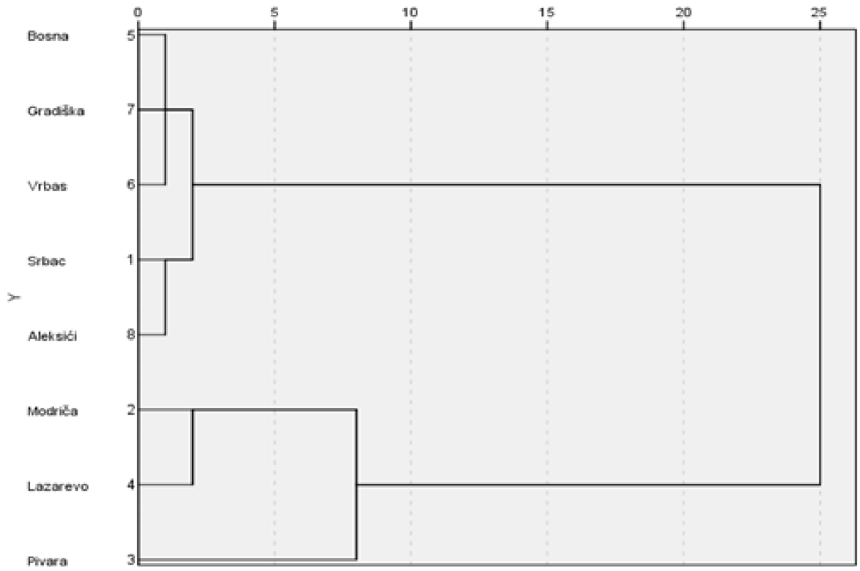

Figure 1. Dendogram of Jerusalem artichoke populations based on quantitative traits across two vegetation periods

On Figure 1. which is created as a result of hierarchical cluster analysis, two groups of populations can be observed. The first group is composed of two sub-groups. In the first subgroup are the populations Bosna, Gradiška and Vrbas. For this group is typically that planted tubers had the lowest tuber weight, and plant height was median. Another subgroup consisted of Srbac and Aleksići populations, and they were characterized by the highest mean values of plant height, green mass and dry mass yield per plant. The second group comprised of Modriča, Lazarevo and Pivara populations. The populations in this group had highest tuber weight and median green mass and dry mass yield per plant.

DISCUSSION

Quantitative traits are under the controll of multiple genes with combined effect. These traits can vary greatly and they are influenced in large proportion by environments (AHMAD *et al.*, 2011). Some quantitative traits of Jerusalem artichoke such as tuber weight, tuber number, green mass yield, dry mass yield, inulin content and maturity are economically important. For crop improvement quantitative traits, especially those which are related to yield are especially important (PUTTHA *et al.*, 2013). In our two-year experiment variability and heritability of several quantitative traits of Jerusalame artichoke populations such as: tuber weight, plant height, stem thickness, stem number/plant, green mass yield/plant and dry mass yield/plant, were analyzed.

Tuber weight ranged from 36.7 g (Bosna) to 61.0 g (Lazarevo). Our results are in agreement with the report of SIKORA *et al.* (2010). They have found average tuber weight of 57 g for twenty genotypes. In the research of ÇALISKAN *et al.* (2003) average tuber weight ranged between 37.3g and 49.9 g. Average tuber weight was 47.0 g according to LIU *et al.* (2011). On the contrary some authors (KILLI *et al.*, 2005; PUTTHA *et al.*, 2013) reported much lower tuber weight (29.5g; 29.2 g; 9.8 g, respectively). PUTTHA *et al.* (2013) stated rather high variability for tuber weight (CV = 50.3%) which ranged between 2.0 g and 21.1 g.

Plant height varied between 1.55 m (Lazarevo) and Aleksići (2.20 m). Similar results are stated by RAGAB *et al.* (2003). In their trial plant height ranged from 1.20 to 2.30 cm. LIU *et al.* (2012), on the basis of two-year experiments conducted in Gansu province, China, reported that plant height varied between 2.27 m and 3.43 m. Generally, the plant height was higher in 2008 than in 2011, which was associated with less drought stress. Significant differences in plant height among genotypes were observed. The four tallest clones (BJ-4, HB-2, HUB-1, and SD-1) exceeded 2.80 m in both years. Plant height varied in 1999 from 2.21 m (Bianka) to 3.09 cm (Wakdsindel) in the experiment carried out in Austria, as communicated by KOCSIS *et al.* (2007). PUTTHA *et al.* (2013) reported that plant height under conditions of Thailand was variable (CV = 25.6%), and ranged from 41.1 cm to 112,7 cm with the average from 70.1 cm. In China at high latitudes, the plants were in average 2.84 m tall (LIU *et al.*, 2011).

Stem thickness in the populations ranged from 1.24 cm (Bosna) to 2.11 cm (Aleksići). Our results are similar with the findings of other authors (LIU *et al.*, 2012). They stated that main stem diameter varied between 1.31 cm and 2.25 cm (2008), and between 1.86 cm and 2.40 cm (2011). Clone HUB-2 had the largest main stem diameter in both years 2.25 cm, and 2.40 cm in 2008 and 2011, respectively. On the contrary, values for mid stem diameter according to results of PUTTHA *et al.* (2013) were much lower and varied between 0.41 cm and 1.11 cm, with average of 0.66 cm.

According to our results average stem number was 3.5. LE COCHEC (1990) reported average of 2.9 stem per plant. These values were much lower as compared with our results.

In the green mass and dry mass yield/plant there were significant differences among populations of Jerusalem artichoke.

During this research the populations of Jerusalem artichoke Aleksici and Srbac had shown the highest equability in the yield of green and dry mass per plant. These two populations of Jerusalem artichoke have obtained the highest yield of green and dry mass during dry vegetation period in the first year and the humid period during the vegetation season in the second year of trials.

For successful breeding on any type of plant it is necessary to understand the genetic origin, structure of genotypic and phenotypic variance, heritability, and the interdependence of functionally related traits. The total variation due to genotype (population), environment (year) and genotype × year interaction indicates the relative importance of these sources of variations. The effect of genotype on all yield components was highly significant, except for plant height, where it was significant. Genotype contributed significantly to total variation, but the values were lower than for environment for all traits, except for stem number/plant. For stem number/plant the variation of genotype and year were equall. All mean squares for years were highly significant. Also genotype × year interaction was highly significant for all examined traits. This means that improvement of these traits will not be easy. Highly significant year and genotype × year effects pointed to the importance of the environmental factors i.e. cultural practices for the production of Jerusalem artichoke. RUTTANAPRASERT *et al.* (2012) also stated significant genotype × year interactions for all studied traits (total biomass, shoot dry weight, leaf area, harvest index, tuber dry weight, number of tubers per plant and weight of individual tubers) in the experiment. If the interaction is high, specific genotypes schould be recommended for specific environments. The evaluated ratio of genotypic and phenotypic variance for tuber weight, plant height, stem thickness, number of stems per plant, green yield mass and dry yield mass per plant, indicated the substantial influence of environmental factors on the variability of all traits in the investigated populations of Jerusalem artichoke. Significant genotypic and ecological variations were observed for tuber yield, tuber number and tuber size in 20 different Jerusalem artichoke varieties during the period of 1994-2000, as reported by BERENJI and SIKORA (2001). Variations in total nitrogen, potassium, sodium and total sugar content were observed in 114 Jerusalem artichoke tubers (TERZIĆ and ATLAGIĆ, 2009). Genotipic variability was very high among six clones of Jerusalem artichoke for inulin and sugar yield from stalks and tubers in the experiments carried out in Italy (BALDINI *et al.*, 2004). Genotypic differences were observed for mineral element concentrations among nine populations of wild Jerusalem artichoke and ten cultivars of Jerusalem artichoke forage (SEILER and CAMPBELL, 2006). For tuber characteristics and yield in Jerusalem artichoke varieties and hybrids conserved at N. Vavilov Institute of Plant Industry (VIR), Russian Federation, significant variations were stated (KIRU and NASENKO, 2010). Genotypic variations for plant height, leaf petiole and mid stem diameter accounted for 84.5 %, 74.1 %, and 71.1 % of total variations, respectively, as stated by PUTTHA *et al.* (2013).

Based on the estimated broad sense heritability values it can be concluded that the investigated traits were quite variable. In most analyzed traits of Jerusalem artichoke populations environment contributed to the large portion of variations. So it can be expected a substantial variation in individual genotypes depending on environmental factors in the tested years. Broad sense heritability of tuber weight (36.38%), plant height (34.66%), and stem number (38.03%) showed that this traits were medium heritable. The contribution of genetic in the phenotypic variance of examined traits of Jerusalem artichoke populations, also indicated that the variability of these traits were largely under the control of environmental factors. Stem thickness (43.70%), green mass yield/plant (47.81%), and dry mass yield/plant (50.99%) had higher values of heritability. LE COCHEC (1990) reported that broad sense heritability estimates ranged between 19.5% and 98.1%. They were very low for yield related characters and very high for tuber dry matter content developmental characters. For stem number broad sence heritability was 25.0%, for tuber number 36.2%, and for the period from planting to flowering 96.1%.

Of particular importance are correlations that suggest possible directions for change in different traits of plant material under the influence of selected and applied selection methods.

Highly significant positive correlations between plant height and stem thickness (r = 0.874), stem thickness and green mass yield (r = 0.919), stem thickness and yield dry mass yield (r = 0.902) were established. Consideration of correlations between observed traits of Jerusalem artichoke populations indicates the complexity of the inheritance of yield components and yield of green mass and dry mass yield per plant. These traits were under the great influence of environmental factors, and of genotype × year interaction. According to LE COCHEC (1990) tuber dry matter had high positive genetic correlation with fresh tuber weight, whole plant dry matter, green leaf area duration and flowering time. Flowering time appeared to be a most efficient character to be associated in a selection for the improvement of the tuber yield. PIMSAEN *et al.* (2010) reported positive and significant correlation coefficient (0.21*) between tuber fresh weight and tuber number, indicating that tuber number might play a significant contribution to tuber yield in some cultivars. PUTTHA *et al.* (2013) found positive and significant correlations between fresh tuber yield and tuber width (r = 0.58**) and tuber size (r = 0.58**), indicating that fresh tuber yield of some accessions were dependent on tuber width and tuber size.

Genetic diversity in crop germplasm is an important resource for crop improvement. Grouping of germplasm into different clusters using qualitative and quantitative traits is used to identify genetic difference of crop germplasm (WATI *et al.*, 2010). Our investigated populations of Jerusalem artichoke, on the basis of hierarchical cluster analysis based on six quantitative traits, were divided into two groups. The first group was composed of two sub-groups. VASIĆ *et al.* (2002) presented three clusters formed exclusively by investigating 31 morphological traits of 79 accessions of *Helianthus tuberosus* collected in the USA, and Montenegro in South Europe. The groups showed a large similarity between some populations collected in Montenegro and those collected in the USA. LIU *et al.* (2011) clustered 59 Jerusalem artichoke clones from 24 provinces in China into 8 groups based on the 17 quantitative traits. Seventy-nine Jerusalem artichoke accessions were clustered into four distinct groups (R^2 = 0.88), based on morphological and agronomic characteristics. The experiments were carried out in Thailand. These groups may be used as parental material to generate progenies for further improvement of this crop, as communicted by PUTTHA *et al.* (2013).

The differencies between obtained results for investigated traits of Jerusalem artichoke may be the result od different germplasm used, and climatic conditions in which the experiments were carried out.

The results stated by RUTTANAPRASERT *et al.* (2016) recommend that the selection of Jerusalem artichoke genotypes with low reduction in yield under drought stress could be a criterion in drought resistance breeding programs for development of Jerusalem artichoke varieties with high tuber yield under drought stress. On the basis of our results it will be possible to choose genotypes which could be used as parents in the process of breeding new varieties of Jerusalem artichoke.

Based to result of this research of plant height, stem thickness, number of stems per plant and green and dry mass yield populations Aleksic and Srbac have distinguished itself and they will be included in a program of creation of new varieties of Jerusalem artichoke.

ACKNOWLEDGEMENT

This work was supported by the Program of preservation of plant genetic resources of Republic of Srpska, carried out by Institute for genetic resources of University of Banja Luka.

Received, January 26th, 2017
Accepted November 18th, 2017

REFERENCES

AHMAD, F., S. KHAN, S.Q. AHMAD, H. KHAN, A. KHAN, S. MUHAMMAD (2011): Genetic analysis of some quantitative traits in bread wheat across environments. Afr. J. Agric. Res., *6*: 686-692.

ATLAGIC, J., S. TERZIC (2006): Cytogenetic study of hexaploid species *Helianthus tuberosus* and its F_1 and BC_1F_1 hybrids with cultivated sunflower, *H. annuus*. Genetika, *38*: 203-213.

BALDINI, M., F. DANUSO, A. ROCCA, E. BULFONI, A. MONTI, G. DE MASTRO (2011): Jerusalem artichoke (*Helianthus tuberosus* L.) productivity in different Italian growing areas: a modelling approach. Ital. J. Agron., *6*: 126-132.

BERENJI, J., V. SIKORA (2001): Variability and stability of tuber yield of Jerusalem artichoke (*Helianthus tuberosus* L.). Helia, *24*: 25-32.

ÇALISKAN, M.E., S. ÇALISKAN, H. ARIOĞLU (2003): Morphological traits and tuber yields of Jerusalem artichoke (*Helianthus tuberosus* L.) genotypes collected from different regions in Turkey under Hatay ecological conditions. 5. Crop Science Congress, Turkey, pp. 261-265.

HAFEZ, M.R. (2013): Effect of some biological components on Jerusalem artichoke (*Helianthus tuberosus* L.) productivity under North Sinai Conditions. J. Appl. Sci. Res., *9*: 804-810.

IZSÁKI, Z., G. NÉMETH KÁDI (2013): Biomass accumulation and nutrient uptake of Jerusalem Artichoke (*Helianthus tuberosus* L.). Am. J. Plant Sci., *4*: 1629-1640.

JOHANSSON, E., T. PRADE, I. ANGELIDAKI, S.E. SVENSSON, W.R. NEWSON, I.B. GUNNARSSON, H.A. PERSSON HOVMALM (2015): Economically viable components from Jerusalem artichoke (*Helianthus tuberosus* L.) in a biorefinery concept. Int. J. Mol. Sci.,*16*: 8997-9016.

KAYS, S.J., S.F. NOTTINGHAM (2008): Biologyand Chemistryof Jerusalem Artichoke (*Helianthus tuberosus* L.). pp: 478. CRC Press, Taylor&Francis Group, Boca Raton, FL, USA.

KILLI, F., A.H. SEREFOĞLU, H. SASTI (2005): Plant and tuber characteristics of red and white skin local Jerusalem artichoke (*Helianthus tuberosus* L.) genotypes. 6. Crop Sci. Congress, Turkey, pp. 1137-1140.

KIRU, S., I. NASENKO (2010): Use of genetic resources from Jerusalem artichoke collection of N. Vavilov Institute in breeding for bioenergy and health security. Agron. Res., *8* (Special Issue III), 625–632.

KOCSIS, L., H.P. KAUL, W. PRAZNIK, P. LIEBHARD (2007): Influence of harvest date on shoot and tuber yield of different Jerusalem artichoke (*Helianthus tuberosus* L.) cultivars in the semiarid production area of Austria. Pflanzenbauwissenschaften, *11*: 67-76.

LAKIĆ, Ž., D. SOKOLOVIĆ, S. BABIĆ, S. VOJIN, J. IKANOVIĆ, T. VELJOVIĆ, I. BALALIĆ (2013): Genetic variability of seed yield and seed components of autochthonous *Lolium perenne* L. populations. Genetika, *45*: 553-556.

LE COCHEC, F. (1990): Variabilite genetique, heritabilites et correlations de 15 characteres d'une population de clones de topinambour (*Helianthus tobinambur* L.). Agronomie, *10*: 797-806.

LIU, Z. X., L.P. HAN, Y. STEINBERGER, G.H. XIE (2011): Genetic variation and yield performance of Jerusalem artichoke germplasm collected in China. Agric. Sci. China, *10*: 668-678.

LIU, Z.X., J.H.J. SPIERTZ, J. SHA, S. XUE, G.H. XIE (2012): Growth and yield performance of Jerusalem artichoke clones in a semiarid region of China. Agron. J., *104*: 1538–1546.

LONG, X.H., H.B. SHAO, L. LIU, L.P. LIU, Z.P. LIU (2016): Jerusalem artichoke: A sustainable biomass feedstock for biorefinery. Renew. Sustainable Energy Rev., *54*: 1382-1388.

PIMSAEN, W., S. JOGLOY, B. SURIHARN, T. KESMALA, V. PENSUK, A. PATANOTHAI (2010): Genotype by environment (G × E) interactions for yield components in Jerusalem artichoke (*Helianthus annuus* L.). Renew. Sustainable Energy Rev., *54*: 11-19.

PUTTHA, R., S. JOGLOY, B. SURIHARN, P.P. WANGSOMNUK, T. KESMALA, A. PATANOTHAI (2013): Variations in morphological and agronomic traits among Jerusalem artichoke (*Helianthus tuberosus* L.) accessions. Genet. Resour. Crop Evol., *60*: 731–746.

RADOVANOVIĆ, M.A. (2013): Utvrđivanje nutritivne vrednosti proizvoda koji sadrže *Helianthus tuberosus* L., *Asteraceae*. (in serbian). PhD, University of Kragujevac, Faculty of Medical Sciences, Kragujevac, Serbia.

RAGAB, M.E., K.A OKASHA, I.I. EL-OKSH, N.M. IBRAHIM (2003): Effect of cultivar and location on yield, tuber quality, and storability of Jerusalem artichoke (*Helianthus tuberosus* L.) I. Growth, yield, and tuber characteristics. Acta Hort., *620*: 103-111.

RAKHIMOV, D.A., A.O. ARIFKHODZAEV, L.G. MEZHLUMYAN, O.M. YULDASHEV, U.A. ROZIKOVA, N. AIKHODZHAEVA, M.M. VAKIL (2003): Carbohydrates and proteins from *Helianthus tuberosus*. Chem. Nat. Compd., *39*: 312-313.

ROPCIUC, S., S. AMARIEI, A. LEAHU, C. DAMIAN, I. CRETESCU (2014)**:** Study on exploitation of Jerusalem artichoke bulbs in relation to chemical composition. J. Anim. Sci. Biotechnol., *47*: 111-115.

RUTTANAPRASERT, R., S. JOGLOY, N. VORASOOT, T. KESMALA, R.S. KANWAR, C.C. HOLBROOK, A. PATANOTHAI (2012): Relationship between chlorophyll density amd SPAD chlorophyll meter reding for Jerusalem artichoke (*Helianthus tuberosus* L.). SABRAO J. Breed. Genet., *44*: 149-162.

RUTTANAPRASERT, R., S. JOGLOY, N. VORASOOT, T. KESMALA, R.S. KANWAR, C.C. HOLBROOK, A. PATANOTHAI (2016): Effects of water stress on total biomass, tuber yield, harvest index and water use efficiency in Jerusalem artichoke. Agric. Water Manag., *166*: 130-138.

STATISTICA 12.0, *StatSoft*. University Licence, Institute of Field and Vegatable Crops, Novi Sad, Serbia.

SAWICKA, B**.,** D**.** KALEMBASA**,** D. SKIBA (2015)**:** Variability in macroelement content in the aboveground part of *Helianthus tuberosus* L. at different nitrogen fertilization levels. Plant Soil Environ., *61*: 158-163.

SEILER, G.J., L.G. CAMPBELL (2006). Genetic variability for mineral concentration in the forage of Jerusalem artichoke cultivars. Euphytica, *150*: 281-288.

SIKORA, V., J. BERENJI, D. LATKOVIĆ (2010): Yield component analysis and diversity in Jerusalem artichoke (*Helianthus tuberosus* L.). Helia, *33*: 37-44.

SONG, Y., S.G. WI, H.M. KIM, H.J. BAE (2016): Cellulosic bioethanol production from Jerusalem artichoke (*Helianthus tuberosus* L.) using hydrogen peroxide-acetic acid (HPAC) pretreatment. Bioresour. Technol., *214*: 30-36.

ŠKORIĆ, D. (2012): Sunflower breeding. In: ŠKORIĆ, D., Z. SAKAČ, editors. Sunflower Genetics and Breeding: International Monography. Serbian Academy of Sciences and Arts, Branch in Novi Sad, Serbia, pp.165-354.

TASSONI, A., N. BAGNI, M. FERRI, M. FRANCESCHETTI, A. KHOMUTOV, M.P. MARQUES, S.M. FIUZA, A.R. SIMONIAN, F.D. SERAFINI (2010): *Helianthus tuberosus* and polyamine research: Pastand recent aplications of a classical growth model. Plant Physiol Bioch., *48*(7): 496-505.

TERZIĆ, S., J. ATLAGIĆ (2009): Nitrogen and sugar content variability in tubers of Jerusalem artichoke (*Helianthus tuberosus*). Genetika, *41*(3): 289-295.

TERZIĆ, S., J. ATLAGIĆ, T. ZEREMSKI, M. ZORIĆ, V. MIKLIČ, I. BALALIĆ (2012): Genetic variability for concentrations of essential elements in tubers and leaves of Jerusalem artichoke (*Helianthus tuberosus* L.). Scientia Horticulturae, *136*: 135-144.

VASIĆ, D., J. MILADINOVIĆ, A. MARJANOVIĆ-JEROMELA, D. ŠKORIĆ (2002): Variability between *Helianthus tuberosus* accessions collected in the USA and Montenegro. Helia, *25*(37): 79-84

WATI, F., A. HARTANA, B.S. PURWOKO (2010): Diversity of Indinesian mango (*Mangifera indica*) cultivars based on morphological and RAPD markers. SABRAO J. Breed. Genet., *42*: 84–95.

YUAN, X., M. GAO, H. XIAO, C. TAN, Y. DU (2012): Free radical scavenging activities and bioactive substances of Jerusalem artichoke (*Helianthus tuberosus* L.) leaves. Food Chem., *133*: 10-14.

GENETIČKA VARIJABILNOST PRINOSA I KOMPONENTE PRINOSA ODABRANIH POPULACIJA ČIČOKE (*Helianthus tuberosus* L.)

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Izvod

Istraživanja kvantitativnih svojstava odabranih populacija čičoke obavljeno je na oglednom polju Poljoprivrednog instituta Republike Srpske u Banjaluci, tokom 2013. i 2014. godine. Korišćeni materijal sakupljen je na širem području Republike Srpske. Analizirane su sledeće populacije: Srbac, Modriča, Pivara, Lazarevo, Bosne, Vrbasa, Gradiška i Aleksići. Ogled je postavljen po slučajnom blok sistemu u tri ponavljanja. Analizirani su sljedeći parametri: masa krtola (g), visina biljke (cm), broj stabljika/ biljci, prosječna debljina stabljike (cm), prinos zelene mase/biljci (kg) i prinos suve materije/biljci (kg). Prosječna masa zasađenih krtola bila je u rasponu od 36,7 g (Bosna) do 61,0 g (Lazarevo). Visina biljaka čičoke bila je od 1,55 m (Lazarevo) do 2,20 m (Aleksići). Broj stabljika/biljci kretao se od 2,2 (populacija Aleksići) do 5,3 (populacija Modriča). Debljina stabljike bila je između 1,24 cm (Bosna) i 2,11 cm (Aleksići). Populacija Bosna imala je najmanji prosječan prinos zelene i suve mase/biljci, dok je najviše srednje vrijednosti imala populacija Aleksići. U širem smislu heritabilnost varirao od 34,66% (visina biljke) do 50,99% (prinos suve mase/biljci). Visoko značajne pozitivne korelacije utvrđene su između visine biljke i debljine stabljike (r = 0,874), debljine stabljike i prinosi zelene mase (r = 0,919), debljine stabljike i prinosa suve mase (r = 0,902). Populacije čičoke grupisane su u dvijegrupe, a prva grupa sastavljena je od dvije podgrupe.Rezultati ovih istraživanja omogućiće izbor populacija čičoke s boljim kvantitativnim svojstvima i njihovo uključivanje u program stvaranja novih sorti.

Primljeno 26.I.2017.
Odobreno 18. XI. 2017.