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Original scientific paper

INTERRELATIONSHIP BETWEEN YIELD AND YIELD RELATED TRAITS OF SPRING CANOLA (*BRASSICA NAPUS* L.) GENOTYPES

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The research was conducted in order to determine yield related characters which are more effective as selection criteria than yield itself. Three spring canola (*Brassica napus* L.) genotypes have been investigated for plant height, number of primary branches (including the main raceme), number of pods per plant, pod length, number of seeds per pod, seed weight per pod and 1000 seed weight and their correlations with seed yield per plant. Seed yield had highest correlation with number of pods per plant (r= 0.935 and r= 0.973 in Skopje and Strumica, respectively), followed by seed weight per pod (r= 0.693 and r= 0.729) and 1000 seed weight (r= 0.627 and r= 0.680). Path coefficient analysis was used to identify the direct and indirect effect of studied characters on seed yield.

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Number of pods per plant (p=0.759 and p=0.877 for Skopje and Strumica, respectively) and seed weight per pod (p=0.216 and p=0.225) had the highest direct effect on seed yield in both locations followed by 1000 seed weight (p=0.056 and p=0.010). The coefficient of determination (R^2) was 0.943.

Key word: path-coefficient, spring oilseed rape, simple correlation coefficient

INTRODUCTION

Canola (*Brassica napus* L.) is one of the major oilseed crops grown worldwide. The major objective for oilseed rape breeders is seed yield improvement. Yield is a complex trait characterized by low heritability and affected by genotype x environment interactions. The genetic background of any pair of characters, whether yield, height, or maturity characters is unlikely to be under totally separate control, mainly due to linkage or pleiotropy. For plant breeders is therefore necessary to examine the relationships between pairs of characters in order to decide upon the appropriate selection criteria for a breeding program (ENGQVIST and BECKER, 1993). Correlations between the yield and yield determinating traits have already been analyzed in rapeseed (OLSSON, 1960; THURLING, 1974; THURLING and VIJENDRA DAS, 1979; TAYLOR and SMITH, 1992; ENGQVIST and BECKER, 1993; OZER et al., 1999; ALI et al., 2003; MARINKOVIC et al., 2003). But, use of simple correlation analysis could not fully explain the relationship among the characters.

Path coefficient analysis is a statistical tool developed by WRIGHT (1921). The advantage of path analysis is that it permits the partitioning of the correlation coefficient into its components- one component being the path coefficient (or standardized partial regression coefficient) that measures the direct effect of a predictor variable upon its response variable; the second component being the indirect effect(s) of a predictor variable on the response variable trough the predictor variables (DEWEY and LU, 1959). The proportion of variance in the response variable explained by the variance in the predictor variable (partial coefficient of determination) is the square of the path coefficient.

Therefore, the path coefficient analysis has been used by many researchers (MARINKOVIC, 1992; SAMONTE et al., 1998; ALI et al., 2002; MOHAMMADI et al., 2003; DAS et al., 2004) in different crops breeding, for complete determination of impact of independent variable on dependent one. The objective of this study was to determine the interrelationships between yield and some yield components and to identify characters with significant effects on yield for potential use as selection criteria.

MATERIAL AND METHODS

Three *Brassica napus* L. cultivars (Liaison, Lisora and Lisonne, kindly provided from DSV- Deutsche Saatveredelung AG, Germany) were sown in four periods (spring 2003, fall 2003, fall 2004 and spring 2005) on three different dates (spring sowing on 20 March, 30 March and 10 April, and fall sowing on 20 September, 30 September and 10 October) at two locations: Skopje (42º00′N, 21º27′E) and Strumica (41º26′N, 22º38′E).

The experiment was arranged in a randomized complete block design with four replications. The seed was sown by hand in seven rows 3m long, with 20 cm distance between rows. At the harvest, 100 plants were taken from the middle 5 rows of each plot. Plant height, number of primary branches (including the main raceme) and number of pods per plant were determined at the field. 50 pods from every plant were measured for pod length, number of seeds per pod and seed weight per pod in laboratory. From plants with less than 50 pods, all pods were analyzed. A 1000 seed sub-sample was taken from every plant for determination of 1000 seed weight. Seed yield per plant represents weight of all seeds from particular plant.

Correlation coefficients between all pairs of variables and standardized regression coefficients were obtained using SPSS 11.0 statistical software. The path coefficient analyses were conducted according to LI (1975). Grain yield per plant was kept as a resultant variable and all other component characters as causal variables.

RESULTS AND DISCUSSION

The correlation between all pairs of variables is given in Table 1, separately for Skopje and Strumica. As can be seen from the table, all traits were positively and significantly correlated with seed yield, except plant height in Strumica.

Seed yield had highest correlation with number of pods per plant (r= 0.935 and r= 0.973 for Skopje and Strumica, respectively), followed by seed weight per pod (r= 0.693 and r= 0.729) and 1000 seed weight (r= 0.627 and r= 0,680). Significant correlations between seed yield and number of pods per plant, 1000 seed weight and seed weight per pod were reported by OLSSON (1960), THURLING and VIJENDRA DAS (1979), TAYLOR and SMITH (1992) and OZER et al. (1999). ALI et al. (2003) found highly significant and positive correlations of seed yield per plant with harvest index and seed weight. ENGQVIST and BECKER (1993) considered 1000 seed weight as most interesting trait to use as an indirect selection criteria for yield, but the correlation between those two traits wasn't significant across years and crosses. Plant height was highly significant, but negatively correlated with number of branches per plant (r=-0.231 and p=-0.177) and seed weight per pod (r=-0.111 and r=-0.068) in both locations and with 1000 seed weight in Skopje (r=-0.220). The correlations between all other traits were positive and highly significant. According to DIEPENBROCK (2000), for breeding purposes, the correlation between pod length and seed number per pod is very important; the length of the pod can be determined easily and may serve as a trait for indirect selection.

Table 1. Simple correlation coefficients between studied traits in Skopje (the upper value per row) and in Strumica (the lower value per row)

	Seed yield per plant	Plant height (cm)	Number of branches per plant	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Seed weight per pod	1000 seed weight
Seed yield per plant	1	0.032** 0.014^{ns}	0.589** 0.593**	0.935** 0.973**	0.549** 0.642**	0.422** 0.615**	0.693** 0.729**	0.627** 0.680**
Plant height (cm)		1	-0.231** -0.177**	0.032** 0.019*	0.026** 0.175**	0.150** 0.205**	-0.111** -0.068**	-0.220** 0.014**
Number of branches per plant			1	0.629** 0.638**	0.237** 0.319**	0.135** 0.315**	0.304** 0.418**	0.312** 0.593**
Number of pods per plant				1	0.440** 0.548**	0.316** 0.532**	0.547** 0.614**	0.513** 0.973**
Pod length (cm)					1	0.723** 0.894**	0.771** 0.848**	0.549** 0.642**
Number of seeds per pod						1	0.591** 0.820**	0.422** 0.615**
Seed weight per pod							1	0.879** 0.936**
1000 seed weight								1

, Correlation is significant at the 0.01 level and 0.05 level respectively; ns- nonsignificant

Path coefficient analysis was performed in order to obtain and interpret information on the nature of interrelationships between grain yield and yield related traits in both locations where the experiment was conducted (Table 2).

All of the characters had highly significant direct effect on seed yield, except for the 1000 seed weight in Strumica (p= 0.010). The direct effect differed from the simple correlation coefficient in the case of number of branches per plant (p= -0.054) and number of seeds per pod (p=-0.041) in Strumica and pod length (p=-0.038) in Skopje. These traits had negative direct effect on seed yield which could not be seen from the simple correlation coefficients because it was strongly covered by the positive indirect effect of number of pods per plant.

Table 2. Pathways of association between yield and yield related traits in Skopje (the upper value per row) and in Strumica (the lower value per row)

Character	Direct effect	Indirect effect via: Plant height (cm)	Number of branches per plant	Number of pods per plant	Pod length (cm)	Number of seeds per pod	Seed weight per pod	1000 seed weight	Correlation
Plant height (cm)	0.045**	0.000	-0.009	0.024	-0.001	0.009	-0.024	-0.012	0.032**
	0.011**		0.010	0.017	0.003	-0.008	-0.015	-0.002	0.014^{ns}
number of branches per plant	0.040**	-0.010	0.000	0.478	-0.009	0.008	0.066	0.018	0.589**
	-0.054**	-0.002		0.559	0.005	-0.013	0.094	0.004	0.593**
number of pods per plant	0.759**	0.001	0.025	0.000	-0.017	0.019	0.118	0.029	0.935**
	0.877**	0.001	-0.035		0.008	-0.022	0.138	0.006	0.973**
pod length (cm)	-0.038**	0.001	0.009	0.334	0.000	0.043	0.167	0.033	0.549**
	0.015**	0.002	-0.017	0.480		-0.037	0.192	0.007	0.642**
number of seeds per pod	0.059**	0.007	0.005	0.240	-0.028	0.000	0.128	0.011	0.422**
	-0.041**	0.002	-0.017	0.467	0.013		0.185	0.006	0.615**
seed weight per pod (g)	0.216**	-0.005	0.012	0.415	-0.029	0.035	0.000	0.049	0.693**
	0.225**	-0.001	-0.023	0.539	0.013	-0.034		0.010	0.729**
1000 seed weight (g)	0.056**	-0.010	0.012	0.389	-0.022	0.011	0.190	0.000	0.627**
	0.010^{ns}	-0.002	-0.023	0.499	0.011	-0.025	0.211		0.680**

**,* Correlation is significant at the 0.01 level and 0.05 level respectively; ns- nonsignifican

Number of pods per plant (p=0.759 and p=0.877 for Skopje and Strumica, respectively) and seed weight per pod (p=0.216 and p=0.225) had the greatest direct effect on seed yield in both locations. THURLING (1974), OZER et al. (1999) and ALI et al. (2002) also reported highest direct effect of pods per plant on seed yield which differs from the findings of MARINKOVIC et al. (2003). ALI et al. (2003) found that the direct effect of the harvest index on seed yield was highest and positive, followed by seed weight and number of pods per plant.

1000 seed weight had positive (and highly significant in Skopje) direct effect on seed yield (p=0.056 and p=0.010 for Skopje and Strumica, respectively) which is in relation with the results of OZER et al. (1999).

The coefficient of determination (R^2=0.943) represents the influence of the traits involved in the study on total variability of seed yield per plant. The remaining 0.057% could be attributed to factors that are not included in this study.

CONCLUSIONS

All traits included in the analysis were positively and significantly correlated with seed yield, except plant height in Strumica. Seed yield had highest correlation with number of pods per plant (r= 0.935 and r= 0.973 for Skopje and Strumica, respectively), followed by seed weight per pod (r= 0.693 and r= 0.729) and 1000 seed weight (r= 0.627 and r= 0,680).

The path coefficient analysis confirmed the findings of the correlation analysis in general, but also provided additional information on interrelationships between the pairs of independent variables. Based on the obtained results, number of pods per plant (p=0.759 and p=0.877 for Skopje and Strumica, respectively), seed weight per pod (p=0.216 and p=0.225) and 1000 seed weight (p=0.056 in Skopje) exhibited highest direct effect on seed yield per plant. Because of that, these yield related traits can be considered to be effective as selection criteria for seed yield improvement in spring canola genotypes.

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MEĐUZAVISNOST PRINOSA I KOMPONENTI PRINOSA GENOTIPOVA JARE ULJANE REPICE (*Brassica napus* L.)

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I z v o d

Istraživanje je sprovedeno sa ciljem da se determinšu komponente prinosa koje mogu pretstavljati efektivniji kriterijum za selekciju nego prinos “per se”. Kod tri jara genotipa uljane repice (*Brassica napus* L.) su bila ispitivana svojstva: visina biljke, broj primarnih grana (uključujući i centralnu), broj ljuski po biljci, dužina ljuski, broj semena po ljusci, masa semena po ljusci i masa 1000 semena, kao i njihove korelacije sa prinosom semena po biljci. Broj ljuski po biljci je imao najveću vrednost koeficijenta korelacije sa prinosom po biljci (r= 0.935 i r= 0.973 u Skoplju i Strumici). Nešto manju vrednost je imao koeficijent korelacije za masu semena po ljusci (r= 0.693 i r= 0.729) i masa 1000 semena (r= 0.627 i r= 0.680). Analiza path koeficijenta je korišćena za razdvajanje direktnih i indirektnih uticaja ispitivanih svojstava na prinos semena. Broj ljuski po biljci (p=0.759 i p=0.877 za Skoplje i Strumicu) i masa semena po ljusci (p=0.216 i p=0.225) su imale najveći direktni efekat na prinos semena po biljci u obe lokacije. Nešto manja vrednost ovog pokazatelja izračunata je za masu 1000 semena (p=0.056 i p=0.010). Koeficijent determinacije (R^2) je iznosio 0.94

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