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VARIABILITY OF MORPHOLOGICAL CHARACTERS AMONG ORNAMENTAL SUNFLOWER COLLECTION

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The research describes the field comparison of 81 decorative sunflower genotypes. In order to assess genetic diversity of sunflower genotypes the studies were conducted in the field conditions during 2010-2015 at the Institute of Field and Crops, Novi Sad, Serbia. The genetic diversity of species *Helianthus annuus* L. has enabled the breeding work in the direction of the decorating and plant landscaping. Depending on the qualitative and quantitative characteristics, production of decorative sunflowers can be divided into three directions. The first line is for the production of cut flowers, the second one is for garden production and the third line is for the production of pot plants. The direction of production dictates the main breeding objectives, which may include: plant architecture, the color of ray and disc flowers and duration of flowering. Investigation of the genetic variability of ornamental sunflowers relies on quantitative traits of which the greatest variability was observed in branching and plant height, which are also the most important qualities for production. The quantitative characteristics of decorative sunflowers have been examined on the basis of 81samples.

Keywords: collection, *Helianthus annuus* L., morphological traits, plant description, variability.

INTRODUCTION

Cultivated plants of domesticated sunflower (*Helianthus annuus* L., Asteraceae) segregated into two groups; those cultivated for their achenes (*Helianthus annuus ssp. macrocarpus* DC. Ckll.) and those cultivated as ornamentals (*Helianthus annuus ssp. annuus*) (RIESEBERG *et al*., 2008). Sunflower has a great potential as an ornamental plant because of its short growing cycle and easy propagation, but mainly because it has attractive inflorescences that are much sought after as cut flowers (SABBAGH *et al*., 2008). Nowadays sunflower is

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worldwide known as ornamental plant and its popularity has increased dramatically in the last decades (YANEZ *et al*., 2005) due to large market demands. According to BLACQUIERE *et al*. (2002) ornamental sunflower are widely cultivated for use as cut flowers, potted plants or in the garden. Development for new varieties is necessary but the aims of ornamental sunflower breeding are different from other types. The development of ornamental sunflower varieties is mostly focused on color and form of flowers, duration of flowering, plant architecture and other morphological characteristics mostly linked to visual effect of the plant.

The success in breeding mostly depends on available genetic collection. There are many available collections concerning wild sunflower species (MAREK *et al*., 2008; ATLAGIĆ *et al*., 2006; NOORYAZDAN *et al*., 2010; SEILER, 2011) as well as cultivated (COQUE *et al*., 2008; ŠKORIĆ, 2008; MANDEL *et al*., 2011; MORENO *et al*., 2013). The sunflowers display an amazing variety of morphological variation, ranging in height from less than 1m to over 4 m, and, having highly branched to unbranched stems, opposite to alternate leaf arrangements, and ray florets ranging in color from yellow to red. Knowledge of the levels and distribution of genetic diversity in germplasm collections is of great importance for the conservation and utilization of genetic resources (MORENO *et al*., 2013).

Sunflower breeding at the Institute of Field and Vegetable Crops in Novi Sad (IFVCNS), Serbia has a successful 50-year long tradition. The result of breeding program is a collection of over 7000 IFVC inbred lines mostly developed for hybrid production (JOCIĆ *et al*., 2012). Collection of inbred lines were created by breeding work on material introduced form other countries, exchanging material with other institutes and interspecies hybridization with wild species. Among these inbred lines there is the great number of ornamental sunflower. The description of collections of ornamental sunflower has been rather limiting and not described jet since the most of available varieties belongs to private companies. Therefore, the aim of the study was to introduce to the collection of IFVCNS ornamental sunflower germplasm by analyzing agro-morphological diversity based on quantitative and qualitative traits. It was also important to evaluate the relationship among the genotypes as a pattern for distribution for the different ornamental use.

MATERIALS AND METHODS

Collection of 81 ornamental sunflower were chosen for genetic diversity study (Table 1). This germplasm was developed by different breeding methods during past 30 years. Ten generations of selling were carried out to insure genetic purity of developed genotypes. Experiment al trial was established at the Institute of Field of Institute of Field and Crops in Novi Sad during 6 year period (2010–2015). The experimental trial was planted in the plots. Each plot consisted of four rows, with row-to-row spacing 0.70 m and plant-to-plant spacing 0.3 m.

Table 1. List of genotypes in the research

No	Genotypes	Origin
1-28	DE4-DE10, DE12, Heliopa, DE14, DE15, Talia, DE17, DE20-DE29, DE31, DE32 ,DE34,	developed from populations derived from crossing the 'Neoplanta' line with commercial oil type restorer lines
29	Neoplanta	Neoplanta, commercial inbred line used as a check (Cvejić et al. 2016)
30-81	DAB1-DAB53	inbred lines derived from the bulk of a few genotypes: Neoplanta, Heliopa, Talia

All characteristics were measured for all genotypes recommended by the European Cooperative Program for Plant Genetic Resources (ECPGR) descriptors, which are important for breeding of ornamental sunflower.

The evaluated characteristics were: days to flowering of central head (FCH), duration of lateral branches flowering (DLBF), uniformity flowering lateral branches (UFLB), color of ray flowers (CRF), color of disk flower (CDF), plant height (PH), diameter of central flower (DCF), diameter lateral flower (DLF), branching (B), number of branches (NB), length of lateral branches (LLB), position of central flower (PCF), position of ray petals (PRP), sterility (S).

Six traits that are measured were: uniformity flowering of lateral branches, color of ray flowers, color of disc flower, branching, position of central head, position of ray petals and sterility were used to describe genetic diversity. Scores were assigned for each trait. Uniformity flowering of lateral branches was based on a rating scale 1-2, where 1=uniformity and 2=non uniformity. Each color is presented as a number: yellow 1, lemon-yellow 2, yellow-orange 3, orange 4, orange-maroon 5, maroon-yellow 6 and burgundy 7. Seven grades of color of disc flower were observed namely yellow=1, orange=2, antocyanine=3, maroon=4, black=5, red antocyanine=6, yellowantocyanine=7. Also, modes of branching are presented with numbers from1-6. Branching all along the stalk as 1, branching on two thirds of stalk 2, the upper part of stalk 3, lower half 4, one thirds of stalk 5 and unbranching 6. Position of central head was based on a rating scale 1-4 where 1=normal, 2=seated, 3=semi-seated and 4=turned. Position of ray petals was categorized on scale 1-3, where 1=open, 2=semiopen and 3=full open. Sterility was recorded as sterile=1 and non-sterile=2. Given that qualitative traits are important in decorative sunflower they were included in analysis (Table 2 and 3).

Table 2. Distribution of phenotypic classes among qualitative traits

Qualitative trait	Score	Category	Number of genotypes	Frequency %
Uniformity flowering lateral branches (UFLB)	1	uniformity	78	100
Color of ray flowers (CRF)	1	yellow	26	32.2
	2	lemon-yellow	15	18.51
	3	yellow-orange	7	8.64
	4	orange	11	13.58
	5	orange-maroon	3	3.7
	6	maroon-yellow	18	22.22
	7	burgundy	1	1.24
Color of disk flower (CDF)	1	yellow	8	9.88
	2	orange	4	4.94
	3	anthocyanine	45	55.56
	4	maroon	16	19.75
	5	black	4	4.93
	6	red anthocyanine	3	3.7
	7	yellow anthocyanine	1	1.24

The results were processed in *STATISTICA 10*. The resulting data were analyzed by ANOVA, Cluster analysis and PCA. PCA is modern and preferred multivariate statistical technique. Very informative outcome of studied genotypes was produced with use of principal component analysis.

Table 3. Distribution of phenotypic classes among qualitative traits

Qualitative trait	Score	Category	Number of genotypes	Frequency %
Branching (B)	1	all along to stalk	64	79.01
	2	two thirds	8	9.88
	3	the upper half	2	2.47
	4	lower half	2	2.47
	6	one thirds	2	2.47
	5	unbranching	3	3.7
Position of central flower (PCF)	1	normal	67	82.71
	2	seated	6	7.41
	3	semi-seated	6	7.41
	4	turned	2	2.47
Position of ray petals (PRP)	1	open	71	87.66
	2	semiopen	9	11.1
	3	full open	1	1.24
Sterility (S)	1	sterile	73	90.12
	2	non- sterile	8	9.88

RESULTS AND DISCUSSION

A large phenotypic variation was observed for all investigated traits. The mean, minimum, maximum, standard deviation and coefficient of variability of seven quantitative traits were recorded for all 81 genotypes and the scores were analyzed and presented in Table 4. By recombination of genes from a relatively narrow origin derived is great variability in the studied traits. According to table 3 length of lateral branches show largest CV (43,69%). Next traits according to great variability are number of branches (CV=39.86%) and duration of lateral branches flowering (CV=38.30%). Variability of plant height was 31.09%.

Table 4. Means and variances for quantitative traits of ornamental sunflower (Helianthus annus L.)

No	***Genotype***	FCH	DLBF	PH	DCF	DLF	NB	LLB
1.	DE1	66	16	123.7	10.2	7.2	15.7	90
2.	DE2	42	6	49.7	4.5	4.3	9	34
3.	DE3	74	15	110	7,7	5.8	17.7	65
4.	DE4	63	10	128	8.3	6.7	18.7	40
5.	DE5	64	19	166.7	9.2	5.7	15	43.3
6.	DE6	61	19	96.7	5,2	3.9	18.7	26.7
7.	DE7	65	10	106.7	10.5	5.4	16.3	63.3
8.	DE8	64	22	155	9	6.1	16	60
9.	DE9	52	19	70	7.2	4.4	13.3	55
10.	DE10	62	25	123.3	7.7	5.2	23.7	60
11.	DE11	62	25	98.3	6.3	4.8	7.7	90
12.	DE12	53	33	131.7	6	4.6	16.3	48.3
13.	DE13	57	30	141.7	9.2	6.5	22.7	56.7

14.	DE14	40	24	53	5.7	5.2	12	15
15.	DE15	53	14	81.7	6.3	4.5	11.7	38.3
16.	DE16	66	25	175	8.3	6.5	16.3	56.7
17.	DE17	51	23	67.7	8.7	4.6	16.3	43.3
18.	DE18	52	21	63.8	8.2	4.4	14	30.4
19.	DE19	53	22	63.6	8.4	5.5	12.9	34.3
20.	DE20	51	20	60.9	5.9	6.9	8.6	29.9
21.	DE21	53	11	85.7	8	6.6	9	29.5
22.	DE22	58	15	135.7	9.2	6.4	12.7	30
23.	DE23	44	22	36.9	4.6	5.3	7.6	23.5
24.	DE24	65	25	130	8.3	6.2	21	46.7
25.	DE25	65	25	145	8.2	5.2	10	40
26.	DE26	62	25	141.7	7.3	5.1	15.7	60
27.	DE27	51	21	78	8.2	8.1	9	18.7
28.	DE28	51	18	91	7.8	7.7	9.6	39.2
29.	DE29	64	25	151.7	8	5.6	20.7	45
30.	DAB 1	65	17	121.7	8.1	7	17	90
31.	DAB 2	60	12	110.6	7.5	4.8	21	56.7
32.	DAB 3	57	8	91.8	6.6	2.9	8.8	26.5
33.	DAB 4	55	18	96.3	7	3.7	11.5	56.3
34.	DAB 5	61	13	132.7	7.6	7.2	23.3	15
35.	DAB 6	56	0	111,2	12.3	0	0	0
36.	DAB 7	55	0	107.3	11.5	0	0	0
37.	DAB 8	60	18	132.3	9.6	7	17.3	56.7
38.	DAB 9	57	17	109.5	9.1	4.8	10.5	45
39.	DAB 10	54	9	96.3	9.1	4.3	10.8	50
40.	DAB 11	57	7	103.7	8.5	2.7	8	7
41.	DAB 12	62	15	116.7	7.7	5.2	11	20
42.	DAB 14	58	21	126.7	8.7	4.8	14.3	60
43.	DAB 15	63	17	111.7	5.5	4.9	10.3	43.3
44.	DAB 16	61	12	153.3	6.6	4.3	14.7	40
45.	DAB 17	59	14	195	6.2	6.3	20	35
46.	DAB 18	61	17	171.7	8.2	6	24.7	55
47.	DAB 19	56	15	145	7.8	4.2	15.3	35
48.	DAB 20	63	16	143.5	6.8	6.6	21.8	32.5
49.	DAB 21	56	18	80	10.8	5.6	11.3	56.7
50.	DAB 22	55	10	71.7	11.7	6.6	9.7	56.7
51.	DAB 23	57	18	101.7	11	7.8	10	51.7
52.	DAB 24	62	19	149.3	9.2	6.2	15.7	63.3
53.	DAB 25	69	16	151.7	9.7	6.6	22.3	50
54.	DAB 26	60	15	173.3	8.3	4.9	15.7	51.7
55.	DAB 27	68	13	143.3	8,3	5.4	10.7	15.7
56.	DAB 28	55	17	96.7	12.2	5	10	41.7
57.	DAB 29	62	18	183.3	7.2	5.1	23.3	41.7
58.	DAB 30	55	15	80	10	6.7	9.1	55
59.	DAB 31	63	15	133.3	9.5	6.2	25.3	33.3
60.	DAB 32	51	17	123	9.5	7.3	22.7	60
61.	DAB 33	46	29	76	6.6	6.7	13.6	40
62.	DAB 34	46	27	70	5.8	6.9	12.3	14.3
63.	DAB 35	45	29	80	9	7.5	8	60
64.	DAB 36	43	21	61.3	8.2	7.3	10.6	25
65.	DAB 37	57	22	105.7	14	9.3	11	45
66.	DAB 38	71	12	163	7.5	5.9	17.3	60
67.	DAB 39	73	27	71.6	5.1	6.1	8.3	21.3
68.	DAB 40	74	25	68.7	5.3	7.3	9.3	27.3
69.	DAB 41	50	24	148.3	9.2	6.2	18.7	50
70.	DAB 42	49	26	130	8.3	5.6	22	50
71.	DAB 43	57	6	125	8	6.5	17	45

72.	DAB 44	78	0	140	8.8	0	0	0
73.	DAB 45	61	14	145	12	8.4	20.3	65
74.	DAB 46	48	28	85	6.7	5.8	10	53.3
75.	DAB 47	45	25	84	9.5	6.1	9.7	60
76.	DAB 48	61	19	105	9.8	7.9	17	80
77.	DAB 49	60	11	91,7	6.7	6.3	12	40
78.	DAB 50	58	14	122	9.8	7.8	15.6	45
79.	DAB 51	43	30	64	5.5	5.2	7.4	32.8
80.	DAB 52	53	20	125.6	7.6	3.6	16.7	40
81.	DAB 53	45	30	108.3	12.5	8.5	11.3	52
	Mean	57.53	18.11	112.31	8.27	5.67	13.98	43.46
	Minimum	40	0	36.9	4.5	0	0	0
	Maximum	78	33	195	14	9.3	25.3	90
	SD	7.90	6.94	34.92	1.92	1.71	5.57	18.99
	CV (%)	13.74	38.30	31.09	23.24	30.08	39.86	43.69

Observations on seven qualitative traits of investigated sunflower genotypes indicate that the all 81 genotypes have uniformity of lateral branches. Opposite the equable uniformity, color of ray flowers was much more variable trait, indicating that yellow color is most frequent. Follow maroon-yellow, lemon-yellow and orange. The smallest number of genotypes were with yellow-orange, orange-maroon and burgundy. Color of disc flower was mostly anthocyanine, followed by maroon and yellow. Only a few genotypes were with orange, black, red anthocyanine and yellow anthocyanine color of disc flowers. This is in accordance with research of CVEJIĆ *et al*. (2016) who concluded that anthocyanin pigmentation is dominant over yellow and lemon-yellow and show monohybrid inheritance. Branching all along stalk was recorded in 79.01% of genotypes, while only 3 genotypes were unbranching. In research of NAMBEESAN *et al*. (2015) in cultivated sunflower selection during domestication resulted in the production of an apically dominant, unbranched growth form that differs markedly from its highly branched wild progenitor. Special decorativeness to flowers provides the central position of the head, so the largest number of genotypes were with normal position, following with seated and semi-seated. Only two genotypes have turned central head. According to position of ray petals 71 genotypes were with open ray petals, 9 with semiopen and only one full open.

The PCA percentage and cumulative variance for the first five principal components are given in table 5. The first five principal components accounted for 67.16 of the total variance. The first PC1 accounted for 23.99 of total variance, while PC2 accounted for 16.12 and PC3 accounted for 10.39.

Table 5. Principal Component Analysis of different traits

	PC1	PC2	PC3	PC4	PC5
eigenvalues	3.36	2.26	1.45	1.29	1.05
cumulative eigenvalues	3.36	5.62	7.07	8.36	9.41
variance (%)	23.99	16.12	10.39	9.13	7.53
cumulative variance	23.99	40.11	50.5	59.63	67.16

The scores of all examined traits were taken into account and subjected to PCA using *STATISTICA 10*. Eigenvectors and principal components were estimated for all traits and presented in Table 6.

Table 6. Principal components of various traits

Characters	Principal components				
	PC1	PC2	PC3	PC4	PC5
FCH *	-0.10	**0.47**	0.15	0.00	0.44
DLBF	0.36	-0.17	0.06	-0.13	0.08
UFLB	**0.46**	0.01	-0.10	-0.11	0.05
CRF	0.20	-0.29	0.13	0.14	**0.33**
CDF	0.06	-0.10	**0.56**	-0.23	0.31
PH	-0.02	**0.58**	0.11	-0.03	0.14
DCF	-0.06	0.19	0.37	**0.49**	-0.54
DLF	**0.43**	0.02	0.17	0.16	-0.10
B	-0.43	0.07	0.17	-0.04	0.14
NB	0.31	0.41	-0.11	-0.09	0.08
LLB	0.34	0.26	0.08	0.10	-0.20
PCF	0.07	-0.16	0.24	**0.53**	0.29
PRP	0.03	-0.01	0.25	-0.55	-0.32
S	0.03	0.09	-0.54	0.19	0.13

* days to flowering of central head (FCH), duration of lateral branches flowering (DLBF), uniformity flowering lateral branches (UFLB), color of ray flowers (CRF), color of disk flower (CDF), plant height (PH), diameter of central flower (DCF), diameter lateral flower (DLF), branching (B), number of branches (NB), length of lateral branches (LLB), position of central flower (PCF), position of ray petals (PRP), sterility (S).

First principal component (PC1) was correlated with uniformity flowering lateral branches (0.46), lateral head diameter (0.43). The PC2 was associated with plant height (0.58) and central head flowering (0.47). The PC3 was correlated with color of disk flowers (0.56). The PC4 was associated with central head position (0.53) and central head diameter (0.49), while PC5 was correlated with color of ray flowers (0.33).

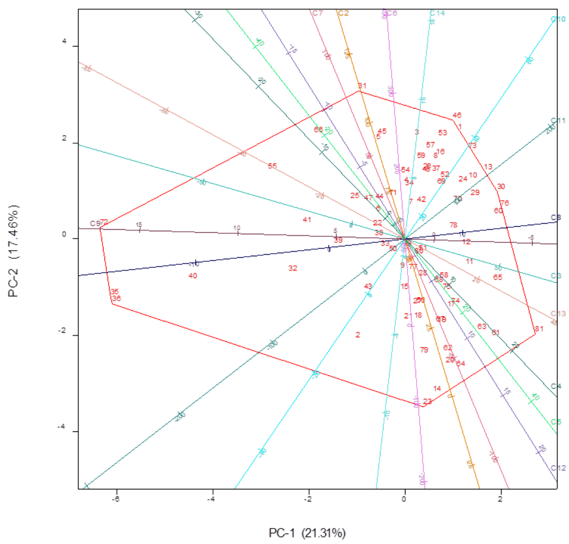

Figure 1. Principal coordinate analysis of ornamental sunflower collection

A scatter plot (Figure 1.) drawn using PC1 and PC2 factor scores and clear pattern of grouping between the genotypes was observed in the factor plane. Convex of the hull occupied by the genotypes numbered 31, 72, 36, 23, 81, 30 and 46. These genotypes showed the highest point among the factors.

As recognized for many crops, the data of the morphological diversity of sunflower collection are very significant for the development of breeding (DE LA VEGA *et al*., 2007; MORENO *et al*., 2013). Serbia is a country that is mostly engaged in the production of oil sunflower genotypes. But the development of horticulture has led to the need for examination of decorative sunflowers. Decorative features of sunflower are crucial for determining properly use of each genotype. According to results of experiment it can be concluded existence of high morphological diversity in decorative sunflower collection. Furthermore, PCA analysis showed that the most important variables included by PC1, PC2 and PC3 were uniformity flowering lateral branches, lateral head diameter, plant height, central head flowering and color of disk flowers. Diameter of central head is important quantitative trait in floriculture practice. The wade range of diameter of central head gives great opportunity for the selection and breeding work. Genotypes with small central head are suitable for garden production but also in arrangements and bouquets. Genotypes with large flowers are used like cut flower. In commercial production of decorative sunflower number of branches is important trait giving that it is in positive correlation with yield. According to WIEN (2013) removal vegetative apex causing branching and the production of a larger number of flowers that are used for cutting. This way requires a lot of manpower and time, so that correct selection can save time and money. More branches mean more flowers and higher profits. Branching genotypes are more closely related to wild sunflowers. This fits with the statements of NAMBEESAN *et al*. (2015) that human-mediated selection has resulted in a dramatic increase in apical dominance relative to its wild progenitor. This corresponds with a research of SCHNEITER (1997) that branching is important trait in wild sunflower. Length of lateral branches is an important feature in terms of ease of use of cut flower. The longer length of lateral branches, giving greater opportunities for the use and manipulation during the making bouquets and arrangements. Larger number of branches provides long time of flowering of whole plant. In gardens duration of flowering is important characteristics because it increases decorativeness and attractiveness. This trait has large act in selection of genotypes suitable for pot usage. Lower genotypes with height 30-40 cm can be use like pot plants, while higher can use like garden plants and for cut flowers. Of total number of investigated sunflowers 73 have sterile flowers while 8 were non-sterile. In terms of allergy to pollen these 8 genotypes are not suitable for cut flower. Uniformity of lateral branches is very important in determining the planting density in the production of cut flower, but also in garden planting. Given that many people have allergic to pollen it is preferable that genotypes used for cut flower to be sterile. Therefore, CVEJIĆ and JOCIĆ (2010) state that certain criteria must be respected in terms of cut flower use.

CONCLUSIONS

The purpose of genotype DAB is oriented towards the production of decorative sunflowers for cut flower and horticultural production, while no genotype has corresponding properties for the production of pot plants. Great variability which has been observed in branching, length of flowering of lateral branches, the diameter of lateral head and plant height, provide a possibility for further processing and creating better varieties of cut flower, as well as for garden production, which will satisfy the desires of the market. Breeding of cut and decorative garden sunflower DAB offspring has great potential which needs to be exploited.

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VARIJABILNOST MORFOLOŠKIH KARAKTERISTIKA KOLEKCIJE UKRASNOG SUNCOKRETA

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Izvod

Istraživanje opisuje karaketristike 81 genotipa dekorativnog suncokreta. U cilju analize genetičkog diverziteta genotipova ukrasnog suncokreta rad je postavljen u periodu 2011-2015 godine na Institutu za ratarstvo i povrtarstvo u Novom Sadu. Velik genetički diverzitet vrste *Helianthus annuus* L. omogućava uspešan oplemenjivački rad u cilju dobijanja genotipova koji su dekorativni i koji se mogu koristiti u pejzažnoj arhitekturi. U zavisnosti od kvalitativnih i kvantitativnih karakteristika, proizvodnja dekorativnof suncokreta ima tri pravca. Prvi pravac je proizvodnja za rezan cvet, drugi pravac je proizvodnja genotipova pogodnih za upotrebu u baštama i treći pravac je proizvodnja za saksijsku upotrebu. U zavisnosti od pravca upotrebe zavise i pravci selekcije. Osobine koje su od velike važnosti su: arhitektura biljke, boja zrakastih i diskoidnih cvetova i dužina cvetanja. Istraživanje varijabilnosti ukrasnog suncokreta obuhvata i analizu visine biljke, koja je veoma važna za određivanje načina upotrebe genotipa.

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