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Biomorphological Association and Path Analysis in Sunflower (*Helianthus annuus* L.)

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Abstract: In breeding process it is important to know the extent of association between the traits that affect the yield. Objective of this study was to determine genotypic and phenotypic correlation and path coefficients in 50 sunflower hybrid combinations in order to identify research priorities in sunflower breeding. Relationships between seed yield and five bio-morphological traits in sunflower (oil content, protein content, 1,000-seed weight, head diameter and plant height) were studied. Head diameter had the highest correlation coefficient with seed yield, at phenotypic and genotypic level. Path analysis revealed that all evaluated traits had positive influence on seed yield at both, genotypic and phenotypic, levels. The highest direct effect on seed yield was found for head diameter, while protein content had the lowest direct effect on seed yield. Study has shown that the greatest improvement in sunflower seed yield can be achieved through selection on head diameter.

Keywords: correlation, morphological traits, path analysis, seed yield

Introduction

Sunflower (*Helianthus annuus* L.) is one of the main oil crops in the world due to the convenient fatty acid of the oil with regards to human consumption (Baydar and Erbas, 2005). The main goal in sunflower breeding is to develop hybrids

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with high seed yield and high oil content and therefore to improve productivity of this important oil crop. Seed yield is a very complex trait, has low heritability and it is very dependent on environmental conditions. It depends on various plant traits and it is very important for plant breeders to find out the association between the traits themselves and with the seed yield (Škorić, 1974; Joksimović *et al*., 1999; Salahudin *et al*. 2010). Prior research has found that head diameter, 1,000-seed weight, oil content and plant height are valuable parameters to determine for seed yield improvement in sunflower (Miller and Fick, 1997; Anandhan *et al*. 2010).

Although, the simple correlation coefficients are very informative, path coefficients provide much clearer picture about relationships between traits (Kaya and Atakisi, 2003; Shankar *et al*. 2006; Yasin and Singh, 2010). Genotypic and phenotypic correlation coefficients reveal the extent of association between different traits but do not provide the clear picture of relative importance of direct and indirect effect of each trait towards seed yield. Path coefficient analysis, being a more precise method, partitions the direct and indirect effects of independent variables on the dependent one. Path coefficient analysis provides the estimation of direct effect of specific trait on seed yield, and estimation of their indirect effect via other traits. Using this method it can be determined which trait has substantial influence on seed yield thus helping in selection criteria. Being very useful method, path coefficient analysis was extensively used by many researchers on different crops (Bidgoli *et al*. 2006; Hladni *et al*. 2010; Bello *et al*. 2010; Nastasić *et al*., 2010; Srećkov *et al*., 2011; Irum *et al*. 2011; Ahmazadeh *et al*. 2012; Manggoel *et al*. 2012; Radić *et al*., 2013; Jocković *et al*., 2014).

This study was conducted in order to obtain information about association (interrelationship) between seed yield and important bio-morphological traits as well as to identify research priorities in sunflower breeding.

Materials and methods

Fifty new sunflower hybrid combinations were evaluated in this study. Hybrid combinations were created by crossing new inbred lines (standard oil type) developed at Institute of Field and Vegetable Crops in Novi Sad during 2011 and tested in 2012. The experiment for the present study was conducted at the experimental field Rimski šančevi of the Institute of Field and Vegetable Crops in Novi Sad. The field experiment was laid out in a randomized block design with three replicates. Basic plot size was 10 m^2, with four 3.6 m long rows and

70 × 30 cm plant spacing. The middle rows were used for data and harvest was done by hand. The data were recorded on 20 plants in each replicate. Head diameter (HD) and plant height (PH) were measured at the stage of physiological maturity. Oil content (OC) was determined using nuclear magnetic resonance analyser (NMR model MARAN Ultra: Oxford-England). Protein content (PC) was determined by conventional micro method according to Kjeldahl. Seed yield/ plant (SY) with moisture of 9% and 1,000-seed weight (TSW) were recorded in laboratory. Average values of the evaluated traits are given in Table 1.

Table 1: Average values for biomorphological traits in sunflower.

Genotype	OC (%)	PC (%)	TSW (g)	HD (cm)	PH (cm)	SY (g)
NS-H-1	51.30	15.94	58.53	22.63	225.53	79.42
NS-H-2	48.99	15.95	61.78	21.82	230.25	79.98
NS-H-3	47.73	15.39	54.52	22.30	224.42	89.92
NS-H-4	49.95	16.85	60.07	21.37	221.67	87.50
NS-H-5	50.40	15.40	51.95	21.37	206.67	68.28
NS-H-6	47.38	18.63	58.71	21.28	222.83	90.98
NS-H-7	48.52	17.22	56.73	20.47	230.00	81.72
NS-H-8	48.80	17.16	60.32	20.72	224.58	87.14
NS-H-9	47.56	18.41	62.78	21.25	221.13	83.15
NS-H-10	48.21	17.63	68.53	23.83	203.90	99.11
NS-H-11	46.51	16.95	57.23	21.68	215.17	78.80
NS-H-12	45.81	18.32	62.90	22.50	224.00	90.19
NS-H-13	47.75	17.82	62.79	21.37	229.17	92.68
NS-H-14	47.85	19.11	64.91	21.83	219.15	88.89
NS-H-15	50.22	16.11	51.43	22.67	226.00	90.57
NS-H-16	48.47	14.95	52.52	23.05	250.17	97.23
NS-H-17	47.79	15.40	55.42	23.93	215.58	109.48
NS-H-18	50.32	15.62	56.28	23.40	212.00	84.05
NS-H-19	48.50	15.17	62.01	22.13	192.83	87.25
NS-H-20	45.59	17.10	55.96	22.00	201.20	83.93
NS-H-21	47.60	17.11	54.37	23.48	197.70	90.30
NS-H-22	49.20	16.84	56.40	22.00	203.75	91.82
NS-H-23	51.37	15.85	55.31	22.35	202.50	90.87
NS-H-24	43.56	18.47	54.08	22.55	201.08	82.11
NS-H-25	49.04	16.35	54.77	21.92	202.00	89.67
NS-H-26	50.42	16.23	72.86	21.80	216.42	91.83
NS-H-27	49.48	15.52	70.23	20.43	214.75	81.33
NS-H-28	48.74	16.46	67.86	19.42	205.50	86.28
NS-H-29	47.66	17.71	69.40	20.17	201.50	86.66
NS-H-30	47.62	18.09	73.95	19.32	202.67	81.03

(*continued*)

Table 1: (*continued*)

Genotype	OC (%)	PC (%)	TSW (g)	HD (cm)	PH (cm)	SY (g)
NS-H-31	49.54	17.09	61.08	19.17	205.42	86.84
NS-H-32	49.01	17.36	65.15	19.45	200.67	87.40
NS-H-33	49.23	17.44	77.23	19.12	209.17	85.17
NS-H-34	51.84	15.63	72.58	19.82	199.34	86.34
NS-H-35	47.87	17.64	64.48	19.65	205.22	84.41
NS-H-36	44.73	18.97	64.58	18.67	208.12	75.64
NS-H-37	47.33	17.90	65.98	19.23	211.70	88.68
NS-H-38	47.42	16.57	66.85	19.25	209.48	80.09
NS-H-39	49.44	16.25	73.88	22.70	228.17	106.21
NS-H-40	53.24	14.63	47.39	23.75	225.50	99.23
NS-H-41	50.48	15.90	60.25	24.53	220.38	99.73
NS-H-42	44.98	15.75	50.59	21.78	202.38	80.23
NS-H-43	50.06	15.39	44.93	19.82	209.62	76.98
NS-H-44	52.19	15.80	52.64	20.70	225.42	87.03
NS-H-45	51.34	15.59	54.40	20.87	220.17	75.88
NS-H-46	52.78	15.38	56.57	21.68	213.80	82.28
NS-H-47	50.11	17.12	51.32	23.30	210.83	88.64
NS-H-48	51.20	16.62	51.71	21.30	225.75	89.30
NS-H-49	49.68	15.01	45.53	20.77	222.25	78.97
NS-H-50	53.80	14.31	55.58	21.57	221.83	89.75
LSD 5%	3.98	3.25	10.90	1.81	10.79	14.56

Correlation coefficients, at genotypic and phenotypic level, were estimated from the analysis of variance and covariance according to the procedure of Singh and Chaudhary (1977). For testing significance of correlation coefficients t-test was applied. Path coefficient analysis was done according to method designed by Wright (1921) and applied by Dewey and Lu (1959). Direct effects were tested using standard errors (SE):

$$SE_{pyk} = \sqrt{\frac{1 - R^2_{yk}}{(n - k - 1) \times (1 - R^2_i)}} \quad F = \left[\frac{P_{yk}}{SE_{pyk}}\right]^2$$

R^2_{yk} – coefficient of determination
n – number of genotypes
k – number of independent variables
$R_i^2 = 1/r_i$; r_i – elements of the inverse matrix diagonal
P_{yk} – direct effect

Basic meteorological data for vegetation period in 2012 at Rimski šančevi (average monthly temperatures in °C and sum of monthly precipitation in mm) are presented in Table 2.

Table 2: Average temperatures (°C) and precipitation (mm) at Rimski šančevi during vegetation period in 2012.

2012	March	April	May	June	July	August	September	October
Temperature (°C)	8.1	13.0	17.4	22.9	25.2	24.6	19.8	12.7
Precipitation (mm)	4.1	82.8	52.2	27.9	47.7	3.5	13.1	51.4

Results and discussion

Year 2012 was the second hottest in last 60 years (http://www.hidmet.gov.rs). Small amount of rainfall and high air temperatures in the early summer have caused severe to extreme drought conditions throughout the territory of Serbia. Also very important period for grain filling in sunflower during August was accompanied by a small amount of rainfall and high temperatures.

Genotypic and phenotypic association revealed that most of the investigated characters had positive effect on seed yield (Table 3). Correlation coefficients were in generally higher at genotypic level, indicating that association between traits was mostly influenced by genetic causes. The highest correlation with seed

Table 3: Genotypic (rg) and phenotypic (rp) correlation coefficients of studied traits on seed yield/plant (g) in sunflower.

Trait	r	OC	PC	TSW	HD	PH	SY
OC	rg	1	−0.826**	−.177	0.271	0.253	0.338*
	rp	1	−0.634**	−0.175	−0.002	0.245	−0.014
PC	rg		1	0.834**	−0.877**	−0.246	−0.417**
	rp		1	0.321*	−0.101	−0.202	0.028
TSW	rg			1	−0.530**	−0.251	0.063
	rp			1	−0.251	−0.174	0.152
HD	rg				1	0.339*	0.493**
	rp				1	0.120	0.607**
PH	rg					1	0.409**
	rp					1	0.086

Note: *$p < 0.05$; **$p < 0.01$; OC: oil content; PC: protein content; TSW: 1,000-seed weight; HD: head diameter; PL: plant height; SY: seed yield/plant.

yield at both, genotypic and phenotypic, levels was obtained for head diameter. In study of Anandhan *et al.* (2010) where they evaluated 55 newly developed hybrids head diameter had significant and positive effect on seed yield, but the biggest contribution on seed yield was found for oil yield/plant. Plants with larger heads produce more seeds and thus increase seed yield. This indicates that the greatest progress in sunflower breeding can be achieved through selection on head diameter. High association between head diameter and seed yield was also reported by other authors (Marinković, 1992; Behradfar *et al.* 2009; Hladni *et al.* 2010).

Plant height was highly significant and positively associated with seed yield at genotypic level, while at phenotypic level association was positive but not significant. Taller plants usually have larger heads, thus increasing seed yield, which is confirmed with significant positive association between plant height and head diameter obtained in this study. Earlier findings of Tahir *et al.* (2002) showed that plant height had highly significant and positive association with seed yield and head diameter at both, genotypic and phenotypic, levels.

Trait 1,000-seed weight exhibited positive but not significant association with seed yield at both investigated levels. In agreement with this study Farhatullah *et al.* (2006) previously reported similar results, while studies of Tahir *et al.* (2002) and Yasin and Singh (2010) reported highly significant and positive correlation between 1,000-seed weight and seed yield. Trait 1,000-seed weight is an important yield component, but it is strongly influenced by environmental factors, especially water availability in the period of seed filling. Low influence of 1,000-seed weight on seed yield can be explained by the fact that smaller heads form less number of seeds which are usually better filled. This can be confirmed with the fact that association between 1,000-seed weight and head diameter was found to be highly significant and negative at genotypic level, while negative but not significant at phenotypic level. Contrary to our results, in study of Joksimović *et al.* (2004) correlation between 1,000-seed weight and head diameter was highly significant and positive.

Oil content had significant and positive association with seed yield on genotypic level, while negative but not significant at phenotypic level. Higher and significant value of genotypic correlation coefficient than its corresponding phenotypic correlation coefficient of oil content with seed yield indicate true genetic association between these traits. Earlier, Arshad *et al.* (2007) found that oil content had significant and positive correlation with seed yield at both, genotypic and phenotypic, levels.

Protein content had highly significant negative association with seed yield at genotypic level, while at phenotypic level association was positive but not significant. As expected, association between protein content and oil content was highly significant and negative. Joksimović *et al.* (2004) found highly significant and positive correlation between oil content and protein content. Bearing in mind that all material used in this study belongs to oil type of sunflower, and seed oil content represent an important part of seed yield, with protein content increasing oil content and seed yield were decreasing.

Path coefficient analysis was used to determine direct and indirect effect of studied traits on seed yield (Table 4). Relatively low coefficient of determination (R^2) at genotypic (0.50) and phenotypic (0.47) level give rise to high residual effects (0.70 and 0.73) meaning that besides variables used in this study other causal variables are also responsible for seed yield. Separation of correlation coefficients into direct and indirect effects revealed that all evaluated traits had positive direct effect on seed yield at both, genotypic and phenotypic, levels.

Table 4: Direct (bold) and indirect effect at genotypic (upper) and phenotypic (lower) level of studied traits on seed yield/plant (g) in sunflower.

Trait	OC	PC	TSW	HD	PH	SY (r)
OC	**0.315****	−0.158	−0.069	0.190	0.060	0.338*
	0.056	−0.023	−0.058	−0.002	0.014	−0.014
PC	−0.260	**0.191***	0.327	−0.617	−0.058	−0.417**
	−0.035	**0.037**	0.107	−0.069	−0.011	0.028
TSWW	−0.056	0.159	**0.392***	−0.373	−0.059	0.063
	−0.010	0.012	**0.332**	−0.173	−0.010	0.152
HD	0.085	−0.167	−0.208	**0.703****	0.080	0.493**
	0.000	−0.004	−0.083	**0.687**	0.007	0.607**
PH	0.080	−0.047	−0.098	0.239	**0.236**	0.409**
	0.014	−0.007	−0.058	0.082	**0.055**	0.086
R^2g	0.50	Genotypic coefficient of determination				
R^2p	0.47	Phenotypic coefficient of determination				
Rg	0.71	Genotypic residual effect				
Rp	0.73	Phenotypic residual effect				

Note: *$p < 0.05$; **$p < 0.01$; OC: oil content; PC: protein content; TSW: 1,000-seed weight; HD: head diameter; PL: plant height; SY: seed yield/plant.

The highest direct effect on seed yield was determined for head diameter, at both investigated levels, while at genotypic level the effect was highly significant. Highly significant direct effect on seed yield was also found for oil content, while for protein content and 1,000-seed weight the effect was statistically significant, at genotypic level. Higher values of the direct effects of head diameter on seed yield than the values of correlation coefficients indicate that direct selection through this trait on seed yield improvement would be effective (Figure 1).

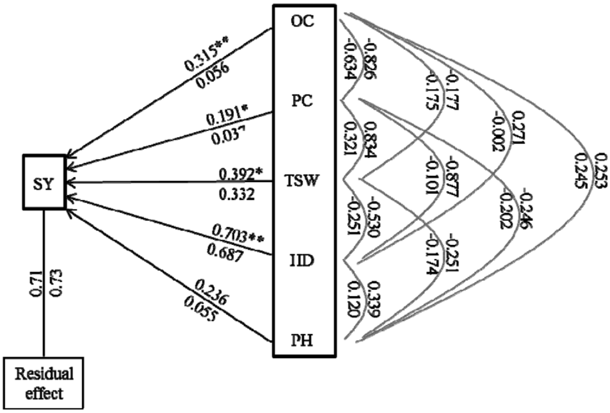

Figure 1: Genotypic (upper value) and phenotypic (lower value) path diagram showing direct effect.

Considering the aforementioned, head diameter is reliable selection criteria for seed yield improvement in sunflower. High positive direct effect of head diameter on seed yield was also reported in previous studies by other authors (Farhatullah *et al.* 2006; Machikowa and Saetang, 2008; Yasin and Singh, 2010). Earlier, Alba *et al.* (1979), Marinković (1992) and Chikkadevaiah *et al.* (2002) reported negative direct effect of head diameter on seed yield. Indirect effect of head diameter on seed yield was found to be positive via oil content and plant height, while negative via protein content and 1,000-seed weight, in this study.

Plant height had positive direct effect on seed yield, at genotypic and phenotypic level. Positive direct effect of plant height on seed yield was also reported by Arshad *et al.* (2007) while Kaya *et al.* (2009) found that plant height had the highest direct effect on seed yield. Plant height had positive indirect effect via oil content and head diameter as well as negative indirect effect via protein content and 1,000-seed weight. Tahir *et al.* (2002) and Farhatullah *et al.* (2006) also reported negative indirect effect of plant height via 1,000-seed weight, while Kaya *et al.* (2009) found that indirect effect of plant height via 1,000-seed weight on seed yield was positive. Positive direct effect of plant height, as well as highly positive correlation coefficients of this trait with seed yield indicate that breeding on this trait can be effective for seed yield improvement.

Trait 1,000-seed weight had positive and second the highest direct effect on seed yield at both investigated levels. Indirect effect of 1,000-seed weight was positive via protein content. However, negative indirect effect of 1,000-seed weight via oil content, head diameter and plant height contributed to a low and insignificant correlation coefficients. Although the values of direct effects of 1,000-seed weight on seed yield were second the highest, low and insignificant correlation coefficients of this trait with seed yield indicate that direct selection through this trait would not be very effective. Yasin and Singh (2010) and Farhatullah *et al.* (2006) reported that 1,000-seed weight had the highest direct effect on seed yield.

Oil content had positive direct effect on seed yield and positive indirect effect via plant height, at genotypic and phenotypic level. Positive indirect effect of oil content was also expressed via head diameter, at genotypic level. Oil content has expressed negative indirect effect on seed yield via protein content and 1,000-seed weight, at both levels, and via head diameter at phenotypic level. Positive direct effects of oil content on seed yield and significant positive genotypic correlation of this trait with seed yield indicate that direct selection for seed yield improvement through this trait can be effective. Consistent with ours, the results of Marinković (1992), Habib *et al.* (2007) and Machikowa and Saetang (2009) also confirmed positive direct effect of oil content on seed yield. Arshad *et al.* (2007) and Kaya *et al.* (2009) found that oil content had negative direct effect on seed yield as well as negative indirect effect via plant height.

Protein content had the lowest direct effect on seed yield. Although the direct effect was positive, high negative indirect effect via head diameter contributed to highly significant negative association with seed yield at genotypic level indicating that direct selection on seed yield through this trait would not be effective. Protein content also had negative indirect effect on seed yield via oil content and plant height. Positive indirect effect of protein content on seed yield was expressed via 1,000-seed weight.

Conclusions

Progress in seed yield relies upon relationships of components that affect the yield, as well as bringing these components into optimal balance that will enable the best productivity of plants. Knowing the portion of direct and indirect effects in the overall correlation allows us to analyse the contribution of traits and thus enable us to make the best choice in the selection for yield improvement. In this preliminary report, correlation and path coefficient analysis revealed that the greatest improvement in sunflower seed yield can be achieved through selection on head diameter because it has the highest and significant correlation coefficients, as well as the highest direct effect on seed yield. Bearing in mind the quantitative nature of the studied traits this research is being continued in order to thoroughly investigate interrelationships between these traits.

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