QUANTITATIVE ANALYSIS OF OIL YIELD AND ITS COMPONENTS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

Increasing of oil yield is one of the most important goals in sunflower (*Helianthus annuus* L.) breeding programs. The objectives of this research were to assess the interrelationships between oil yield and its components on 14 sunflower hybrids developed within a breeding program of the Agricultural Institute Osijek, Croatia. Field trials were set up according to completely randomized block design (CRBD) on three locations during two growing seasons (2002 and 2003). Plant height, 1,000 grain weight, test weight, grain yield, oil content and oil yield were analyzed. Phenotypic and genotypic coefficients of variation were highest for grain yield, followed by oil yield and 1,000 grain weight. High values of heritability were estimated for oil content and plant height, medium for 1,000 grain weight and test weight, and low values for grain and oil yield. Highly significant positive correlation was estimated between grain yield and oil yield, but the association between grain yield and oil content was negative and low. A positive correlation coefficient was estimated between 1000 grain weight and grain yield, and a negative one between 1000 grain weight and oil content. Grain yield and oil content expressed the strongest direct effect on oil yield.

Key words: sunflower hybrids, variability, heritability, genetic gain, correlations, path analysis.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is grown on 22 million ha in the world, producing 27 million tones total grain yield (FAO STAT Database, 2007) and so comprising an important part of the world agro industrial complex. It is primarily grown for oil, which is mainly used for human consumption, but also as a raw material for the processing industry, livestock feed and beekeeping. In the last few years, sunflower oil is used for biodiesel production. Sunflower is harvested early in the fall, leaving the field free of weeds, and providing enough time for planting winter crops. It has an important role in crop rotation systems.

Sunflower breeders intend to achieve the highest grain yield and oil content, through the best expression of heterosis (Vrânceanu, 2000; Vrânceanu et al., 2005).

The breeding strategies are mainly oriented toward these two traits. The success of a breeding program depends on the variability of the initial material (Fick and Miller, 1997; Vrânceanu, 2000). In order to apply an optimum breeding strategy for targeted quantitative traits, a genetic analysis of those traits needs to be performed (Haş, 1999; Nistor et al., 2005). Heritability represents the ratio between genetic and all factors (including non genetic ones) that influence the variability (Fick and Miller, 1997; Bernardo, 2002). The higher ratio of the genetic component in phenotypic expression of a certain trait, the higher is the heritability, and selection for these traits can be performed in earlier generations in field trials set up at a smaller number of locations, years and replications. Heritability accompanied with an estimation of genetic gain is more useful than heritability alone in accurate prediction of the selection effects (Johnson et al., 1955).

Besides coefficients of variability and heritability it is important to know the relationship between the analyzed traits. It is important to estimate simple correlation coefficients, but also the direct and indirect effects of investigated traits on characters that represent selection aims described through path coefficient analysis. Path coefficient analysis has an advantage over estimation of simple correlation coefficients because it allows partitioning of the correlation coefficient into its components. These components are: 1) the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable; and 2) the indirect effect(s) of a predictor variable on the response variable through the predictor variables (Dewey and Lu, 1959).

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The purpose of this study was to estimate phenotypic and genotypic coefficients of variation, heritability, correlations and path coefficients between important agronomic traits and oil yield in fourteen sunflower hybrids. The results will be usefull for implementing a more efficient breeding strategy.

MATERIAL AND METHODS

The experimental material included 7 single cross hybrids (H-2001 A, H-101 E, H-1999 F, H-103 E, H-93 OL, H-93 FA and H-219 E) and 7 three-way cross hybrids (H-259 E, H-189 E, H-93 OR, H-59 E, H-25 E, H-253 E and H-269 E) developed at the Agricultural Institute Osijek, Croatia. The field trials were set up during 2002 and 2003 growing seasons in three locations with different pedodynamic characteristics (Osijek in Eastern Slavonia county on eutric cambisol soil type, Karanac in Baranja county on eutric cambisol soil type, and Feričanci in Western Slavonia county on pseudogley soil type). At each environment the hybrids were planted by hand planters in randomized complete block design with three replications. Plot size was 14 m^2 (5 m lenght, 4 rows, 70 cm distance between rows). At maturity, the two middle rows were harvested. Following traits were analysed: plant height, 1,000 grain weight, test weight, grain yield, oil content and oil yield. Plant height was determined in full flowering stage and other measurments were conducted after harvesting. Test weight and grain moisture were determined by Dickey John, GAC 2000 grain analysis computer. Grain yield per plot was calculated on hectare basis according to standard method (9% kernel moisture and 2% kernel impurity). Oil content was determined by MQA 7005 NMR analyzer and calculated on dry matter (D.M.) basis. Oil yield was calculated by multiplication of grain yield and oil content. Phenotypic (PCV) and genotypic (GCV) coefficients of variability and heritability (h^2) were estimated as described by Singh et al. (1993). Expected genetic gain (GG) was estimated in accordance to Johnson et al. (1955) and Falconer (1989). Simple correlation coefficients were calculated from the analysis of covariance given by Singh and Chaudhary (1979).

Path analysis partitions the total correlation coefficients into direct and indirect effects of various characters and helps to understand the relationship among variables based on an *a priori* model. Direct and indirect path coefficients were calculated according to Dawey and Lu (1959), Williams at al. (1990) and Lynch and Walsh (1998). Statistical analyses were performed using SAS for Windows (2003).

RESULTS AND DISCUSSION

Highly significant differences between hybrids, regarding all investigated traits, indicate the divergence of the material selected for analysis (Table 1). Comparing mean values of six environments, the hybrid H-2001A had the highest oil content (52.98%) and oil yield (2,191 kg ha^{-1}). The same hybrid had the highest test weight (43.1 kg hl^{-1}), and the shortest plant (137.8 cm). The highest grain yield (4,715 kg ha^{-1}), plant height (166.8 cm) and 1,000 grain weight (66.7 g) were noticed in hybrid H- 93 FA. This hybrid also had the lowest oil content (45.00%). The lowest value for oil yield was observed in hybrid H-101 E (1692 kg ha^{-1}), for grain yield in hybrid H-259 E (3,714 kg ha^{-1}), for test weight in hybrid H-219 E (37.0 kg hl^{-1}) and for 1,000 grain weight in hybrid H-253 E (54.8 g).

Phenotypic and genotypic coefficients of variability (Table 2) were highest for grain yield (11.56% and 6.67%, respectively), followed by oil yield (11.32%; 5.69%). Oil content (4.54%) had the lowest value for PCV and test weight for GCV (3.65%).

Low h^2 values (Table 2) were estimated for oil yield (0.25) and grain yield (0.33) indicating the strong influence of the environment and genotype x environment interaction on the expression of these traits. Similar values were determined by Khan (2001), which is not in accordance to the results of Saravanan et al. (1996) and Sujatha et al. (2002).

Because of the low h^2, selection for grain and oil yield should be performed in later generations, in field trials set up across more years, locations, and replications.

Medium values of h^2 were determined for plant height (0.60), weight of 1,000 grain (0.46) and test weight (0.52).

Similar findings were reported by Loganathan and Gopalan (2006), but our results are not in correspondence with the results of Sujatha et al. (2002). High h^2 of oil content (0.73) confirms that phenotypic expression of this trait is mainly determined by genetic factors, and the influence of the environment and genotype x environment interaction is rather low.

Table 1. Mean values of the investigated traits

Hybrid	Trait					
	Plant height (cm)	1000 grain weight (g)	Test weight (kg hl^{-1})	Grain yield (kg ha^{-1})	Oil content in D.M. (%)	Oil yield (kg ha^{-1})
H-259 E	146.9	57.8	42.1	3714	51.62	1746
H-2001 A	137.8	58.0	43.1	4534	52.98	2191
H189 E	146.0	57.0	40.8	4077	50.56	1877
H-1999 F	141.6	59.3	42.4	3824	50.55	1759
H-59 E	143.8	57.5	41.1	4016	51.01	1864
H-93 OL	157.3	64.9	42.1	4053	49.06	1808
H-25 E	147.8	59.4	40.9	3872	50.46	1777
H-93 FA	166.8	65.9	39.8	4715	45.00	1930
H-253 E	151.2	54.8	41.1	3873	50.79	1788
H-101 E	153.8	59.4	39.5	3837	48.50	1692
H-269 E	150.8	57.5	41.4	3819	50.65	1762
H-103 E	161.6	56.8	39.3	3825	50.93	1773
H-93 OR	164.2	66.7	40.8	4341	47.54	1877
H-219 E	152.8	59.0	37.0	4353	49.24	1951
$LSD_{0.05}$	6.11	4.13	2.10	273.9	1.71	139.7
$LSD_{0.01}$	8.07	5.46	2.77	361.5	2.25	184.4

Table 2. Components of variance, heritability and genetic gain for oil yield components in sunflower

Trait	Plant height	1,000 grain weight	Test weight	Grain yield	Oil content	Oil yield
Mean	151.59	59.57	40.81	4060.85	49.92	1842.33
Vp	111.54	25.26	4.23	220443.89	5.14	43499.46
Vg	67.18	11.60	2.21	73282.02	3.73	10992.48
Vi	30.00	7.08	0.33	118290.18	0.29	24992.53
Ve	14.37	6.58	1.69	28871.69	1.12	7514.46
PCV(%)	6.97	8.44	5.04	11.56	4.54	11.32
GCV(%)	5.41	5.72	3.65	6.67	3.87	5.69
h^2	0.60	0.46	0.52	0.33	0.73	0.25
GG	11.19	6.37	4.05	742.94	9.47	356.29
RGG (%)	7.38	10.69	9.92	18.30	18.97	19.34

Vg - genetic variance, Vp - phenotypic variance, Vi - variance of genotype x environment interaction, Ve - error variance, h^2 - broad sense heritability, GG - genetic gain, RGG % - genetic gain as percent of mean.

Khan (2001) and Leon et al. (2003) estimated high h^2 for oil content. Medium h^2 for the same trait was stated by Teklewold et al. (2000) and Sujatha et al. (2002). Relative genetic gain was highest for oil yield (19.34%), followed by oil content (18.97%) and grain yield (18.30%). Similar results were reported by Seneviratne et al. (2003).

Correlations between oil yield and other investigated traits were positive and highly significant (Table 3). The strongest relationship was estimated between grain yield and oil yield (r = 0.957). Other researchers (Suzer, 1998; Teklewold et al., 1999) indicated a positive relationship of different intensity between grain and oil yield. Weak correlations were found between oil yield and plant height (r = 0.311), 1,000 grain weight (r = 0.258) and test weight (r = 0.264). The relationship between oil yield and oil content was low (r = 0.169). These findings are related to the results of Suzer (1998) and Hladni et al. (2004), but different from Sarno et al. (1992).

Table 3. Simple correlation coefficients of oil yield components

Trait	1,000 grain weight	Test weight	Grain yield	Oil content	Oil yield
Plant height	0.158*	0.163**	0.259**	0.206**	0.311**
1,000 grain weight		-0.059	0.409**	-0.50**	0.258**
Test weight			0.192**	0.255**	0.264**
Grain yield				-0.120	0.957**
Oil content					0.169**

Low, negative and non-significant correlation was estimated between grain yield and oil content (r = -0.120) which corresponds with investigations of Mogali and Virupakshappa (1994) and Gonzales et al. (2000). Different results were presented by Suzer (1998), Khan (2001) and Kaya et al. (2007). Sunflower breeders would achieve their goals much easier if oil content would have the same value or would increase together with grain yield. In that case, the direct selection for grain yield would probably result in high oil yield.

1,000 grain weight had a positive relationship with grain yield (r = 0.409), but negative with oil content (r = -0.501). Joksimović et al. (2004) and Kaya et al. (2007) reported similar results, which did not correspond with the findings of Doddamani et al. (1997) and Suzer (1998).

The correlation coefficients among other studied traits were low or very low. This is in agreement with Dušanić et al. (2004), but different from Joksimović et al. (2004). Kaya et al. (2007), analyzing sunflower hybrids Sanbro and Tarsan 1018, estimated positive and highly significant correlation between plant height and 1,000 grain weight.

Path coefficient analysis was performed in order to obtain and interpret information on the nature of interrelationships among oil yield and related traits (Table 4). Grain yield had the highest direct effect on oil yield (p = 0.995), followed by oil content (p = 0.287).

Table 4. Direct and indirect effects of traits on oil yield

Trait	Direct effect	Indirect effects via					r
		Plant height	1,000 grain weight	Test weight	Grain yield	Oil content	
Plant height	-0.006		-0.00085	0.00014	0.25808	0.05913	0.311**
1,000 grain weight	-0.005	-0.00091		-0.00005	0.40753	-0.14365	0.258**
Test weight	0.001	-0.00094	0.00032		0.19102	0.07312	0.264**
Grain yield	0.995**	-0.00149	-0.00220	0.00016		-0.03455	0.957**
Oil content	0.287**	-0.00118	0.00269	0.00021	-0.11993		0.169**

Coefficient of determination R^2 = 0.998

Direct selection for grain yield will give the best results for achieving high oil yield. The direct effects of plant height, mass of 1,000 grain and test weight were non-significant and mainly realized through the indirect effects of grain yield and oil content. For breeding purposes, the most important traits are those having significant direct effect on main target traits. Mogali and Virupakshappa (1994) emphasized the direct effect of grain yield on oil yield, but also the effects of oil content, percentage of filled grains and head diameter. Nehru and Manjunath (2003) reported highest direct effect of grain yield and number of grains per head on oil yield. These findings are different from the results presented by Joksimović et al. (1999), who indicated the effect of protein content, Kaya and Atakisi (2003) for plant height and mass of 1,000 grain and Patil et al. (1996) for number of grains per head, 1,000 grain weight and head weight.

The coefficient of determination (R^2 = 0.998) represents the influence of the traits involved in the study on total variability of oil yield per plant. The remaining 0.002% could be attributed to factors that were not included in this study.

CONCLUSIONS

Based on the conducted analyses, the following can be concluded:

Grain yield and oil yield had the highest genetic and phenotypic coefficients of variability. The lowest PCV was estimated for oil content and the lowest GCV for test weight.

Low heritability values for oil and grain yield reflect the influence of environment and genotype x environment interaction on their expression. The influence of genotype was stronger for oil content.

Very strong, positive and highly significant correlation was estimated between grain and oil yield. Grain yield and oil content were in a weak negative association.

The strongest direct effect on oil yield was estimated for grain yield and oil content. These two traits can be used as selection criteria for increasing oil yield in breeding programs. The influence of other studied traits on oil yield was covered by the indirect effect of grain yield. High value of the coefficient of determination (R^2 = 0.998) indicates that the traits chosen for this study explained almost all oil yield variation.

REFERENCES

Bernardo, R., 2002. *Breeding for quantitative traits in plants*. Stemma Press. Woodbury. MN, USA.

Dewey, D.R., Lu, K.H., 1959. *A correlation and path coefficient analysis of components of crested wheat grass grain production.* Agron. J., 51: 515-518.

Doddamani, I.K., Patil, S.A., Ravikumar, R.L., 1997. *Relationship of autogamy and self fertility with grain yield and yield components in sunflower (Helianthus annuus L.).* Helia, 20(26): 95-102.

Dušanić, N., Miklič, V., Joksimović, J., Atlagić, J., 2004. *Path coefficient analysis of some yield components of sunflower*. Proceedings of the 16th Intern. Sunfl. Conf. Fargo. ND USA., vol. II: 531-537.

Falconer, D.S., 1989. *Introduction to Quantitative Genetics*. 3rd edn., Longman, London.

FAO STAT DATABASE (http://faostat.fao.org)

Fick., G.N., Miller, J.F., 1997. *Sunflower breeding*. In Sunflower technology and production, edited by E.E. Schneiter. SA, CSSA, SSSA. Madison, Wisconsin, USA.

Goksoy, A.T., Turkec, A., Turan, Z.M., 2002. *Corelation and path analysis between grain yield and certain yield components in new-improved syntetic varietes of sunflower (Helianthus annuus L.).* Ulud. Zir. Fak. Derg., 16: 139-150.

Gonzales, J., Mancuso, N., Oliva, C., 2000. *Factores geneticos, ambientales y correlaciones entre rendimiento y calidad de girasol*. Proc. 15th Intern. Sunfl. Conf. Toulouse. France, tome II E: 105-110.

Haş, V., 1999. *Genetic analysis of some yield components and cernel kernel quality in sweet corn*. Romanian Agricultural Research, 11-12 : 9-20.

Hladni, N., Škorić, D., Kraljević-Balalić, M., Ivanović, M., Sakač, Z., Jovanović, D., 2004. *Correlation of yield components and grain yield per plant in sunflower* (*Helianthus annuus* L.). Proceedings of the 16th Intern. Sunfl. Conf. Fargo, ND, USA, vol. II: 491-496.

Johnson, H.W., Robinson, H.F., Comstock, R.E., 1955. *Estimates of genetic and environmental variability in soybeans*. Agron. J., 47: 314-318.

Joksimović, J., Atlagić, J., Jovanović, D., Marinković, R., Dušanić, N., Miklič, V., 2004. *Path-coefficient analysis of some head and grain characteristics in sunflower*. Proceedings of the 16th Intern. Sunfl. Conf. Fargo. ND USA, vol. II: 525-530.

Joksimović, J., Atlagić, J., Škorić, D., 1999. *Path-coefficient analysis of some oil yield components in sunflower (Helianthus annuus L.).* Helia, 22 (31): 35-42.

Kaya, Y., Atakisi, I.K., 2003. *Path and correlation analysis in different yield characters in sunflower (Helianthus annuus L.).* Anadolu J., 13: 31-45.

Kaya, Y., Evci, G., Durak, S., Pekcan, V., Gucer, T., 2007. *Determining the relationships between yield and yield attributes in sunflower*. Turk J. Agric. For., 31: 237-244.

Khan, A., 2001. *Yield perfomance, heritability and interrelationship in some quantitative traits in sunflower*. Helia, 24: 35-40.

Leon, A.J., Andrade, F.H., Lee, M., 2003. *Genetic analysis of grain-oil concentration across generations and environments in sunflower*. Crop Sci., 43: 135-140.

Loganathan, P., Gopalan, A., 2006. *Gene action for certain quantitative characters in sunflower (Helianthus annuus L.)*. Research on Crops, 7(1): 218-220.

Lynch, M., Walsh, B., 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates Inc. Sunderland, MA, USA.

Mogali, S.C., Virupakshappa, K., 1994. *Characterization and evaluation of sunflower* (*Helianthus annuus L.) germplasm.* Indian J. of Gen. and Pl. Breeding., 54 (4): 360-365.

Nehru, S.D., Manjunath, A., 2003. *Correlation and path analysis in sunflower (Helianthus annuus L.).* Karnataka Journal of Agricultural Sciences, 16(1): 39-43.

Nistor, T., Sturzu, R., Nistor, G., Mîrlogeanu, S., Anghel, J., 2005. *Genetic control of the agronomically useful genetic traits in cotton*. Romanian Agricultural Research, 22: 27-32.

Patil, B.R., Rudraradhya, M., Vijayakumar, C.H.M., Basappa, H., Kulkarni, R.S., 1996. *Correlation and path analysis in sunflower*. Journal of Oilgrains Research, 13 (2): 162-166.

Saravanan, K., Gopalan, M., Senthil, N., 1996. *Heritability and genetic advance in sunflower*. Gujarat Agricultural University Research Journal, 22(1): 101-102.

Sarno, R., Leto, C., Carrubba, A., Cibella, R., 1992. *Correlation between some yield factors in sunflower* (*Helianthus annuus* L.). Proc. 13th Intern. Sunfl. Conf. Pisa. Italy, vol. I: 368-389.

SAS Institute Inc., 2003. SAS for Windows (r) 9.1. Cary, NC, USA.

Seneviratne, K.G.S., Ganesh, M., Ranganatha, A.R.G., 2003. *Effect of recurrent selection on variability and genetic parameters of yield and yield attributes in sunflower*. Annals of the Sri Lanka Department of Agriculture, 5: 227-232.

Singh, M., Ceccarelli, S., Hamblin, J., 1993. *Estimation of heritability from varietal trials data*. Theor. Appl. Genet., 86: 437-441.

Singh, R.K., Chaudhary, B.D., 1979. *Biometrical methods in quantitative genetic analysis*. Kalyani Publishers, New Delhi.

Sujatha, H.L., Chikkadevaiah, Nandini, 2002. *Genetic variability study in sunflower inbreds*. Helia, 25 (37): 93-99.

Suzer, S., 1998. *Effects of different phosphorus rate and application time on sunflower grain yield and yield components*. Helia, 21 (28): 117-124.

Suzer, S., Atakisi, I., 1993. *Yield components of sunflower hybrids of different height*. Helia, 16: 35-40.

Teklewold, A., Jayaramaiah, H., Ramesh, S., 1999. *Genetic variability studies in sunflower* (*Helianthus annuus* L.). Crop Improvement, 26(2): 236-240.

Teklewold, A., Jayaramaiah, H., Jagadeesh, D.N., 2000. *Correlations and path analysis of physio-morphological characteristics of sunflower (Helianthus annuus L.) as related to beeding method*. Helia, 23 (32): 105-114.

Vrânceanu, A. V., 2000. *Floarea-soarelui hibridă*. Editura Ceres. Bucharest, Romania.

Vrânceanu, A. V., Stanciu, D., Stanciu, M., Păcureanu-Joița, M., Șorega, I., Mantu, I., 2005. *Jupiter - a new Orobanche resistant sunflower hybrid*. Romanian Agricultural Research, 22: 19-22.

Williams, W.A., Jones, M.B., Demment, M.W., 1990. *A concise table for path analysis statistics*. Agron. J., 82: 1022-1024.