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Interrelationship Between 1000 Seed Weight with Other Quantitative Traits in Confectionary Sunflower

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ABSTRACT

Breeding for increase in 1000 seed weight, results in increased seed yield. Therefore it is considered an important criterion in the development of confectionary sunflower hybrids. In this paper, we studied mutual relationships among several quantitative traits on one hand, and between 1000 seed weight on the other. Path coefficient analysis was used to separate direct and indirect effects of studied traits on 1000 seed weight, and to identify traits that could be used as selection criteria in sunflower breeding. The research was conducted during three vegetation seasons on 22 NS high-protein two-line confectionary sunflower hybrids, produced within the breeding program at IFVCNS, Novi Sad, Serbia. Significant and highly significant correlations were found among the largest number of examined traits. The analysis of simple correlation coefficients showed a highly significant positive correlation between 1000 seed weight and length of seed (0.717^{**}), seed hull ratio (0.609^{**}) and significant positive correlation with thickness of seed (0.549^{*}). A significant negative interdependence was determined between 1000 seed weight and seed protein content (-0.538^{*}). Path coefficient analysis for 1000 seed weight at phenotypic level showed that the length of seed and thickness of seed had a highly significant direct positive effect on 1000 seed weight ($DE=0.849^{**}$; $DE=0.748^{**}$). Width of seed had a strong negative direct effect on 1000 seed weight ($DE=-387^{*}$). A weak direct negative effect of kernel protein content and seed hull ratio was established, whereas seed protein content had a weak direct positive effect on 1000 seed weight. This indicates that length and thickness of seed have high influence on 1000 seed weight.

Keywords: confectionary sunflower, correlations, 1000 seed weight, path coefficient analysis, quantitative traits

Introduction

Although sunflower is mainly grown for the production of vegetable oils in the world, it is one of the most preferred confectionary seeds in Turkey, Eastern Europe, US, Canada, and in some Asian countries, such as China, Pakistan, Iran, Middle East countries, etc. (Pekcan *et al*. 2015). Confectionary sunflower produces large seeds with low oil contents, which are used in baking and as a snack food (Lu and Hoeft 2009). Although the favored seed color of confectionary hybrid in Turkey is white with grey stripes, consumers from Balkan countries such as Serbia, Bulgaria, Moldova and Romania prefer black seeds (Sincik and Goksoy 2014). The major breeding objectives for all sunflower types should be high yields and quality of oil, proteins and other products for food and non-food industries, approach to management of resistance genes, and stability of sunflower resistance to certain pathogens (Škorić *et al*. 2012). Besides their seed oil content, seeds of confectionary and oil type sunflower are distinguished by their hullability, shell color, seed weight and morphology, and kernel-to-pericarp weight ratio (Hladni *et al*. 2011). Seed of high protein sunflower is usually black with white stripes, or colorful and 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). The selection for seed size i.e. for increased mass of 1000 seeds may be an important criterion in sunflower yield increase (Jocić *et al*. 2000). The best confectionary types should have the oil content lower than 30%, and husk content up to 50% (Kaya *et al*. 2009). However, large kernel size is the characteristic of confectionary sunflower most preferred by customers. Thus , in addition to seed yield, 1000 seed weight and seed size are major interests in confectionary sunflower breeding (Pekcan *et al*. 2015).

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 decrease of its content in the seed (<40%), increase of kernel ratio and decrease of shell ratio, uniformity in seed size and color, dehulling, as well as tolerance to dominant diseases in the cultivation region (Hladni *et al*. 2009).

Mass of 1000 seeds belongs to the major yield components, breeding for increase of the mass of 1000 seeds leads to seed yield increase, so this trait is used as selection criteria when creating sunflower hybrids (Miller and Fick 1997; Kaya *et al*. 2003; Goksoy and Turan 2007; Hladni *et al*. 2008; Yasin and Singh 2010; Kholghi *et al*. 2011). Seed protein content and mass of 1000 seeds demonstrated a strong positive correlation with protein yield, which means that breeding for these components is simultaneously breeding for protein yield (Hladni *et al*. 2011). Plant breeders commonly prefer yield components that indirectly increase yield (Kaya *et al*. 2007).

The aim of this paper was to determine the interdependence between 1000 seed weight and seed protein content, kernel protein content, hull ratio, length of seed, width of seed and thickness of seed.

Materials and methods

The research was conducted during three vegetation seasons on 22 confectionary sunflower hybrids, produced within the breeding program at the Institute of Field and Vegetable Crops. Novi Sad, Serbia. 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 genotype, were examined during three vegetation seasons (2008, 2009, 2010), at three locations: Rimski Šančevi, Erdevik in the Vojvodina region, and Kula in central Serbia. The following traits were examined: 1000 seed weight, seed protein content, kernel protein content, hull ratio, length of seed, width of seed and thickness of seed. The plot where the experiment was conducted was 28 m^2 in size and 70cm x 28cm plant density was used. Seeds were planted by hand in 4 rows in April, and all plants from the two middle rows were harvested in September except for the first plants on each plot. The experiment was done as a randomized complete block design with 3 replications. Mass of 1000 seeds (g) was measured on a random sample of absolutely clean and air-dried seed. Seed protein content and kernel protein content was determined by a conventional micro Kjeldahl method. Hull ratio was determined by dehulling the seeds and their separation into kernel and hull. Length of seed, width of seed and thickness of seed (mm) was measured using a vernier caliper.

Mutual relationships of the examined characteristics, and their direct and indirect effects on seed yield, were analyzed using the path coefficient analysis (Wright 1921; Dewey and Lu 1959; Ivanović and Rosić 1985). Statistical analysis was performed using R (2014).

Results and discussion

In the development of new high-protein hybrids for confectionary use, it is important to find the traits that are easily determined and show their interdependence with 1000 seed weight, based on which those traits could be defined as selection criteria.

The analysis of simple correlation coefficients showed a significant negative correlation between 1000 seed weight and seed protein content (-0.538*). This result is in contradiction to the research performed by Radić *et al*. (2013) who determined weak positive correlations between 1000 seed weight and seed protein content, and findings of Joksimović *et al*. (1999), Dagustu (2002) and Drumeva *et al*. (2011), who determined a significant positive correlation between 1000 seed weight and seed protein content.

A highly significant positive correlation was found between 1000 seed weight and the length of seed as well as hull ratio. A significant positive correlation was found between thickness of seed and width of seed. A nonsignificant positive correlation was determined between width of seed and kernel protein content and 1000 seed weight (Table 1). This result is in agreement with the findings of Kaya *et al*.

(2008) who stated a very strong positive correlation between hull ratio and 1000 seed weight, and Li *et al*. (2010) who found a strong positive correlation between hull ratio and 1000 seed weight. However, our results are in disagreement with Ergen and Saglam 2005; Kaya *et al*. 2009, who found a strong negative correlation between hull ratio and 1000 seed weight.

A highly significant negative correlation was observed between seed protein content and both seed hull ratio and length of seed, whereas it exhibited a significant negative correlation with seed thickness, and a nonsignificant negative correlation with kernel protein content and width of seed. These results are in agreement to the findings of Ergen and Saglam (2005) who determined a strong negative correlation between seed protein content and hull ratio.

The analysis of the simple correlation coefficient showed a significant positive correlation between kernel protein content and hull ratio, and a nonsignificant positive correlation with length of seed, width of seed and thickness of seed (Table 1). Hull ratio demonstrated a highly significant positive interdependence with length of seed and width of seed (0.734^{**};0.671^{**}), and a significant positive interdependence with thickness of seed. The analysis of simple correlation coefficient showed a significant negative correlation between length of seed and thickness of seed, as well as a nonsignificant positive interdependence with thickness of seed. Width of seed had a highly significant positive correlation with thickness of seed (Table 1).

Since the values of simple correlation coefficients did not provide clear connections between the examined characteristics on one hand and 1000 seed weight on the other, their correlations were further analyzed by using path coefficient analysis to determine the involvement of correlation coefficients in a direct and indirect effect on a specific trait (Table 2). Path coefficient analysis for 1000 seed weight at the phenotypic level showed that the length of seed and thickness of seed had a very strong direct positive effect on 1000 seed weight (DE=0.849^{**} ; DE=0.748^{**}), which is in accordance with the simple correlation coefficient. Width of seed had a strong negative direct effect on 1000 seed weight (DE=-387^{*}), which is discordance with the simple correlation coefficient as the simple correlation coefficient is significant positive. The effect of the simple correlation coefficient was masked with the indirect effect of the width of seed through length of seed and thickness of seed. Seed protein content demonstrated a weak positive direct effect (DE=0.113) on 1000 seed weight, while the simple correlation coefficient is very strong and in the opposite direction. The direct effect of seed protein content was masked by its negative indirect effect through the length of seed (ID=-0.515) and thickness of seed (ID=-0.280), and by the positive indirect effect through the width of seed (IE=0.113).

Kernel protein content had a weak negative direct effect on 1000 seed weight (DE=-0.052), while the simple correlation coefficient is weak and of the positive direction. The existence of a weak positive simple correlation coefficient between 1000 seed weight and kernel protein content is the result of the indirect positive effect of kernel protein content through length of seed (IE=0.274) and thickness of seed (IE=-0.188). Joksimović *et al*. (2004) found that protein content had a very strong negative direct effect on 1000-seed weight (-0.840), which was in agreement with the very strong negative correlation based on simple correlation coefficients.

Hull ratio had a weak negative direct effect (DE=-0.019) on 1000 seed weight, while the simple correlation coefficient is very strong and of the positive direction. This correlation was masked with the positive indirect effect of hull ratio through length of seed (IE=0.623) and thickness of seed (IE=0.369), as well as the negative indirect effect of hull ratio through width of seed (IE=-0.260).

The differences in the presented results can be explained by the fact that different plant material was used by the authors in their research. In sunflower breeding for productivity, it is important to find the traits which are easy to evaluate, demonstrate their causal connection with 1000 seed weight, and therefore can be used as selection criteria. Higher 1000 seed weight is an ultimate objective of confectionary sunflower researchers. The focus should be placed on traits with a very strong positive direct effect on 1000 seed weight. Presence or absence of correlations can contribute to the right choice of examined traits, so as to enhance the efficiency of some selection criteria.

Conclusion

The main direction in breeding low oil content confectionary sunflower is directed towards the increased mass of 1000 seeds, higher protein content and quality, with the decrease in shell ratio. Within the development of new high-protein hybrids for confectionary use, it is important to find the traits that can be easily determined, and at the same time show their interdependence with 1000 seed weight. 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 quantitative traits on 1000 seed weight of sunflower. It allowed us to detect those components which exhibit the highest effect on 1000 seed weight expression. The data obtained in this investigation, as well as various literature data, indicate that the characteristic such as length and thickness of seed (0.849**; 0.748**) are the main 1000 seed weight components which should be used as selection criterion in sunflower breeding. Width of seed had a strong negative direct effect on 1000 seed weight (DE=-0. 387*). On the basis of the research in this paper it appeared that the length and thickness of seed were the most important traits for 1000 seed weight, and can be used for the improvement of seed yield and evaluation of sunflower breeding materials.

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Table 1. Simple correlation coefficients of quantitative traits and 1000 seed weight.

Trait		**KPC**	**SHR**	**LS**	**WS**	**TS**	**TSW**
		X2	X3	X4	X5	X6	y
SPC	X1	-0.355	-0.687**	-0.607**	-0.293	-0.374*	-0.538*
KPC	X2		0.521*	0.323	0.197	0.252	0.285
HR	X3			0.734**	0.671**	0.494*	0.609**
LS	X4				0.424*	0.175	0.717**
WS	X5					0.730**	0.463*
TS	X6						0.549*

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

X1	seed protein content (SPC)	X5	width of seed (WS)
X2	kernel protein content (KPC)	X6	thickness of seed (TS)
X3	hull ratio (HR)	Y	1000 seed weight (TSW)
X4	length of seed (LS)		

Table 2. Analysis of direct and indirect effects of the six traits on 1000 seed weight

Components	**DE (P)**	**IE (Pxr)**	**CC (r)**
Seed protein content (SPC)	0.113		
Indirect effect KPC		0.018	
Indirect effect HR		0.013	
Indirect effect LS		-0.515	
Indirect effect WS		-0.113	
Indirect effect TS		-0.280	
Total			-0.538
Kernel protein content (KPC)	-0.052		

Continuing table 2

Components	DE (P)	IE (Pxr)	CC (r)
Indirect effect SPC		-0.040	
Indirect effect HR		-0.010	
Indirect effect LS		0.274	
Indirect effect WS		-0.076	
Indirect effect TS		0.188	
Total			0.285
Hull ratio (HR)	-0.019		
Indirect effect SPC		-0.077	
Indirect effect KPC		-0.027	
Indirect effect LS		0.623	
Indirect effect WS		-0.260	
Indirect effect TS		0.369	
Total			0.609
Length of seed (LS)	0.849**		
Indirect effect SPC		-0.068	
Indirect effect KPC		-0.017	
Indirect effect HR		-0.014	
Indirect effect WS		-0.164	
Indirect effect TS		0.130	
Total			0.717
Width seed (WS)	-0.387*		
Indirect effect SPC		-0.033	
Indirect effect KPC		-0.010	
Indirect effect HR		-0.013	
Indirect effect LS		0.360	
Indirect effect TS		0.546	
Total			0.462
Thickness of seed (TS)	0.748**		
Indirect effect SPC		-0.042	
Indirect effect KPC		-0.013	
Indirect effect HR		-0.009	
Indirect effect LS		0.148	
Indirect effect WS		-0.283	
Total			0.549
Coefficient of R^2 determination	0.753		

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