Direct and indirect effects of morphophysiological traits on seed yield of sunflower (*Helianthus annuus* L.)

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ABSTRACT

In this paper, we have studied the interdependence of seed yield per plant and the following morphophysiological traits: total leaf number per plant, total leaf area per plant, plant height, total seed number per head, head diameter, weight of 1,000 seeds and oil content. Path coefficient analysis was used to separate direct and indirect effects of studied traits on seed yield, and to identify traits that could be used as selection criteria in sunflower breeding. The research was conducted during two vegetation seasons on 21 experimental sunflower hybrids, produced within the breeding program at the Institute of Field and Vegetable Crops. Among the large number of examined traits, significant and highly significant correlations were found. A strong positive correlation between the weight of 1,000 seeds and seed yield (0.791^{**}) was determined. On the contrary, a strong negative correlation between oil content and seed yield was found (-0.649^{**}). The biggest highly significant positive effect on seed yield was determined for the following traits: the weight of 1,000 seeds (0.789^{**}), total seed number per head (0.473^{**}) and total leaf number per plant (0.199^{**}). Total leaf area per plant has demonstrated a significant direct positive effect on seed yield (0.139^{*}). The weight of 1,000 seeds and total seed number per head were the most important traits for seed yield. Based on the coefficient of determination in F_1 generation (R^2=0.92), it can be concluded that the influence of all traits involved in the study on total variability of seed yield per plant, was 92%.

Key words: correlations – hybrids – path analysis – quantitative traits.

INTRODUCTION

The basic direction in sunflower breeding at the Institute of Field and Vegetable Crops, Novi Sad is the creation of hybrids with high genetic potential for seed yield (above 5t/ha) and the seed oil content (>50%) providing oil yield per hectare over 2.5 t (Miklič et al., 2008).

Breeding for high seed yield, components of seed yield and creating new sunflower ideotypes demands an increase of genetic variability of sunflower by interspecies hybridization (Škorić et al., 2007).

High seed yield and oil content are the two important criteria for introducing new hybrids in the production. These two traits, however, pose problems for breeders because they are both characterized by low heritability and affected by genotype x environment interaction.

In sunflower breeding for productivity, it is important to find morphophysiological traits, which are easy to score and, at the same time demonstrate a causal connection with the seed yield, and, therefore which could be used as selection criteria (Škorić et al., 2002). The mutual connection of seed yield with morphophysiological traits is often studied by the simple correlation coefficient analysis (Škorić, 1974; Marinković, 1992; Hladni, 2006). Since the simple correlation analysis cannot fully explain the relationships between characters, the path coefficient analysis is introduced for more successful breeding work. This type of analysis enables the partition of correlation coefficients to their components, which, in turn, allows the separation of a direct effect of one variable from indirect effects of other variables, thus giving a clear picture of the individual contribution of each variable to the seed yield.

Positive direct effects of total leaf area and plant height (Hladni et al., 2004), total seed per head (Gonzales et al., 2000) and weight of 1,000 seeds (Marinković, 1992; Gonzales et al., 2000) on seed yield were found. However, different results were obtained for the effects of the oil content on the seed yield. Positive direct effects (Chaudhary and Anand, 1993; Razi and Assad, 1999) as well as negative direct effects (Doddamani et al., 1997) of oil content on seed yield per plant were established.

In this paper, we studied mutual relationships between several morphophysiological traits on one side and seed yield on the other, as well as the direct and indirect effects of these components on seed yield of sunflower hybrids of CMS inbred lines originating from interspecies crosses.

MATERIALS AND METHODS

In this research, 21 experimental hybrids, developed by using new divergent (A) CMS inbred lines were used. Female inbred lines (NS-GS-1, NS-GS-2, NS-GS-3, NS-GS-4, NS-GS-5, NS-GS-6, NS-GS-7) developed from interspecies hybridization and restorer inbred lines with good combining characteristics (RHA-R-PL-2/1, RHA-N-49, RUS-RF-OL-168) were created at the Institute of Field and Vegetable Crops, Novi Sad.

The experiment was set up at an experimental field of the Institute of Field and Vegetable Crops at Rimski Šančevi, in a randomized complete block system with three replications, during the period of two vegetation seasons. The soil was characterized by 2.8% humus content, moderate content of phosphorus and potassium and pH 6.92 (Vasin et al., 2002).

The basic sample for analysis of the examined trait consisted of thirty plants (ten plants per replication) sampled from middle rows of each block.

Plants in the flowering stage were transferred to the laboratory and the total leaf number per plant (TLN), as well as the total leaf area per plant (TLA; cm^2/plant) were measured on the leaf area meter (LI-300-LiCOR, USA). At the stage of physiological maturity the plant height (PH) and head diameter (HD) were measured (cm) in the field. After the harvest, the seed yield (SY) produced in free fertilization for every single plant was measured by technical balance in the laboratory. The number of full seeds per head (total seed number-TSN) was determined by counting. On a random sample of completely pure and air dried seed the weight of 1,000 seeds (M1000S) was determined (g). The analysis of oil content (OC) in seed was carried out nondestructively on a nuclear magnetic resonance (NMR) analyzer. The determination of main values and the correlation coefficients (r) was carried out according to Hadživuković (1991). The strength and the direction of the correlation was determined according to the Roemer-Orphalov scale.

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, 1952). Statistical analysis was performed using Mstat C (1991) and SAS System Software (2003) programs.

RESULTS AND DISCUSSION

Knowing the mutual relationships between different yield components as well as the dependence of seed yield on different yield components is an important precondition for a successful application of suitable selection criteria in sunflower breeding. Presence or absence of correlations can contribute to the right choice of examined traits so as to enhance the efficiency of some selection criteria.

Positive highly significant interdependence between SY and M1000S (0.791^{**}), TLA (0.623^{**}), HD (0.446^{**}), TSN (0.369^{**}), is shown in (Table 1). Similar results of highly significant correlations between SY and: M1000S, TSN (Dagustu, 2002; Dušanić et al., 2004), TLA (Merrien et al., 1982; Joksimović et al., 1999; Hladni et al., 2001), and HD (Hladni et al., 2003; Mijić et al., 2006) were obtained by others.

Table 1. Phenotypic coefficient of correlation among analyzed traits

Trait		TLA	PH	HD	TSN	M1000S	OC	SY
		X2	X3	X4	X5	X6	X7	y
TLN	X1	-0.202^{ns}	0.566^{**}	-0.452^{**}	-0.075^{ns}	0.010^{ns}	0.168^{ns}	0.087^{ns}
TLA	X2		-0.161^{ns}	0.602^{**}	0.253^{*}	0.461^{**}	-0.461^{**}	0.623^{**}
PH	X3			-0.544^{**}	0.040^{ns}	0.220^{*}	-0.011^{ns}	0.199^{ns}
HD	X4				0.297^{*}	0.291^{**}	-0.589^{**}	0.446^{**}
TSN	X5					-0.164^{ns}	0.090^{ns}	0.369^{**}
M1000S	X6						-0.786^{**}	0.791^{**}
OC	X7							$-0,649^{**}$

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

X1	total leaf number (TLN)	X5	Total seed number per head (TSN)
X2	total leaf area per plant (TLA)	X6	Mass of 1000 seed (M1000S))
X3	plant height (PH)	X7	Oil content (OC)
X4	head diameter (HD)	Y	seed yield per plant (SY)

Highly significant negative interdependence was established between SY and OC (-0.649^{**}), which is in agreement with the research of Doddamani et al. (1997), and in disagreement with the research of Chaudhary and Anand (1993) and Razi et al. (1999).

There was no correlation between TLN and SY, which is in disagreement with the research of Chaudhary and Anand (1993), El-Hosary et al. (1999) and Dagustu (2002), who determined a positive and significant correlation of TLN and SY. Significant positive interdependence was not established between PH and SY which was detected by others (Marinković, 1992; Hladni i sar., 2003; Mijić et al., 2006).

A positive highly significant interdependence was established between TLN and PH (0.566**); TLA and HD (0.602**); TLA and M1000S (0.461**); HD and M1000S (0.291**). The positive significant connection between TLA and HD was determined by Hladni et al. (2004).

Negative highly significant interdependence was established between M1000S and OC (-0.786**), HD and OC (-0.585**), PH and HD (-0.544**), TLA and OC (-0.461**), TLN and HD (-0.452**). These results are in agreement with the investigations of Punnia and Gill (1994) who determined the negative significant interdependence of M1000S and OC.

The correlation relations were further analyzed by using path coefficient analyses which include the involvement of correlation coefficients in direct and indirect effect on a specific trait (Table 2).

M1000S (0.789**) and TSN (0.473**) have the biggest positive effect on SY, which justifies the existence of a highly significant simple correlation and confirms that these two traits are important components of seed yield. These results are in agreement with the work of Marinković (1992) and Dušanić et al. (2004).

A positive direct influence of TSN on SY was also demonstrated by others (Škorić, 1974; Marinković and Škorić, 1988; Punia and Gill, 1994). A high direct effect of the M1000S on SY was noted both under good water supply conditions as well as under limited water conditions (Razi et al., 1999).

TLN has shown an important direct effect on SY. These results are in agreement with the research of Razi et al. (1999) and Nirmala et al. (2000), but are in disagreement with the results published by Marinković and Škorić (1988).

TLA has shown a positive significant direct effect on seed yield. These results are in agreement with the work by Alba et al. (1979).

Other traits in the investigation have shown a significantly lower direct influence, which means they had an indirect influence through other traits. The direct influence of HD and SY was not significant, which means that the HD had a high and indirect positive influence through M1000S and TSN. Different results were obtained by Green (1980) and Nirmala et al. (2000), who state that HD has a significant direct influence on SY, while according to Škorić (1974), Fick et al. (1974) and Hladni et al. (2004) that influence was negative.

Negative direct influences of OC on SY was not significant which means that OC had a high indirect influence and a negative one through M1000S.

Table 2. Path coefficient analysis of grain yield

Traits	Direct effects	Indirect effects via							r* SY
		TLN	TLA	PH	HD	TSN	M1000S	OC	
TLN	0.1990*		-0.0281	-0.0373	-0.0151	-0.0354	0.0079	-0.0038	0.082
T L A	0.1390*	-0.0402		0.0106	0.0201	0.1196	0.3637	0.0104	0.6232
P H	-0.0659	0.1126	-0.0224		-0.0182	0.0189	0.1736	0.0002	0.1988
H D	0.0334	-0.0899	0.0837	0.0358		0.1404	0.2296	0.0133	0.4463
TS N	0.4726**	-0.0149	0.0352	-0.0026	0.0099		-0.1294	-0.0020	0.3688
M1000S	0.7889**	0.0020	0.0641	-0.0145	0.0097	-0.0775		0.0178	0.7905
OC	-0.0226	0.0334	-0.0641	0.0007	-0.0197	0.0425	-0.6201		-0.6499

r*- Correlation coefficient
Determination coefficient: R^2= 0.918

The differences in acquired results can be explained by different plant material which the authors used in their research.

In sunflower breeding, attention should be paid to the ways in which the increase in morphophysiological components influences the SY.

In this research, with the increase in TLA, HD, M1000S ,SY also increased, but OC decreased. Similary the increase in HD led to the increase in TNL, M1000S and SY, and to the decrease in OC. The increase in TSN and M1000S would cause an increase in SY. In short, the increase in TLN, HD, TSN and M1000S influences the increase in SY.

Path coefficient analysis helped to separate direct and indirect effects of individual traits on SY and identify traits such as M1000S and TSN, which should be used as selection criteria in sunflower breeding.

CONCLUSIONS

A positive highly significant interdependence has been established between seed yield per plant and total leaf area per plant (0.623^{**}), head diameter (0.446^{**}), total seed number per head, (0.369^{**}) and mass of 1000 seed (0.791^{**}). Highly significant negative effect was established between seed yield per plant and oil content (-0.649^{**}).

The path coefficient analysis applied gave a somewhat different picture from what the correlation analysis did. The path coefficient analysis partitioned the direct and indirect effects of the morphophysiological 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 morphophysiological character: mass of 1000 seed, total seed number per head, total leaf number and total leaf area per plant are the main yield components which should be used as selection criteria in sunflower breeding .

The coefficient of determination (R^2) was 0.92 which indicates that the influence of all traits involved in the study affected 92% of total variability in seed yield per plant.

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