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CORRELATION AND PATH ANALYSIS OF YIELD AND YIELD COMPONENTS IN WINTER RAPESEED

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Five different rapeseed genotypes were tested. The following traits were considered: seed yield, seed germination, seed oil content, 1000 seed weight and seed protein content and they were used to determine whether there is significant or nonsignificant correlation. Highest average results were determined in genotype G-3 (yield 2.544 kg; germination 90%; 1000 seed weight 4,30 g; oil content 45,31% and protein content 19,83%) while G-5 (1.838 kg; 87%; 3,50 g; 44,77% and 17,28%) had the lowest average result of observed parameters. Highly significant positive correlations were found while comparing seed yield with 1000 seed weight (0.753**) and protein content (0.726**). High significant positive correlation were also determined comparing seed germination with 1000 seed weight (0.832**) and protein content (0.892**). Also high significant correlation was determined comparing 1000 seed weight and protein content (0.812**). Positive significant correlations were found by comparing seed yield and seed germination (0.644*). Path analysis indicated highest significant positive direct effect of 1000 seed weight (0.716**) and protein content (0.666**) on seed yield. High but negative significant value had seed germination (-0.645**). In the study of indirect effects on seed yield, none of significant effects were determined. The study of direct effects on oil content showed that the seed germination had high significant positive effect (-1.296**) on oil content. Significant but hot high effect has seed yield (0.556*). In other two traits it was determined negative high significant effects (1000 seed weight – 0.797** and protein content – 0.717**) on seed oil content. The existence of indirect significant effects on oil content in four cases was determined.

Keywords: rapeseed, yield, oil, correlation, path analysis

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INTRODUCTION

Rapeseed is an important species from the *Brassica* genus and a high value crop for oil production (RAMEEH, 2011). It is primarily grown because of both, high quality oil, which meets criteria of the most demanding nutritionists, and proteins that are used as feed pellets for the majority categories of livestock species (MARJANOVIĆ-JEROMELA *et al.*, 2007; VUJAKOVIĆ *et al.*, 2014). Only varieties and hybrids of winter rapeseed with high genetic potential for seed yield (over 4 t ha^{-1}), for oil content (between 43 and 47%) and for protein content (between 18-20%) in the seed are used in the production today.

Rapeseed breeding strategies are mostly dealing with developing varieties characterized by high and stable seed and oil yield, as well as by low content of glucosinolates and erucic acid (MARJANOVIĆ-JEROMELA *et al.*, 2008). Various researchers studied genetic parameters to determine the selection criteria for yield improvement in rapeseed (ALI *et al.*, 2003). Seed yield is a quantitative trait, its expression is the result of genotype, environmental effect and genotype-environment interaction (MARINKOVIĆ *et al.*, 2003; GUNASEKERA *et al.*, 2006; HASAN *et al.*, 2014). Knowing the relationship between these traits and investigating other quantitative traits make breeding programs and their success more real and secure (MIJIĆ *et al*., 2006). TOORCHI and NADERI (2012) reported that seed yield is a combination of many traits, which are polygenic in nature and it is difficult to make direct selection for these traits. Therefore, indirect selection through associated component traits can be effective for improving the seed yield. Correlations between yield and yield components have repeatedly been analyzed in traditional cultivars of rape with a high oil ratio (BASALMA, 2008).

Determination of correlation coefficients is an important statistical procedure to evaluate breeding programs for high yield, as well as to examine direct and indirect contributions to yield variables (ALI *et al.*, 2003). To separate correlation coefficients into components of direct and indirect effects, the path coefficient analysis provides an excellent tool as it can measure the direct and indirect effects of interrelated components of a complex trait like yield. KORKUT *et al.* (1993) described that the simple correlation analysis could not fully give detailed link among the characters. Therefore, path coefficient analysis can be utilized for complete determination of the impact of certain independent variable on the dependent one. So, direct and indirect effects can clearly be understood by path analysis (TAHIRA *et al.*, 2017). With this conclusion are agree SABAGHNIA *et al.* (2010) and RAMEEH (2011); they also concluded that path-coefficient technique splits the correlation coefficients into direct and indirect effects can be helpful in formulating an efficient selection strategy.

The present study aim is to estimate the coefficients of correlation among observed parameters and their direct and indirect effects on seed yield and oil content, which will lead to selecting the criteria for yield and oil seed content improvement in winter rapeseed.

MATERIALS AND METHODS

Testing took place on two localities in Bosnia and Herzegovina (Bijeljina and Brčko) in two production years (vegetation seasons 2014/2015 and 2015/2016). All examined genotypes represent winter rapeseed varieties of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. Five different rapeseed genotypes were tested (Slavica, Banaćanka, Zlatna, Kata and Prima code as G1, G2, G3, G4 and G5). Upon maturity, 10 plants were picked manually, from different locations on the plot, and seed yield per plant was determined. By the application of previously established plant density (500.000 plants ha^{-1}), obtained seed yield per plant was recalculated in kg ha^{-1} with 9% of moisture. Trashing of sampled plants and determination of 1000 seed weight, seed germination, oil and protein content were done in the laboratory of Oil Crops Department of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. For examination of seed germination 4 replication of 100 seeds were used. Germination was determined after 10 days, counting only normal germinated seeds and was expressed in relative values. 1000 seed weight was measured on 4 samples containing 100 seeds each. The obtained values were converted to 1000 seed weight and were specified in grams. Oil content was determined by the classical method by Ruškovski with Soxlet apparatus and protein content by standard Kieldahl method with the help of VAP-50-Gerhardt apparatus. Both parameters were expressed in relative values.

Analysis of simple correlation coefficient and path analysis for examined characters were performed using GENSTAT software.

RESULTS

The average seed yield of analyzed genotypes is 2157 kg ha^{-1}; the genotype G-5 (1838 kg ha^{-1}) had the lowest yield and while the highest yield had genotype G-3 (2543 kg ha^{-1}; Table 1.). The average seed germination was 87%; between genotypes, highest value had G-3 (91%) and lowest has G-5 (75%). Determined 1000 seed weight was between 3.50 g (G-5) and 4.30 g (G-3); average of all observed genotypes was 4.01 g. Average of oil seed content is 45.96%; between genotypes, highest values has G-4 (48.15%) and lowest has G-2 (44.64%). Protein content in observed genotypes was between 17.27% (G-5) and 20.03% (G-2) and average was 19.05%.

Table 1. Mean values for analyzed traits of rapeseed genotypes for two observed years on two locality

	Seed Yield (kg/ha)	Seed Germination (%)	1000 seed weight (g)	Oil Content (%)	Protein Content (%)
G1	2.158	90	4.10	46.94	19.11
G2	2.172	90	4.15	44.64	20.03
G3	2.543	91	4.30	45.30	19.82
G4	2.075	90	4.00	48.15	19.04
G5	1.838	75	3.50	44.77	17.27
Average	2.157	87	4.01	45.96	19.05

Coefficient of correlation

By calculation of simple coefficients of correlation, all correlation of observed parameters are positive (Table 2.). Highly significant correlation was determined between seed yield and 1000 seed weight (0.753**) and between seed yield and protein content (0.726**). High significant correlation also was stated between seed germination and 1000 seed weight (0.832**) and between seed germination and protein content (0.892**). Highly significant correlation between 1000 seed weight and protein content was also determined (0.812**).

Between seed yield and seed germination, significant positive correlation was determined (0.644*).

Table 2. Coefficient of correlation of the observed parameters in rapeseed genotypes

Parameters	Seed germination	1000 seed weight	Oil content	Protein content
Seed Yield	0.644*	0.753**	0.268	0.726**
Seed germination		0.832**	0.350	0.892**
1000 seed weight			0.118	0.812**
Oil content				0.196

Not significant correlation is detected between seed yield and oil content; between seed germination and oil content; between 1000 seed weight and oil content and between oil content and protein content (Table 2.)

Path analysis

Seed yield

The coefficient of determination (R^2=0.6831) represents the influence of the traits involved in the study on total variability of seed yield. The remaining (0.3169) is the undetermined portion or residual of factors that are not included in this study (Table 3.). Path analysis indicate highest significant direct effect of seed germination, 1000 seed weight and seed protein content on seed yield. First effect had negative value (-0.6459** as confirmed by the significant correlation coefficient 0.644* but with positive value), while other two effects had positive value (0.716** and 0,666**; as confirmed by the high correlation coefficient 0.753** and 0.726**). Direct effect of oil content on seed yield had not significant value.

Table 3. Analysis of direct and indirect effects of observed characters on seed yield in rapeseed genotypes

Character	Direct effect	Indirect effect via:				Total
		Seed germination	1000 seed weight	Oil content	Protein content	
Seed germination	-0.645**		0.594	-0.233	0.594	0.310
1000 seed weight	0.716**	-0.537		0.032	0.541	0.752
Oil content	0.279	0.100	0.081		0.052	0.512
Protein content	0.666**	-0.575	0.582	0.130		0.803

Coefficient of determination R^2=0.683

In the study of indirect effects, sixteen effects were determined but not with statistical significant values. Six of observed indirect effects had a very strong value. Positive value had effects of seed germination through 1000 seed weight (0.594) and through protein content (0.594) on seed yield; effect of 1000 seed weight through protein content (0.541) and effect of protein content through 1000 seed weight (0.582) on seed yield. Negative value had effects of 1000 seed weight through seed germination (-0.537) and effect of protein content through seed germination (-0.575) on seed yield (Table 3.).

Oil seed content

Relatively low coefficient of determination (R^2=0.3683) give rise to high residual effects (0.6317) meaning that besides traits used in our study other causal variables may also be responsible for oil content (Table 4.).

The study of direct effects on oil seed content showed that seed germination (1.296**), 1000 seed weight (-0.797**), protein content (-0.717**) had high significant effect (Table 4.). Seed yield had significant positive effect on oil seed content (0.556*).

Table 4. Analysis of direct and indirect effects of observed characters on oil seed content in rapeseed genotypes

Character	Direct effect	Indirect effect via:				Total
		Seed germination	1000 seed weight	Protein content	Seed yield	
Seed germination	1.296**		-0,663	-0.640	0.363	0.356
1000 seed weight	-0.797**	1.078*		-0.584	0.422	0.119
Protein content	-0.717**	1.156*	-0.649		0.399	0.189
Seed yield	0.556*	0.833*	-0.600*	-0.521		0.268

Coefficient of determination R^2=0.368

In the study of indirect effects, the existence of three indirect significant effects on oil seed content was determined. Positive indirect effects on oil seed content had 1000 seed weight, protein content and seed yield through seed germination (1.078*, 1.156* and 0.833*). In the case of seed yield, we determined negative significant indirect effect through 1000 seed weight (-0.600*) on oil seed content. Strong but not significant effects on oil seed content were determined by seed germination through 1000 seed weight (-0.663) and through protein content (-0.640); protein content through 1000 seed weight (-0.649) and seed yield through protein content (-0.521). All these effects were negative. The values of all other indirect effects were much less (Table 4.).

DISCUSSION

Regarding observed parameters, it can be concluded that genotype G-3 had the best result in seed yield, seed germination and 1000 seed weight. Results of oil and protein content of G-5 were on the level of average. But if we include oil and protein yield, then we can concluded that this genotype had the best results of observed parameters. Lowest results had genotype G-5 (seed yield, seed germination, 1000 seed weight and protein content).

Correlation

Coefficient of correlation presents (base on given results) high significant correlation between seed yield and seed germination, 1000 seed weight and protein content. Also between seed germination and protein content; and between 1000 seed weight and protein content. Similar conclusion was represented by RADIĆ *et al.* (2015). ALI *et al.* (2003) reported positive correlation of all the yield components with seed yield. It was concluded that seed weight and flowering duration was significantly correlated with seed yield. These authors also reported that seed yield was negatively and non-significantly correlated with days to maturity and branches per plant. For rapeseed breeding, seed per plant was the variable with a maximum potential of selection for seed yield improvement (HASAN *et al.*, 2014). According to RAMEEH (2011) seeds per silique had a significant positive correlation with seed yield and also it had significant positive direct effect on seed yield. Due to compensative yield components, 1000-seed weight had no significant correlation with seed yield. According to TUNCTURK and CIFTCI (2007) highly significant and positive correlations were found between seed yield and number of branches, number of pods per plant, number of seeds per pod and 1000-seed weight. The relationships between seed yield and plant height and oil content were found positive but non-significant. These results confirm the finding of ALGAN and AYGÜN (2001). According to BASALMA (2008), negative correlation was recorded between seed yield, 1000-seed weight, oil content and plant height. The correlation studies revealed that the most important traits in selection for yield are plant height, days to maturity, seeds per plant and silique per plant (RAMEEH, 2011; HASAN *et al.*, 2014); while these results are also in partial agreement with the earlier findings of DAR *et al.* (2010) and TAHIRA *et al.* (2011). Strong positive correlation was estimated between seed oil content and seed yield per plant (MARJANOVIĆ-JEROMELA *et al.*, 2008). Same authors also concluded that the direct effect of seed oil content on seed yield per plant was very low. MRĐA *et al.* (2011) concluded that seed germination plays a direct role (high correlation) in determining plant number per hectare, which is one of three main components of seed yield. BALALIĆ *et al.* (2012) reported a significant correlation between seed yield, oil yield and oil content. While HLADNI *et al.* (2016) reported a significant correlation between protein content and yield in confectionary sunflower. SUPRIYA *et al.* (2017) concluded that simultaneous improvement in two or more parameters of seed yield is possible when positive correlations are observed.

Path analysis

Base on the results it seems that a large number of parameters have an effect on seed yield. These results confirm the conclusions of MARINKOVIĆ *et al.* (2003), GUNASEKERA *et al.* (2006), MARJANOVIĆ-JEROMELA *et al.* (2011) and HASAN *et al.* (2014). Meanwhile in path analysis of oil seed content situation is different. There is also significant direct effects of observed parameters but some of them had also indirect effects on seed oil content (seed germination and 1000 seed weight through seed yield, for example). MARJANOVIĆ-JEROMELA *et al.* (2011) reported that according to path-coefficient analysis pods per plant and oil content were the most important components of seed yield per plant as their direct effects on seed yield. TAHIRA *et al.* (2017) concluded that direct selection for the higher number of pods per plant and pod length would be effective to increase seed yield. These authors also concluded that days to maturity had positive indirect effects via pod length (0.468), seeds per pod (0.170), and seed weight (0.056) with seed yield. BASALMA (2008) concluded that oil content and oil yield had the highest value of direct effect on seed yield. The same author also reported that comparing indirect effects, the highest positive effect on seed yield was recorded from the interaction of plant height together with oil yield. KHAYAT *et al.* (2012) and HASAN *et al.* (2014) found a positive direct effect of 1000 seed weight, days to flowering, and days to maturity on seed yield. The direct effect of harvest index on seed yield was highest and positive followed by seed weight and pods per plant (ALI *et al.*, 2003). ALI *et al.* (2002) found similar results in Indian mustard reporting the highest direct effect of pods per plant and seed weight on yield per plant. TUSAR *et al.* (2006) concluded that the strongest direct effect on seed yield was estimated for the number of pods per plant followed by the number of seeds per pod and 1000 seed weight. MARINKOVIĆ *et al.* (2003) estimated a highly significant direct effect of time from seed germination to the end of flowering on seed yield. According to JOCKOVIĆ *et al.* (2015), highest direct effect on seed yield was determined in sunflower for head diameter and oil content, while for protein content and 1000 seed weight the effect was statistically significant.

According to SUPRIYA *et al.* (2017) seed oil content had a non-significant positive association with seed yield per plant. In further this authors also concluded that selection for higher seed oil content (higher oil yield) along with high seed yield is the most important objective in any breeding program of oil seed crops.

CONCLUSION

By comparing the correlation coefficients values of four independent variables against the seed yield, significant correlation were determined between seed yield and seed germination, 1000 seed weigh and protein content. Significant correlation also was determined three more cases (between seed germination and 1000 seed weight; between seed germination and protein content and between 1000 seed weight and protein content).

By comparing the correlation coefficients values of four independent traits against the seed yield/oil seed content, significant differences between them are evident. Because of that, it is very important or necessary to use path analysis and divide this effect on direct and indirect.

Highest direct effect on seed yield had seed germination (negative value), 1000 seed weight and protein content (both traits had positive value). Effect of oil content didn't have significant value. Highest of direct effects on oil content had seed germination (positive value), 1000 seed weight and protein content (both traits had negative value). Significant but not high direct effect on oil content had seed yield.

On the basis of acquired results, we concluded that it can help us in the further selection of rapeseed and to a proper selection of varieties for commercial production. Therefore, these characters seem to be good selection criteria to improve seed yield.

According to observed results, best results had genotype G-3 (variety ZLATNA).

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KORELACIJA I PAT ANALIZA PRINOSA I KOMPONENTI PRINOSA OZIME ULJANE REPICE

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Izvod

Ispitivano je pet različitih genotipova ozime uljane repice. Ispitivani su sledeći parametri: prinos semena, klijavost semena, masa 1000 semena, sadržaj ulja i proteina u semenu. Genotip G-3 ostvario je nabolje rezultate (prinos 2.544 kg; klijavost 90%; masa 1000 semena 4,30 g; sadržaj ulja 45,31% i sadržaj proteina 19,83%) dok je genotip G-5 ostvario najlošije rezultate (1.838 kg; 87%; 3,50 g; 44,77% i 17,28%) posmatranih parametara. Visoko značajna pozitivna korelacija utvrđena je upoređivanjem vrednosti: prinosa semena sa masom 1000 semena (0.753**) i sadržajem proteina (0.726**); klijavosti semena sa masom 1000 semena (0.832**) i sadržajem proteina (0.892**) odnosno mase 1000 semena i sadržaja proteina (0.812**). Pozitivna značajna vrednost korelacije utvrđena je posmatranjem prinosa semena i klijavosti semena (0.644*). Pat analiza prinosa semena pokazala je da masa 1000 semena (0.716**) i sadržaj proteina (0.666**) imaju najveći pozitivan uticaj dok klijavost semena ima najveći negativan visoko značajan uticaj (-0.645**) na prinos semena. Posmatranjem indirektnih uticaja na prinos semena nije utvrđena nijedna značajna vrednost posmatranih parametara. Kod sadržaja ulja Pat analiza utvrdila je da klijavost semena (1.296**) ima najveći pozitivan uticaj na sadržaj ulja u semenu. Značajan pozitivan uticaj na sadržaj ulja ima prinos semena (0.556*). U preostalim direktnim uticajima utvrđen je negativan visoko značajan uticaj (masa 1000 semena – 0.797** i sadržaj proteina – 0.717**) na sadržaj ulja u semenu. Posmatranjem indirektnih uticaja utvrđeno je da postoje 4 značajna uticaja, od kojih su tri pozitivna a jedan negativan.

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