ANALYSIS OF CORRELATIONS BETWEEN SEVEREAL GRAINS TRAITS IN SUNFLOWER UNDER DIFFERENT FERTILIZATIONS

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Abstract. *Yield is a complex trait and is a function of several component characteristics and their interactions with the environment. As experimental material was used the sunflower hybrid NK Neoma. Under unfertilized conditions and treatments with $N_{50}P_{50}K_0$ and $N_{50}P_{50}K_{50}$, were carried out measurements on thousand kernel weight, test weight, oil an protein content. The objective of this research was to assess the correlations between several grains traits under different fertilizations in order to obtain efficient grain yields or amount of oil. Considering all the results it can be seen that the applied fertilization has had a strong influence on the intensity and nature of the relationships between different traits. Thus, under unfertilized conditions the TKW has a significant and major influence of approximately 79.43% to yield achievement, while under the fertilization with $N_{50}P_{50}K_0$ the contributions of the two morphological grains traits are balanced, following that under the effect of fertilization with $N_{50}P_{50}K_{50}$ the test weight will have a predominant influence of about 96% on yield variability. Under unfertilized conditions the test weight has a main and significant contribution of 91.73% to oil accumulation in grains, instead under the fertilization with $N_{50}P_{50}K_0$ the influence (83.28%) of TKW is the most important, resulting balanced effects of the two morphological grains traits under the fertilization with $N_{50}P_{50}K_{50}$. This information is necessary for the orientation of the technological works in order to obtain morphological characteristics of the grains that can ensure efficient yields or amount of oil.*

Key words: sunflower, correlations, grains traits, fertilization.

INTRODUCTION

The forecast of sunflower seed production worldwide in 2016/2017 (after STATISTA) was around 44 million tons, with three main largest producers: Ukraine (11.9 million t.); Russia (11.9 million t.) and European Union (8.57 million t.). Romania ranked first in the European Union in 2017 for the area cultivated with sunflower of 1.01 million hectares and a production of 1.95 million tons (after Romanian National Statistics Institute).

The amount of fertilizer and combination between different nutrients are important factors that determine the yield and quality in sunflower. Nitrogen is a constituent of the proteins, nucleic acids and nucleotides that are essential to the metabolic function of a plant. The oil content of sunflower seeds seems to be insignificantly affected by nitrogen application, this could be attributed to the diluting effect of nitrogen on seed oil content due to increased number of seeds/head. (KHOKANI *ET AL.*, 1993; MOJIRI AND ARZANI, 2003; ALI *ET AL.*, 2014). The plant metabolic processes require protein to increase the vegetative, reproductive growth and yield of the crop. The protein is wholly dependent upon the amount of nitrogen fertilization available for plant use (NASIM *ET AL.*, 2012).

The application of phosphorus had significant effect on some yield parameters in sunflower (BAHI *ET AL.*, 1997; ALI *ET AL.*, 2014) and no significant effect on some chemical components like oil (MAHESWARAPPA *ET AL.*, 1985 ; SCHULTZ ET AL., 2018) and protein (SINGH *ET AL*. 1977). The response of sunflower to phosphorus fertilization is quite different because the ability of soils to provide nutrients range between regions (ROY *ET AL.*, 2006).

The significant affect of NP fertilization on sunflower might be due to the positive effect of nitrogen on growth which could have enhanced uptake and effect of phosphorus on plant growth (SUBHASH *ET AL*., 2013; ALI *ET AL*., 2014). The application of phosphorus increased the apparent use efficiency of the supplied nitrogen in sunflower (ZUBILLAGA *ET AL*., 2002).

Yield is a complex trait and is a function of several component characteristics and their interactions with the environment (CHIKKADEVAIAH *ET AL*., 2002). As such, the assessment of the relationships between yield and other important traits are necessary to optimize the sunflower technology under different environment conditions.

The objective of this research was to assess the correlations between several grains traits under different fertilizations in order to obtain efficient grain yields or amount of oil.

MATERIAL AND METHODS

The study was performed at Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara during 2014-2016, using a randomized block design with three replications, and plots of 42 m^2 with six rows of 10 m long. The sowing density was 53908, 70 x 26.5 cm, respectively. As experimental material was used the sunflower hybrid NK Neoma.

The soil of the experimental field is classified as a cambic black cernosiom weak decarbonated, clay-loamy, on the middle loess deposits, with the following physical-chemical parameters: humus 2,97 %, nitrogen index 2,98, phosphorus 51 ppm, potassium 148 ppm, total porosity 53,35 %, aeration porosity 21,84 %.

In order to provide the fertilization treatments, were applied combined fertilizers using doses of 250 kg ha $^{-1}$ (20-20-0) for $N_{50}P_{50}K_0$ and 333 kg ha $^{-1}$ for $N_{50}P_{50}K_{50}$. For weed control, before emergence was sprayed Dual Gold 960 EC at a rate of 1.5 l ha $^{-1}$, and after emergence Killer Super 5EC 0.85 l ha $^{-1}$ and Pulsar 40 at 0.85 l ha $^{-1}$.

The thousand kernel weight (TKW) and test weight were measured on a random sample of clean kernel with determined moisture. Kernel oil and protein content were determined using NIR technology with Granolyzer (Pfeuffer), on 600 ml kernel sample.

The simple, partial and semi-partial correlation coefficients between the five studied traits were calculated according to the method given by CIULCA (2006). The results concerning the grains yield and oil content were statistically processed using variance analysis for multiple regressions with four and three independent variables.

RESULTS AND DISCUSSIONS

Taking into account the data from Table 1 it is noticed that under unfertilized conditions a considerable part (99.93%) of the yield variability can be explained as the result of the influence of the four traits included in this regression model. The TKW has a significant and major influence of approximately 79.43% to yield achievement, followed by the test weight which influences this trait to an extent of 18.63%. Also, it is noted that the change of the biochemical characteristics of the grain had low influences to the variability of yield.

The closer values of the two coefficients of determination (R^2 =0.9993; R^2_a =0.9986) indicates that the number of observations was adequate for this study, allowing for a proper assessment of the relations between yield and the other four traits.

In this case the regression model allows a meaningful assessment of yield with an error of 3.67 kg. Since the Durbin-Watson index is greater than 1.4, probably there is not any significant autocorrelation in the residuals, and the order of traits in the regression equation does not influence the estimated values of yield under unfertilized conditions.

Analysis of variance for multiple regression regarding the influence of different traits on yield under the treatment with $N_{50}P_{50}K_0$ attests that 99.95% of the yield variability is due to the influence of the four variables. In this case it is noted that the test weight has a significant influence of approximately 57.77% to yield achievement, along with the TKW which influences the variability of this trait to an extent of 41.94%. The oil and protein content had a very low influence. The number of observations was appropriate for this study taking into account that the values of the two coefficients of determination are very close.

The regression model used to analyze the relationships between yield and other traits shows a strong statistical assurance, assessing the yield with an error of about 7 kg. The value of DW statistic indicates that the errors related to the obtained results are independent, while the order of the four variables does not affect the estimated results of yield.

Table 1

Variance components of multiple regressions between yield and several grains traits in sunflower under different fertilizations

Fertilization	$N_0P_0K_0$			
Variability source	SS	DF	MS	F
Regression	77114	4	19279	1483**
TKW (x_1)	61296	1	61296	4715**
Test weight (x_2)	14375	1	14375	1106**
Oil content (x_3)	1439	1	1439	111**
Protein content (x_4)	4	1	4	0.31
Residual	52	4	13	
Total	77166	8		
$y = 6738.14 - 80.12x_1 - 11.43x_2 - 41.99x_3 + 38.20x_4$; $R^2 = 0,9993$; $R^2_a = 0,9986$; SDE = 3.62 kg; DW= 1.77				
.Fertilization	$N_{50}P_{50}K_0$			
Variability source	SS	DF	MS	F
Regression	401140	4	100285	2006**
TKW (x_1)	168335	1	168335	3367**
Test weight (x_2)	231872	1	231872	4637**
Oil content (x_3)	931	1	931	18.62*
Protein content (x_4)	2	1	2	0.04
Residual	200	4	50	
Total	401340	8		
$y = 12457 + 0.29x_1 - 286.35x_2 + 79.05x_3 - 56.59x_4$; $R^2 = 0,9995$; $R^2_a = 0,9990$; SDE = 7.08 kg; DW= 2.62				
Fertilization	$N_{50}P_{50}K_{50}$			
Variability source	SS	DF	MS	F
Regression	229794	4	57449	1512**
TKW (x_1)	6289	1	6289	166**
Test weight (x_2)	220653	1	220653	5807**
Oil content (x_3)	2594	1	2594	68.26**
Protein content (x_4)	258	1	258	6.79
Residual	152	4	38	
Total	229946	8		
$y = 19761 - 27.50x_1 - 10.17x_2 + 96.99x_3 - 586.84x_4$; $R^2 = 0,9993$; $R^2_a = 0,9988$; SDE = 6.17 kg; DW= 2.04				

Under the fertilization with $N_{50}P_{50}K_{50}$ it was found that 99.93% of the yield variability can be explained as the result of the influence of the four traits included in this regression model. The test weight has a significant and major influence of approximately 95.96% to yield achievement, followed by TKW which has a significant contribution of 2.73%. It is also noticed that the change of oil and protein content of grains had a small contribution to the yield achievement.

In this case the regression model allows a significant assessment of yield with high accuracy, an error of 6.17 kg, respectively. Taking into account that Durbin-Watson value is greater than 1.4, probably there is not any significant autocorrelation in the residuals, and the order of traits in the regression equation does not influence the estimated values of yield under this fertilization.

Table 2

Simple correlation coefficients between some yield and quality traits in sunflower under different fertilizations

Traits	Fertilization	1	2	3	4	5
1.TKW	$N_0P_0K_0$	1.000	0.978***	0.017	0.495	-0.891***
	$N_{50}P_{50}K_0$	1.000	0.905***	0.913***	-0.664	-0.648
	$N_{50}P_{50}K_{50}$	1.000	0.641	0.680	0.393	-0.165
2. Test weight	$N_0P_0K_0$		1.000	-0.182	0.657	-0.782*
	$N_{50}P_{50}K_0$		1.000	0.656	-0.286	-0.909***
	$N_{50}P_{50}K_{50}$		1.000	-0.118	0.954***	-0.850***
3. Oil content	$N_0P_0K_0$			1.000	-0.856**	-0.468
	$N_{50}P_{50}K_0$			1.000	-0.909***	-0.283
	$N_{50}P_{50}K_{50}$			1.000	-0.401	0.608
4. Protein content	$N_0P_0K_0$				1.000	-0.050
	$N_{50}P_{50}K_0$				1.000	-0.137
	$N_{50}P_{50}K_{50}$				1.000	-0.970***
5. Yield	$N_0P_0K_0$					1.000
	$N_{50}P_{50}K_0$					1.000
	$N_{50}P_{50}K_{50}$					1.000

*: significant at p=0.05; **: significant at p=0.01; ***: significant at p=0.001.

Considering the simple correlation coefficients between the five traits (Table 2), it is noticed the existence of positive and generally significant associations between TKW and test weight under the three fertilization treatments, with the remark that the correlation between these traits is stronger under unfertilized conditions and decreases progressively with the applied doses. The increase of TKW was associated with an increase in oil content under fertilization with NP and NPK, in accordance with the results of OZER *ET AL.* (2003) and RADIC *ET AL.* (2013).

TKW has shown negative correlations with yield, stronger under unfertilized conditions and progressively weaker under fertilization conditions. This relation between TKW and yield was also determined by ERGEN AND SAGLAM (2005) and HLDANI *ET AL.* (2015).

Under unfertilized conditions and in case of treatment with $N_{50}P_{50}K_{50}$ there is a positive correlation between the size of the grains and their protein content, in accordance with the results obtained by SINCIK AND GOKSOY (2014) and HLDANI *ET AL.* (2015).

The test weight has shown a positive and very significant influence on protein content under the fertilization with $N_{50}P_{50}K_{50}$. Regardless of the applied fertilization, the yield showed a negative and significant correlation with test weight.

The yield showed a highly significant negative influence on protein content under the fertilization with $N_{50}P_{50}K_{50,}$ while on the other two treatments the association between these traits is very weak. Other authors (HLDANI *ET AL.* 2015; FIDA HASSAN *ET AL.* 2013; SINCIK AND GOKSOY 2014) reported also a strong negative correlation between seed yield and protein content.

Taking into account the partial and semi-partial correlations between yield and the other studied traits (Table 3) it can be noticed that estimates of individual relations to the four traits have a high accuracy, considering that the coefficients of determination are over 0.99.

The correlation between TKW and yield express a high stability under unfertilized conditions and for the treatment with $N_{50}P_{50}K_{50}$, while under the application of $N_{50}P_{50}$ K_0 the highest stability is manifested for the relation between yield and test weight. Under the fertilization with $N_{50}P_{50}K_{50}$ the association between protein content and yield is influenced in a very limited extent by the effect of other traits. The fact that the values of the partial correlations for the oil content are superior to the simple ones indicates that other traits with suppressor effect acts over these correlations.

Table 3

Partial (Pc) and semi partial (SPc) correlation coefficients between yield and several grains traits in sunflower under different fertilizations

Fertilization	$N_0P_0K_0$			$N_{50}P_{50}K_0$			$N_{50}P_{50}K_{50}$		
Traits	R^2	Pc	SPc	R^2	Pc	SPc	R^2	Pc	SPc
TGW	0.9964	-0.872**	-0.046	0.9978	0.007	0.000	0.9930	-0.724*	-0.027
Test weight	0.9967	-0.323	-0.009	0.9967	-0.955***	-0.072	0.9940	-0.279	-0.007
Oil content	0.9893	-0.854**	-0.043	0.9975	0.746*	0.025	0.9927	0.897**	0.052
Protein content	0.9923	0.261	0.007	0.9964	-0.106	-0.002	0.9956	-0.793*	-0.034

*: significant at p=0.05; **: significant at p=0.01; ***: significant at p=0.001.

Analysis of variance for multiple regression regarding the influence of different grain traits on oil content under unfertilized conditions (Table 4) indicates that 98.93% of the protein variability is due to the influence of the three variables. In this case it is noted that the test weight has a major and significant influence of 91.73% to oil accumulation in grains, followed by the protein content which influences the variability of this trait to an extent of 7.07%. The TKW had a very low influence. The number of observations was appropriate for this study taking into account that the values of the two coefficients of determination (R^2=0.9893; R^2_a=.0.9829) are very close.

Table 4

Variance components of multiple regressions between oil content and several grains traits in sunflower under different fertilizations

Fertilization	$N_0P_0K_0$			
Variability source	SS	DF	MS	F
Regression	7.42	3	2.47	154.58**
TKW (x_1)	0.01	1	0.01	0.63
Test weight (x_2)	6.88	1	6.88	430.00**
Protein content (x_3)	0.53	1	0.53	33.13**
Residual	0.08	5	0.02	
Total	7.50	8		
$y = 180.25 + 0.77x_1 - 0.14x_2 - 5.15x_3$; R^2 = 0,9893; R^2_a = 0,9829; SDE = 0.13; DW= 2.87				
.Fertilization	$N_{50}P_{50}K_0$			
Variability source	SS	DF	MS	F
Regression	15.87	3	5.29	661.25**
TKW (x_1)	13.25	1	13.25	1656.25**
Test weight (x_2)	2.53	1	2.53	316.25**
Protein content (x_3)	0.09	1	0.09	11.25*
Residual	0.04	5	0.01	
Total	15.91	8		
$y = 227.01 + 0.612x_1 + 0.39x_2 - 6.21x_3$; R^2 = 0,9975; R^2_a = 0,9959; SDE = 0.09; DW= 158				
Fertilization	$N_{50}P_{50}K_{50}$			
Variability source	SS	DF	MS	F
Regression	9.13	3	3.04	217.38**
TKW (x_1)	4.26	1	4.26	304.29**
Test weight (x_2)	4.81	1	4.81	343.57**
Protein content (x_3)	0.06	1	0.06	4.29

Residual	0.07	5	0.01	
Total	9.20	8		
$y = 233.05 + 0.51x_1 + 0.09x_2 - 6.62x_3$; $R^2 = 0{,}9927$; $R^2_a = 0{,}9884$; SDE = 0.11; DW= 3.01				

The regression model used to analyze the relationships between oil content and other traits shows a high significance, assessing the amount of protein with an error of about 0.13 %. The value of DW statistic indicates that the errors related to the obtained results are independent, while the order of the three variables does not affect the estimated results of oil content.

Under the fertilization with $N_{50}P_{50}K_0$ it was found that 99.75% of the variability of oil amount can be explained as the result of the influence of the three traits included in this regression model. The size of seeds has a significant and major influence of approximately 83.28% to oil accumulation, followed by the test weight which has a significant contribution of 15.90%. It is also noticed that the change of grains protein content had a small contribution to the values of oil content.

In this case the regression model allows a significant assessment of oil content with high accuracy, an error of 0.09%, respectively. Taking into account that Durbin-Watson value is greater than 1.4, probably there is not any significant autocorrelation in the residuals, and the order of traits in the regression equation does not influence the estimated values of yield under this fertilization. The accuracy of the regression between oil content and other traits is also supported by the high value (0.9959) of the adjusted coefficient of determination.

Under the fertilization with $N_{50}P_{50}K_{50}$ a considerable part (99.27%) of the oil content variability can be explained as the result of the influence of the three traits included in this regression model. The morphological traits of grains, like test weight (52.28%) and TKW (46.30%) has a significant and major influence to oil accumulation. Also, it is noted that the change of grain protein content had low influences to the variability of oil amount.

The closer values of the two coefficients of determination (R^2=0.9927; R^2_a=0.9984) indicates that the number of observations was adequate for this study, allowing for a proper assessment of the relations between oil content and the other traits.

In this case the regression model allows a significant assessment of oil amount with an error of 0.11%. Since the Durbin-Watson value (3.01) is greater than 1.4, probably there is not any significant autocorrelation in the residuals, and the order of traits in the regression equation does not influence the estimated values of oil content under this fertilization.

Table 5

Partial (Pc) and semi-partial (SPc) correlation coefficients between oil content and several grains traits in sunflower under different fertilizations

Fertilization	$N_0P_0K_0$			$N_{50}P_{50}K_0$			$N_{50}P_{50}K_{50}$		
Traits	R^2	Pc	SPc	R^2	Pc	SPc	R^2	Pc	SPc
TKW	0.9955	0.436	0.050	0.9978	0.185	0.009	0.9432	0.936***	0.227
Test weight	0.9966	-0.108	-0.011	0.9963	0.314	0.017	0.9940	0.118	0.010
Protein content	0.9413	-0.932***	-0.267	0.9887	-0.828**	-0.074	0.9913	-0.701*	-0.084

*: significant at p=0.05; **: significant at p=0.01; ***: significant at p=0.001.

The study of the partial and semi-partial correlation coefficients between oil content and other traits (Table 5) indicates that there are real and very strong and negative relations to protein content, which is less influenced by the other traits under unfertilized and $N_{50}P_{50}K_0$ conditions. Strong and negative correlation between oil and protein content in sunflower was also reported by ZHANG *ET AL.* (2010), XIANG *ET AL.* (2010) and HLDANI *ET AL.* (2015).

The high differences between the values of the simple and partial correlation coefficients for TKW under unfertilized conditions and for protein content under $N_{50}P_{50}K_{50}$

certifies that relations between them and oil content are strongly influenced by the variability of the third traits included in this study.

CONCLUSIONS

Considering all the results it can be seen that the applied fertilization has had a strong influence on the intensity and nature of the relationships between different traits. Thus, under unfertilized conditions the TKW has a significant and major influence of approximately 79.43% to yield achievement, while under the fertilization with $N_{50}P_{50}K_0$ the contributions of the two morphological grains traits are balanced, following that under the effect of fertilization with $N_{50}P_{50}K_{50}$ the test weight will have a predominant influence of about 96% on yield variability.

Under unfertilized conditions the test weight has a main and significant contribution of 91.73% to oil accumulation in grains, instead under the fertilization with $N_{50}P_{50}K_0$ the influence (83.28%) of TKW is the most important, resulting balanced effects of the two morphological grains traits under the fertilization with $N_{50}P_{50}K_{50}$.

This information is necessary for the orientation of the technological works in order to obtain morphological characteristics of the grains that can ensure efficient yields or amount of oil.

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