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INTERDEPENDENCE OF YIELD AND YIELD COMPONENTS OF CONFECTIONARY SUNFLOWER HYBRIDS

Nada HLADNI, Siniša JOCIĆ[1], Vladimir MIKLIČ[1], Dejana SAFTIĆ-PANKOVIĆ[3], Marija KRALJEVIĆ-BALALIĆ[2]

[1] Institute of Field and Vegetable Crops, Novi Sad, Serbia
[2] Faculty of Agriculture, Novi Sad, Serbia
[3] EDUCONS University, Sremska Kamenica, Serbia

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The two most important criteria for introducing new confectionary hybrids into production are high seed and protein yield. That is why it is important to find the traits that are measurable, and that at the same time show a strong correlation with seed and protein yield, so that they can be used as a criteria for confectionary hybrid breeding. Results achieved during 2008 at the locations Rimski Šančevi (Region of Vojvodina) and Kula (Central Serbia) show that the new confectionary hybrids are expressing higher seed yields in comparison to standards (Vranac and Cepko) though with a lower seed oil content. A very strong positive correlation was determined between seed yield and seed protein content, kernel content and mass of 1000 seeds. A very strong positive correlation was determined

Corresponding author: Nada Hladni, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, fax: +3821 6413833, phone: 021 4898411, *e-mail:* nada.hladni@ifvcns.ns.ac.rs

between seed protein content, seed yield and mass of 1000 seeds, with protein yield. This indicates that seed yield, seed protein content and mass of 1000 seeds have a high influence on protein yield. The degree of interdependence between different traits is a sign of direction which is supposed to facilitate better planning of sunflower breeding program.

Key words: confectionary sunflower, seed yield, protein yield, yield components, correlations

INTRODUCTION

Sunflower breeding in the world and Serbia alike is directed towards the increase of: genetic potential for yield, yield stability, health safety and nutritive quality with the increase of production economy (HLADNI, 2010). There are two primary types of cultivated sunflower: oilseed sunflower and non-oil seed - confectionary sunflower (DUIHUA and HOEFT, 2009). Oil seed type is grown for vegetable oil and non-oil seed type which supply the bird food and confectionery market. Non-oil type *Helianthus annuus* L. var. *macrocarpus* (DC.) Ckll. is also called confectionary, protein, and big seed sunflower. Seeds of confectionery and oil type are distinguished by differences in, hullability, shell color, seed weight and morphology and kernel-to-pericarp weight ratio, in addition to seed oil content. Seed of high protein sunflower is usually black with white stripes or colorful, significantly bigger than the seed of oil type sunflower with thicker hull loosely connected to the kernel. The shell is easily separated from the kernel and allows the whole seed to be dehulled (GONZALEZ-PEREZ and VEREIJKEN, 2007). Confectionary type sunflower is distinguished by a large shell ration, usually up to 40 to 50% (JOVANOVIĆ, 2001), high mass of 1000 seeds which is usually higher than 100 g (HLADNI *et al*., 2011) and should ideally be less than 30% oil content (KAYA *et al*., 2008). The demand for confectionary sunflower seed type in Serbia is increasing due to its nutritional value and increasing use in human nutrition (HLADNI *et al.* 2010). It is rich in oil, protein, vitamins and mineral content (HLADNI *et al*. 2010). Vegetable oil from sunflower seeds is lower in saturated fats than most vegetable oils. Nutritionally, common sunflower oil ranks as one of the highest quality edible vegetable oils known (ŠKORIĆ *et al*., 2008). Confectionary sunflower hybrid breeding is directed towards the increase of protein content and quality (>25%), mass of 1000 seeds (>100 g), hectoliter mass, oil stability with lowering of its content in the seed (<40%), increase of kernel ratio with the lowering of the shell ratio, uniformity in seed size and color, dehullness as well as tolerance to dominant diseases in the cultivation region (HLADNI *et al*., 2009a).

When creating confectionary hybrids it is very important to combine genes responsible for high potential for yield and good technical and technological traits of the seed (HLADNI *et al*., 2010). The two most important criteria for introducing new confectionary (high protein) hybrids into production are high seed and protein yield (HLADNI *et al*., 2009b). These two traits, however represent a problem for the breeders because they are both characterized by low heritability and they both were under the influence of genotype x environment. Seed yield is not a simple trait

rather, it is a complex one, an aggregate of traits, or a super trait (ŠKORIĆ *et al.*, 2007), it is under a strong influence of external environment, it represents the result of the interaction between the genotype and external environment factors during the entire vegetation period (MARINKOVIĆ *et al.*, 2003). Protein yield depends on seed yield and seed protein content. Seed protein content is one of the indicators of sunflower seed quality, according to HLADNI *et al.*(2009c) protein content varies depending on the genotype, agro ecological conditions and the interaction of the genotype and external environment conditions, it is around 16-28%. With kernel increase, the amount of protein in the seed also increases so breeding for increased seed protein amount should be followed by the selection of genotypes with larger kernels (HLADNI *et al.*, 2009b). A strong negative correlation between hull ratio, seed yield and mass of 1000 seeds was determined by (ERGEN and SAGLAM, 2005).

The aim of this paper was to test the value of the new confectionary sunflower hybrids in comparison to hybrids that are already in production, as well as to determine interdependence between protein yield and seed yield, oil yield, mass of 1000 seeds, seed oil content, seed protein content, seed kernel ratio and seed hull ratio.

MATERIALS AND METHODS

Thirteen new high protein two-line confectionary hybrids: NS-H-04, NS-H-05, NS-H-06, NS-H-07, NS-H-09, NS-H-10, NS-H-11, NS-H-12, NS-H-15, NS-H-17, NS-H-18, NS-H-19, NS-H-20 created by crossing cytoplasmic male sterile female line and male line with a fertility restorer gene, were examined during 2008 at two locations Rimski Šančevi in Vojvodina region and Kula in central Serbia, in order to evaluate production characteristics and the degree of adaptability in comparison to the standard Vranac and Cepko. These two already well known confectionary hybrids are registered in Serbia and EU. The following traits have been examined: mass of 1000 seeds, seed oil content, and seed protein content hull ratio, kernel ratio, seed yield, oil yield and protein yield. The plot where the experiment was conducted was 28 m^2 and (70cm x 28cm plant density) seeds were planted by hand in 4 rows (in April) and plants from two mean row were harvested (in September) all except first plants at each plots. The experiment was done in a randomized complete block design with 3 replications. Seed yield was measured on a scale and calculated to 11% seed humidity content. Seed oil content (%) was determined from absolutely clean and air dried seed on the NMR-analyzer. Seed protein content was determined by Kjeldahl method. Mass of 1000 seeds (g) was measured on a random sample of an absolutely clean and air dried seed. Oil yield was determined from seed yield and seed oil content (tha^{-1}) while protein yield was determined from seed yield and seed protein content (tha^{-1}).

Genetic correlation coefficients were calculated by SINGH and CHAUNDHARY (1979).

RESULTS AND DISCUSSION

When creating new high-protein hybrids for confectionary use it is important to find traits that are easily determined and at the same time show their interdependence

with seed yield and protein yield, based on that those traits can become selection criteria. In order to evaluate in the best way possible the values of new hybrids in comparison with hybrids already in production tests have been done during 2008 on two locations Rimski Šančevi (region Vojvodina) and Kula (central Serbia). Results achieved during 2008 on both locations show that the new confectionary hybrids are expressing higher seed yields in comparison to standards (Vranac and Cepko) with lower seed oil content (Table 1).Average mean value for mass of 1000 seeds was from 85.9 g (NS-H-19) to 112.4 g (NS-H-15).

Tab. 1a. Average value of examined traits of sunflower confectionary hybrids

Hybrids	MTS	R	SOC	R	SPC	R	KR	R
	g		%		%		%	
NS-H-04	108.7	3	39.7	4	14.2	1	62.0	6
NS-H-05	100.1	6	31.9	13	12.6	6	56.0	14
NS-H-06	97.3	10	30.9	14	12.9	5	62.0	7
NS-H-07	97.9	8	34.9	11	12.3	10	62.0	8
NS-H-09	87.5	12	41.0	3	11.7	13	65.5	3
NS-H-10	97.7	9	36.2	7	11.5	14	59.0	11
NS-H-11	95.5	11	35.5	8	11.7	12	61.0	9
NS-H-12	101.2	4	35.0	10	12.6	7	61.0	10
NS-H-15	112.4	1	37.2	6	12.4	8	65.0	4
NS-H-17	110.1	2	29.0	15	10.7	15	52.0	15
NS-H-18	100.2	5	35.4	9	12.3	9	57.5	13
NS-H-19	85.9	13	37.9	5	12.1	11	63.0	5
NS-H-20	99.9	7	33.9	12	13.8	2	58.5	12
Mean	99.6		35.3		12.4		60.4	
Vranac	69.3	15	45.1	1	13.1	4	73.0	1
Cepko	76.9	14	42.5	2	13.7	3	71.0	2

mass of 1000 seeds (MTS), seed oil content (SOC), seed protein content (SPC), kernel ratio (KR), hull rank (R)

Tab. 1b. Average value of examined traits of sunflower confectionary hybrids

Hybrids	HR	R	SY	R	OY	R	PY	R
	%		tha^{-1}		tha^{-1}		tha^{-1}	
NS-H-04	38.0	8	3.94	6	1.57	3	0.559	1
NS-H-05	44.0	2	3.78	10	1.20	13	0.476	10
NS-H-06	38.0	9	3.86	7	1.19	14	0,499	5
NS-H-07	38.0	10	3.81	8	1.33	11	0.468	11
NS-H-09	34.5	13	3.70	13	1.52	5	0.431	13
NS-H-10	41.0	5	3.73	11	1.35	10	0.427	14
NS-H-11	39.0	6	4.10	2	1.33	12	0.479	9
NS-H-12	39.0	7	4.18	1	1.44	7	0.525	3
NS-H-15	35.0	12	3.97	5	1.55	4	0.493	6
NS-H-17	48.0	1	3.69	14	1.07	15	0.393	15
NS-H-18	42.5	3	4.07	3	1.44	8	0.502	4
NS-H-19	37.0	11	3.81	9	1.45	6	0.460	12
NS-H-20	41.5	4	4.02	4	1.36	9	0.553	2
Mean	39.6		3.90		1.26		0.482	
Vranac	27.0	15	3.72	12	1.59	1	0.486	7
Cepko	29.0	14	3.52	15	1.58	2	0.481	8

ratio (HR), seed yield (SY), oil yield (OY), protein yield (PY), rank (R)

The lowest mean value for seed oil content was had by NS-H-17 hybrid (29.0%), and the highest NS-H-09 hybrid (41.0%). Mean values for seed protein content were from 10.7% (NS-H-17) to 14.2% (NS-H-04). The kernel ratio in the F_1 generation was the lowest with NS-H-17 hybrid (52.0%), and the highest with NS-H-09 (65.5%). The lowest average hull ratio was determined with NS-H-09 hybrid (34.5%), and the highest with NS-H-17 (48%). NS-H-17 had the lowest average yield (3. 69 tha^{-1}) and the highest average yield was determined with NS-H-12 hybrid (4.18 tha^{-1}). Average oil yield was from 1.07 tha^{-1} (NS-H-17) to 1.57 tha^{-1} (NS-H-04), while the average protein yield was the lowest with NS-H-17 hybrid (0.393 tha^{-1}), and the highest with NS-H-04 (0.559 tha^{-1}), table 1.

In 2008 the average seed yield for all the examined hybrids was 3.90 tha^{-1}. When seed yield is concerned confectionary hybrids NS-H-12, NS-H-11, NS-H-18 stood out. New confectionary hybrids have demonstrated significantly lower average seed oil content during 2008 in comparison to standards. Average seed oil content 35.3% is significantly lower in comparison to hybrids Vranac and Cepko (45.1%; 42.5%).

In 2008 the lowest average oil content on two locations was demonstrated by the following hybrids NS-H-17 (29.0%), NS-H-06 (30.9%), NS-H-05 (31.9%), NS-H-20 (33.9%), table 1. The average seed protein content 12.4% was somewhat lower than the standard, while the average protein yield was on the same level as the standard (0.482 tha^{-1}). The average oil yield (1.26 tha^{-1}) gained was considerably lower than the standard (1.59 tha^{-1}; 1.58 tha^{-1}). The lowest average oil yield was demonstrated by hybrids NS-H-17, NS-H-06, NS-H-05. In 2008 average mass of 1000 seeds was significantly higher in comparison to standards (69.3g; 76.9g) and it was 99.6g. The highest mass of 1000 seeds was had by NS-H-15, NS-H-17, NS-H-04 and it was (112.4g; 110.1g; 108.7g). With hybrid NS-H-09 the lowest hull ratio was determined (34.5%) which is somewhat higher in comparison to standard (27.0%; 29.0%), while the kernel ratio is somewhat lower (65.5%) in comparison to standard. Similar ratio between hull and kernel was determined with hybrids NS-H-15 and NS-H-19. The highest protein yield was observed in hybrids NS-H-04 (0.559 tha^{-1}), NS-H-20 (0.553 tha^{-1}), NS-H-12 (0.525 tha^{-1}), NS-H-18 (0.502 tha^{-1}) in comparison to Vranac (0.486 tha^{-1}) and Cepko (0.481 tha^{-1}), while the lowest average oil yield was determined with hybrids NS-H-17 (1.07 tha^{-1}), NS-H-06 (1.19 tha^{-1}), NS-H-05 (1.20 tha^{-1}), table 1.

When it comes to achieved seed yield, lowered oil content, increased mass of 1000 seeds, protein content and yield the following hybrids stand out - NS-H-12, NS-H-18, NS-H-20 and NS-H-04. The creation of confectionary hybrids of a high genetic yield potential requires knowledge of the interdependence of protein yield with other traits through correlation coefficient. The analysis of simple correlation coefficients showed that very strong correlation existed between the seed protein content (0.943^{**}), seed yield (0.802^{**}) and oil yield (0.496^{**}) on one side and protein yield on the other (Table 2).

Simple correlation coefficient show very strong positive correlation between mass of 1000 seeds and seed yield this results is in agreement with the results of DAGUSTU, 2002; DUŠANIĆ *et al*., 2004; KAYA *et al*., 2007; HLADNI *et al*., 2008a; BEHRADFAR *et al*., 2009; HLADNI *et al*., 2010.

Very strong positive correlation was found between seed protein content and seed yield. Seed oil content has exhibited low positive correlation with seed yield, which is in accordance with ASHOK *et al*. (2000), and in contradiction to the research performed by KAYA *et al*. (2007) who determined a very strong correlation of a positive direction. A negative weak correlation between seed oil content and seed yield was determined by ARSHAD *et al*. (2010) and in contradiction to the research performed by. HLADNI *et al*. (2008a) who determined a strong negative correlation between seed yield and seed oil content (-0.649^{**}). Weak negative correlation was found between shell ration and seed yield (Table 2).

Tab. 2. Correlation coefficient of the analyzed traits with protein yield

Trait		SOC	SPC	KR	HR	SY	OY	PY
		X_2	X_3	X_4	X_5	X_6	X_7	Y
MTS	X_1	-0.321 ^{ns}	0.181 ^{ns}	-0.353	0.353 ^{ns}	0.448**	-0.080	0.318 ^{ns}
SOC	X_2		0.212 ^{ns}	0.752**	-0.752	0.138 ^{ns}	0.918**	0.206 ^{ns}
SPC	X_3			0.276 ^{ns}	-0.276	0.557**	0.403**	0.943**
KR	X_4				0.975**	0.242 ^{ns}	0.740**	0.288 ^{ns}
HR	X_5					-0.242	-0.740	-0.288 ^{ns}
SY	X_6						0.519**	0.802**
OY	X_7							0.496**

** F test significancy at level P<0.01, * F test significancy at level P<0.05, ns- not significantly different
X_1 mass of 1000 seeds (MTS), X_2 seed oil content (SOC), X_3 seed protein content (SPC), X_4 kernel ratio (KR), X_5 hull ratio (HR), X_6 seed yield (SY), X_7 oil yield (OY), Y protein yield (PY)

A weak negative correlation was found between mass of 1000 seed and seed oil yield. This result is in agreement with those of OZER *et al.* (2003) and in opposition to the research performed by KRIZMANIĆ *et al.* (2006) who reported a strong positive correlation based on direction and a weak correlation based on strength and HLADNI *et al.* (2008b) who determined a very strong correlation of a positive direction.

Simple correlation coefficient showed that the seed oil content, seed protein content, kernel ratio and seed yield exhibited a very strong positive correlation with oil yield. A strong positive relationsheep between oil content and oil yield was reported by KRIZMANIĆ *et al.*, 2006; HLADNI *et al.*, 2006; TAKLEWOLD *et al.*, 2000; OZER *et al.*, 2003. A weak positive correlation was determined between oil content and oil yield as stated by KRIZMANIĆ *et al.*, 2006.

The analysis of simple correlation coefficient show a very strong positive correlation between seed oil content and kernel ratio (0.752**) this is in agreement to the research performed by OZER *et al.* (2003).

A weak positive correlation has been determined between seed protein content and seed oil content, this resultant is dis agreement with DIJANOVIĆ (2003) determined a weak negative correlation between seed oil and protein content.

A weak positive correlation has been determined between seed protein content and kernel ratio and a negative weak correlation was found between seed protein content and shell ratio. These results are opposite to the research performed by ERGEN and SAGLAM (2005) who determined a strong negative correlation of seed protein content with shell ratio. The differences in the presented results can be explained by different plant material used by the authors in their research. When

creating high protein hybrids for confectionary use it is important to determine traits that are important to protein yield and its parts, such are protein content and seed yield.

According to JOVANOVIĆ (2001), one of the efficient ways of increasing seed yield is lowering shell ratio and increasing the kernel ratio because special attention is paid to the shell and kernel correlation in all sunflower breeding programs.

In this research, seed oil content and kernel ratio have shown a weak correlation of a positive direction, while the shell ratio had shown a weak correlation of a negative direction with seed yield, seed protein content and protein yield (Table 3).

Tab. 3. A study of interdependence between seed yield, seed protein content and protein yield

	MTS	SOC	KR	HR	OY	SPC	PY
Seed yield	0.448**	0.138	0.242	-0.242	0.519**	0.557**	0.802**
	MTS	SOC	RK	RH	OY	SPC	PY
Seed protein content	0.181	0.212	0.276	-0.276	0.403**	0.557**	0.943**
	MTS	SOC	RK	RH	OY	SPC	PY
Protein yield	0.318	0.206	0.288	-0.288	0.496**	0.802**	0.943**

** *F test significancy at level P<0.01*, * *F test significancy at level P<0.05*

Mass of 1000 seeds has presented a very strong positive correlation with seed yield and a weak correlation of a positive direction with protein content and protein yield. According to research by KAYA *et al*. (2008) and MIJIĆ *et al.* (2009) there is a strong correlation between mass of 1000 seeds and seed yield. Seed protein content has a very strong positive correlation with seed yield and protein yield, while the seed yield has shown a very strong positive correlation with protein yield. A very strong positive correlation was determined between seed protein content and seed yield (DUŠANIĆ *et al*., 2004; HLADNI *et al*., 2010).

A very strong positive correlation was present between seed protein content and protein yield (Table 3).

Correlations between different traits are aspects that should be kept in mind for better planning of breeding programs in sunflower (HLADNI *et al*., 2010). Presence or absence of correlations can contribute to the right choice of examined traits so as to enhance the efficiency of some selection criteria. The focus should be placed on traits that have a very strong positive correlation on seed and protein yield. Sunflower breeders intend to achieve the highest grain yield, through the best expression of heterosis (VRANCEANU *et al*., 2005).

Mass of 1000 seeds belongs to the major yield components, breeding for increase of the mass of 1000 seeds leads to the seed yield increase that is why this

trait is used as selection criteria when creating sunflower hybrids (HLADNI *et al.*, 2008a).

The research results discussed in this paper indicate that, among the studied traits seed yield, seed protein content and mass of 1000 seeds are the traits that have demonstrated a strong positive correlation with protein yield and can be used in improvement of seed protein yield as well as for assessment of confectionery sunflower breeding materials.

CONCLUSION

The main direction in breeding lowered oil confectionery sunflower is directed towards increased mass of 1000 seeds and protein content and quality while lowering the seed oil content and shell ratio. According to presented results the new high protein confectionery hybrids have demonstrated better high genetic potential for seed yield and good technical and technological seed traits than the hybrids already in production, Vranac and Cepko. Based on the results obtained, the following confectionery hybrids: NS-H-12, NS-H-18, NS-H-20, NS-H-04, stand out on the basis of reached seed yield, lowered oil content, increased mass of 1000 seeds, protein content and yield. When creating new high-protein hybrids for confectionery use it is important to find traits that are easily determined and at the same time show their interdependence with seed yield and protein yield. The focus should be placed on traits that have a very strong positive correlation on seed and protein yield based on that those traits can become selection criteria. In this research seed oil content and kernel ratio have shown a weak correlation of a positive direction, while the shell ratio has shown a weak correlation of a negative direction with seed yield, seed protein content and protein yield. Seed protein content and mass of 1000 seeds have demonstrated a strong positive correlation with protein yield which means that breeding for these components is at the same time breeding for protein yield.

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MEĐUZAVISNOST PRINOSA SA KOMPONENTAMA PRINOSA KOD KONZUMNOG SUNCOKRETA

Nada HLADNI[1], Siniša JOCIĆ[1], Vladimir MIKLIČ[1], Dejana SAFTIĆ-PANKOVIĆ[1,3], Marija KRALJEVIĆ-BALALIĆ[2]

[1]Institut za ratarstvo i povrtarstvo, Novi Sad, Srbija
[2] Poljoprivredni fakultet, Novi Sad, Srbja
[3] EDUCONS Univerzitet, Sremska Kamenica, Serbia

I z v o d

Dva najznačajnija kriterijuma za uvođenje novih konzumnih hibrida u proizvodnju su visok prinos semena i proteina. Zato je važno pronaći osobine koje su merljive, a istovremeno ispoljavaju jaku korelaciju sa prinosom semena i proteina tako da se mogu koristiti kao kriterijumi za oplemenjivanje konzumnih hibrida. Postignuti rezultati u toku 2008. godine na lokalitetima Rimski Šančevi (region Vojvodina) i Kula (uža Srbija) pokazuju da novi hibridi konzumnog tipa postižu veće prinose semena u poređenju sa standardima (Vranac i Cepko) uz smanjenje sadržaja ulja. Utvrđena je veoma jaka pozitivna korelacija između prinosa semena i sadržaja proteina u semenu, sadržaja jezgra, mase 1000 semena. Pozitivna veoma jaka korelacija konstatovana je između sadržaja proteina u semenu, prinosa semena i mase 1000 semena sa prinosom proteina. To pokazuje da prinos semena, sadržaj proteina u semenu i masa 1000 semena imaju visok uticaj na prinos proteina. Stepen međuzavisnosti između različitih osobina je putokaz koji treba da omogući bolje planiranje programa za oplemenjivanje suncokreta.

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