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CORRELATION AND PATH ANALYSIS OF YIELD AND YIELD COMPONENTS OF CONFECTIONARY SUNFLOWER

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Path coefficient analysis was applied to gain information on direct and indirect effects of studied traits (seed oil content, kernel oil content, seed protein content, kernel protein content, head diameter, kernel ratio and plant height) on sunflower seed yield. Traits which exhibit the highest effects on seed yield will be used as a selection criterion in confectionary sunflower breeding. The research was conducted during three vegetation seasons on 22 experimental confectionary sunflower hybrids, created in breeding program the Institute of Field and Vegetable Crops. Among the largest number of examined traits, significant and highly significant correlations were found. With the analysis of simple correlation coefficients a low interdependence was determined between, kernel protein content, plant heights with seed yield. Negative but weak correlation was determined between kernel oil content, seed protein content, kernel ratio with seed yield. Established a negative strong correlation of head diameter (-0.190^{*}) and negative very strong correlation of seed oil content (-0.351^{**}) with seed yield. The seed oil content had a very strong direct negative effect on seed yield ($DE=-0.831^{**}$). The head diameter, plant height, seed protein content had weak negative direct effect on seed yield. Kernel protein content and kernel oil content has demonstrated a weak direct positive effect on seed yield. Path coefficient analysis for seed yield showed very strong direct effect for kernel ratio ($DE=0.487^{*}$) on seed yield, it shows that the kernel ratio is important selection criterion for confectionary sunflower breeding.

Keywords: confectionary sunflower, seed yield, yield components, correlations, path coefficient analysis

INTRODUCTION

Cultivated sunflower (*Helianthus annuus* L.) is one of the most important oil crops in the world. Two primary types of cultivated sunflower exist: oil seed sunflower and non-oil seed

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confectionary sunflower DUIHUA and HOEFT (2009). Confectionary sunflower produces large seeds with low oil contents, used in baking and snack applications LU and HOEFT (2009). Seeds of confectionary and oil type are distinguished by hull ability, hull color, seed weight and morphology and kernel-to-pericarp weight ratio, in addition to seed oil content HLADNI *et al*. (2012). The major sunflower breeding objectives, for all sunflower types should be high yields and quality of oil, proteins and other products for non-food and food industries and approaches to management of resistance genes, stability of sunflower resistance to certain pathogens ŠKORIĆ *et al*. (2012). For confectionary sunflower the main direction in breeding is towards increased protein content and quality, while lowering the seed oil content and hull ratio HLADNI *et al*. (2011c). 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*. (2011a).

Relationships between seed yield and morphological and physiological traits are effectively studied by the simple correlation coefficient analysis (HLADNI *et al*., 2010; SINCIK and GOKSOY, 2014). A positive and important interdependence was determined among morpho-physiological traits like plant height and head diameter with seed yield: DUŠANIĆ *et al*. (2004), GOKSOY and TURAN (2007), HLADNI *et al*. (2008, 2010), KAYA *et al*. (2009) and HASSAN *et al*. (2013). A negative weak correlation between seed oil content and seed yield was determined by ARSHAD *et al*. (2010) in contradiction to the research performed by KAYA *et al*. (2007) who determined a very strong correlation of a positive direction. Correlation between seed yield and seed protein content was positive but not significant (RADIĆ *et al*. 2013). The focus should be placed on traits that have a very strong positive correlation on seed yield HLADNI *et al*. (2011b).

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 seed yield and seed oil content, kernel oil content, seed protein content, kernel protein content, head diameter, kernel ratio and plant height.

MATERIALS AND METHODS

The research was conducted during three vegetation seasons on 22 experimental confectionary sunflower hybrids, produced within the breeding program at the Institute of Field and Vegetable Crops. Twenty-two high protein two-line confectionary hybrids: NS-H-1, NS-H-2, NS-H-3, NS-H-4, NS-H-5, NS-H-6, NS-H-7, NS-H-8, NS-H-9, NS-H-10, NS-H-11, NS-H-12, NS-H-13, NS-H-14, NS-H-15, NS-H-16, NS-H-17, NS-H-18, NS-H-19, NS-H-20, NS-H-21, NS-H-22 created by crossing cytoplasmic male sterile female line and male line with a fertility restorer gene, were examined during three vegetation seasons 2008, 2009, 2010, at three locations Rimski Šančevi, Erdevik in Vojvodina region and Kula in central Serbia. The following traits have been examined: seed yield, seed oil content, kernel oil content, seed protein content, kernel protein content, head diameter, kernel ratio and plant height. 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 and kernel oil content (%) was determined from absolutely clean and air dried seed on the NMR-analyzer. Seed protein content and kernel protein content

was determined by Kjeldahl method. Dehulling of a seed sample and its separation into kernel and hull.

Mutual relationships of the examined characteristics and direct and indirect effects on seed yield were analyzed by the path coefficient analysis (WRIGHT, 1921; DEWEY and LU, 1959; IVANOVIĆ and ROSIĆ, 1985). Statistical analysis was performed using MSTAT-C (1991) and SAS System Software (2003) programs.

RESULTS AND DISCUSSION

One of the basic statistical methods to study relationships between traits is simple correlation coefficient analysis AHMAD *et al*. (2013). With the analysis of simple correlation coefficients negative very strong correlation was determined between seed yield and seed oil content (-0.351**). Seed yield had negative correlation with seed oil contents ARSHAD *et al*. (2013). A negative weak correlation between seed oil content and seed yield was determined by KAYA *et al*. (2008) and ARSHAD *et al*. (2010), and in contradiction to the research performed by HLADNI *et al*. (2008) who determined a strong negative correlation between seed yield and seed oil content (-0.649**). Positive weak correlation was found while comparing seed yield with seed oil content in sunflower RADIĆ *et al*. (2013) and positive strong correlation was found with seed yield and seed oil content: HAKIM *et al*. (2007), BEHRADFAR *et al*. (2009), JALIL *et al*. (2014). Strong negative correlations were found between head diameter (-0.190*) with seed yield (Table 1). This result is agreement with KAYA *et al*. (2008), HABIB *et al*. (2006), GOLPARVAR *et al*. (2012). However, our results disagree with IQBAL *et al*. (2013), SRIDHAR *et al*. (2005), DARVISHZADEH *et al*. (2011) who found a strong positive correlation between seed yield and head diameter.

A weak negative correlation was determined for kernel oil content, seed protein content and kernel ratio with seed yield, a positive but weak correlation for kernel protein content, plant height with seed yield (Table 1). This result is in agreement with GOLPARVAR *et al*. (2012), who found a positive strong correlation between plant height and seed yield.

Table 1. Phenotypic coefficient of correlation among analyzed traits

Trait		KOC	SPC	KPC	HD	KR	PH	SY
		X2	X3	X4	X5	X6	X7	Y
SOC	X1	0.552**	0.542**	-0.398**	0.355**	0.850**	-0.257*	-0.351**
KOC	X2		0.032	-0.340**	0.091	0.441**	-0.195	-0.038
SPC	X3			-0.327**	0.260*	0.605**	0.068	-0.237
KPC	X4				-0.139	-0.510**	0.041	0.054
HD	X5					0.419**	0.103	-0.190*
KR	X6						-0.077	-0.195
PH	X7							0.097

*** F test significance at level P<0.01 * F test significance at level P<0.05* ns- *not significantly different*

X1	Seed oil content (SOC)	X5	Head diameter (HD)
X2	Kernel oil content (KOC)	X6	Kernel ratio (KR)
X3	Seed protein content (SPC)	X7	Plant height (PH)
X4	Kernel protein content (KPC)	Y	Seed yield (SY)

Was observed a very strong negative correlation of kernel protein content with seed oil content, strong negative correlation of plant height with seed oil content and a very strong positive correlation of kernel oil content, seed protein content, head diameter and kernel ratio with seed oil content. Very strong positive correlation plant height with seed oil content reported JOCKOVIĆ *et al*. (2012) and ARSHAD *et al*. (2013).

The analysis of the simple correlation coefficient shows a very strong negative correlation between kernel oil content and kernel protein content and a very strong positive correlation with kernel ratio (Table 1). Seed protein content has demonstrated a very strong negative interdependence with kernel protein content, a strong interdependence of a positive direction with head diameter. The analysis of simple correlation coefficient shows a very strong positive correlation between seed protein content (0.605^{**}), head diameter (0.419^{**}) with kernel ratio (Table 1). A very strong correlation of a negative direction was found between kernel protein content and kernel ratio and a weak correlation of a negative direction with plant height and kernel ratio. Head diameter had positive weak correlation with plant height which is disagree with research ARSHAD *et al*. (2013) and JOCKOVIĆ *et al*. (2012) who have determined very strong positive correlation head diameter with plant height. Plant height showed significant and positive correlation with head diameter consorted ANANDHAN *et al*. (2010) and SINCIK and GOKSOY (2014).

Since the values of simple correlation coefficients did not provide clear connections between the examined characteristics on one hand and seed yield on the other, the correlation relations were further analyzed by using path coefficient analysis, which included the involvement of correlation coefficients in direct and indirect effect on a specific trait (Table 2). Kernel ratio has demonstrated the strong direct effect of a positive direction on seed yield (DE=0.487*) while the simple correlation coefficient has demonstrated a weak negative correlation. The effect of the simple correlation coefficient has been masked with the negative indirect effect of the kernel ratio through seed oil content (IE=-0.706) and the positive indirect effect of kernel oil content through seed yield (IE=0.099). Seed oil content has demonstrated a very strong highly significant negative direct effect on seed yield (DE=-0.831**) which is in accordance with simple correlation coefficient. Kernel protein content has demonstrated a weak positive direct effect (DE=0.224) on seed yield while the simple correlation coefficient is weak and of the negative direction.

Simple coefficient of the correlation of kernel oil content is negative weak in comparison to the direct effect, that relation has been masked with a negative indirect effect of the kernel oil content through seed oil content (IE=-0.459) and a positive indirect effect through kernel ratio (IE=0.215). Seed protein content had a weak negative direct effect on seed yield (DE=-0.003). This relation has been masked with the positive indirect effect of seed protein content through kernel ratio (IE=0.259) as well as with the negative indirect effect of seed protein content through seed oil content (IE=-0.450). The direct effect of kernel oil content on seed yield is weak and of positive direction, its effect has been masked with the positive indirect effect kernel protein content through the seed oil content (0.331) and the negative indirect effect of kernel protein content through kernel ratio (-0.248). Correlation and direct effect between seed yield and seed protein content was positive but not significant RADIĆ *et al*. (2013).

The direct effect of head diameter on seed yield is weak and of negative direction. The existence of a weak negative simple correlation coefficient between head diameter and seed yield is the result of the indirect negative effect of seed oil content and the positive indirect effect of

kernel ratio. Negative strong direct effect (-0.812) of head diameter on seed yield indicated HABIB *et al.* (2006). Positive strong direct effect of head diameter on seed yield in sunflower reported (HLADNI *et al.*, 2006; MACHICOWA and SAETANG, 2008; YASIN and SINGH, 2010; KHOLGHI *et al.*, 2011; IQBAL *et al.* 2013).

Interdependence between plant height and seed yield is of weak positive direction (CC=0.097) while the direct effect of a negative direction on seed yield (DE=-0.022). A negative indirect effect of plant height on seed yield has been determined through positive indirect effect of seed oil content and the negative indirect effect of plant height through kernel oil content, kernel ratio and head diameter (Table 2).

Table 2. Path coefficient analysis of seed yield

Components	DE (P)	IE(Pxr)	CC (r)	Components	DE (P)	IE(Pxr)	CC (r)
Seed oil content (SOC)	-0.831**			Head diameter (HD)	-0.148		
Indirect effect KOC		0.124		Indirect effect SOC		-0.259	
Indirect effect SPC		-0.002		Indirect effect KOC		0.020	
Indirect effect KPC		-0.010		Indirect effect SPC		-0.001	
Indirect effect HD		-0.052		Indirect effect KPC		-0.004	
Indirect effect KR		0.414		Indirect effect KR		0.204	
Indirect effect PH		0.006		Indirect effect PH		-0.002	
Total			-0.351	Total			-0.190
Kernel oil content (KOC)	0.224			Kernel ratio (KR)	0.487*		
Indirect effect SOC		-0.459		Indirect effect SOC		-0.706	
Indirect effect SPC		0.001		Indirect effect KOC		0.099	
Indirect effect KPC		-0.009		Indirect effect SPC		-0.002	
Indirect effect HD		-0.013		Indirect effect KPC		-0.013	
Indirect effect KR		0.215		Indirect effect HD		-0.062	
Indirect effect PH		0.004		Indirect effect PH		0.002	
Total			-0.038	Total			-0.195
Seed protein content (SPC)	-0.003			Plant height (PH)	-0.022		
Indirect effect SOC		-0.450		Indirect effect SOC		0.214	
Indirect effect KOC		0.007		Indirect effect KOC		-0.044	
Indirect effect KPC		-0.010		Indirect effect SPC		0.000	
Indirect effect HD		-0.038		Indirect effect KPC		0.001	
Indirect effect KR		0.259		Indirect effect HD		-0.015	
Indirect effect PH		-0.002		Indirect effect KR		-0.037	
Total			-0.237	Total			0.097
Kernel protein content (KPC)	0.026						
Indirect effect SOC		0.331					
Indirect effect KOC		-0.076					
Indirect effect SPC		0.001					
Indirect effect HD		0.021					
Indirect effect KR		-0.248					
Indirect effect PH		-0.001					
Total			0.054				
Coefficient of R^2 determination 0.222							

The differences in the presented results can be explained by different plant material used by the authors in their research. In sunflower breeding for productivity, it is important to find traits, which are easy to score and in the same time demonstrate a causal connection with seed yield and therefore could be used as selection criteria. Higher seed yield is an ultimate objective of confectionary sunflower researchers. The focus should be placed on traits that have

a very strong positive direct effect with seed yield. 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 path analysis indicated that the kernel ratio has demonstrated the strongest direct effect of a positive direction on seed yield (DE=0.487*) and seed oil content had a very strong negative direct effect on seed yield (DE=-0.831**).

CONCLUSIONS

The applied path coefficient analysis gave a somewhat different picture than the one given by the correlation analysis. Path coefficient analysis has partitioned the direct and indirect effects of the yield components on seed yield of sunflower. It allowed us to detect those components which exhibit the highest effect on yield expression. The data obtained in this investigation, as well as various literature data, indicate that the characteristic such as kernel ratio is the main seed yield components which should be used as selection criteria in sunflower breeding. Seed oil content had a very strong negative direct effect on seed yield (DE=-0.831**). On the basis of the research in this paper it was determined that the kernel ratio was the most important trait for seed yield and can be used for improvement of seed yield and assessment of sunflower breeding materials.

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KORELACIJA I PATH ANALIZA PRINOSA I KOMPONENTI PRINOSA KONZUMNOG SUNCOKRETA

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Izvod

Path koeficijent analiza je primenjena radi dobijanja informacija o direktnim i indirektnim efektima proučavanih svojstava (sadržaja ulja u semenu, sadržaja ulja u jezgru, sadržaja proteina u semenu, sadržaja proteina u jezgru, prečnika glave, udela jezgra, visine biljke) na prinos semena suncokreta. Svojstva koja imaju najveći uticaj na povećanje prinosa semena suncokreta će se koristiti kao selekcioni kriterijum u oplemenjivanju konzumnog suncokreta. Istraživanje je sprovedeno tokom tri vegetacione sezone sa 22 eksperimentalna konzumna hibrida suncokreta, stvorena u oplemenjivačkom programu Instituta za ratarstvo i povrtarstvo. Između najvećeg broja ispitivanih svojstava postojale su jake i vrlo jake korelacije. Analiza prostih koeficijenata korelacije je pokazala da postoji niska međuzavisnost između sadržaja proteina u jezgru i visine biljke sa prinosom semena. Negativna slaba korelacija je pronađena između sadržaja ulja u jezgru, sadržaja proteina u semenu, udela jezgra sa prinosom semena. Ustanovljena je negativna jaka korelacija prečnika glave (-0.190^{*}) i negativna jako jaka korelacija sadržaja ulja u semenu (-0.351^{**}) sa prinosom semena. Sadržaj ulja u semenu je imao jak negativan efekat na prinos semena (DE=-0.831^{**}). Prečnik glave, visina biljke, sadržaj proteina u semenu su imali negativan slab direktan efekat na prinos semena. Sadržaj proteina u jezgru i sadržaj ulja u jezgru su ispoljili slab pozitivan efekat na prinos semena. Path koeficijent analiza je pokazala jako jak direktan efekat udela jezgra (DE=0.487^{*}) na prinos semena, to pokazuje da je udeo jezgra važan selekcioni kriterijum kod oplemenjivanja konzumnog suncokreta.

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