Oil Yield Stability of Winter Rapeseed (*Brassica napus* L.) Genotypes

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Summary

The identification of the highest yielding cultivar for a specific environment on the basis of both genotype and genotype x environment interaction could be useful for breeders and producers since yield estimation based only on genotype and environment effects are insufficient. The trial was carried out during six growing seasons using eight registered cultivars of rapeseed developed at European breeding stations and 11 experimental lines developed in the Institute of Field and Vegetable Crops, Novi Sad, Serbia. The objective of the study was to identify genotypes with most stable oil yield by using combination of three parameters: ecovalence (w_i), regression coefficient (b_i) and deviations mean square (s^2_{di}) (first model) and AMMI model analysis (second model). Average oil yield per area of experimental genotypes was higher comparing to registered genotypes. According to the first model, seven experimental lines and two registered varieties (Falcon and Banacanka) were estimated as stable and wide adaptable genotypes. A complete positive and highly significant correlation was estimated between w_i and s^2_{di} that implies that both of these parameters could be used independently. According to the AMMI models, in the environmental conditions of Northern Serbia, the genotypes UM-8 and UM-11 were the most stable and with high average oil yield. Such genotypes can be implemented in future breeding programs and recommended for growing in South Eastern Europe.

Key words

Brassica napus L., cultivars, stability, AMMI model, oil yield

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Introduction

Rapeseed (*Brassica napus* L.) has been produced on about 28 million ha in the world in 2005, which is more than 3.5 million ha comparing to 1995 (FAOSTAT Database, 2005). In Europe, it is grown on 5.7 million ha and is the most important oil crop (Kis et al., 2006). Considering that the rapeseed oil, beside its use for food, feed and industrial purposes, is also used for metilester, which is important component for biodiesel production, it can be expected that the rapeseed production area will continue expanding in the next years. The main objective of the rapeseed producers and breeders is obtaining higher seed and oil yields per area unit. High variability of these traits indicates the great influence of the environment (soil type, fertilization, irrigation, weather conditions, photoperiodism) and the complex genotype ×environment interaction (GEI) on their expression. The breeding programs comprise assessment of new genotypes in a wide range of different environments and the understanding of the GEI is a basis for interpreting results from such investigations. The stability analysis can be continued with biological (static) or agronomic (dynamic) concept. The stability estimation could be done by using AMMI (Additive Main Effects and Multiplicative Interaction) model analysis (Gauch and Zobel, 1996), or using other methods (Hill et al., 1998; Luguez et al., 2002). AMMI model analysis combines the ANOVA (with additive parameters) and PCA (with multiplicative parameters) into a single analysis (Crossa et al., 1990). It is especially useful in making cultivar recommendations, because the best performing cultivar for each subregion of the crop's growing region can be identified (Zobel et al., 1988).

Results obtained from such analyses are very important for developing and recommending best cultivars for production in a specific area, as a selection criteria for further genetic improvements (Sudarić et al., 2003) and can enable objective estimation of experimental genotypes and hence developing best possible varieties for official testing by national registration authorities (Mijić et al., 2007).

Materials and methods

The trial was consisted of nineteen winter rapeseed cultivars as follows: two varieties from Hungary ('Oktavija', 'Jana'), two varieties from Serbia ('Sremica', 'Banacanka'), three varieties from France ('Samuray', 'Jet Neuf', 'B-009'), one variety from Germany ('Falcon'), and 11 experimental lines from Serbia (UM-1, UM-2, UM-5, UM-6, UM-8, UM-9, UM-10, UM-11, UM-12, UM-13, UM-14).

Cultivars were grown during six growing seasons (from 1996 to 2003) at the experimental fields of Institute of Field and Vegetable Crops, Novi Sad. The field trial was arranged in a randomized complete block design with three replications. The seed was sown by hand in four rows, 4 m long, with a between-row spacing of 25 cm. Thinning at HB 3 stage (according to Harper and Berkenkamp, 1975) provided within-row spacing of 5 cm.

The trial was set up in chernozem type of soil, according to pedodinamic classification of Vasin et al. (2002), with 2.87% humus content, 1.95% $CaCO_3$, 0.19% N, moderate content of phosphorus (20.57 mg $100g^{-1}$ soil) and potassium (25.25 mg $100g^{-1}$ soil), pH in KCl - 7.07 and pH in H_2O - 7.71. Before tillage, 250 kg ha^{-1} NPK fertilizer was applied. Other agricultural practices were optimal in all investigated seasons.

The data for each cultivar was collected on a plot basis. Stability and adaptability estimation was performed using combination of three parameters: ecovalence (w_i), regression coefficient (b_i) and deviations mean square (s^2_{di}). The results were interpreted according to Haufe and Geidel model (1978; according to Becker and Leon, 1988). Simple correlations strength and their direction between oil yield and stability parameters, as well as between parameters themselves, were also computed.

AMMI model was used for determination and assessment of genotype and environmental effects, as well as for GEI effect. Sources of variability for GEI effect were split by the main components analysis (interaction IPCA) (Gauch and Zobel, 1990). Analysis and interpretation of results were based on procedure of Zobel et al. (1988). Program IRRISTAT was used for AMMI analysis, while for making biplot was used AMMI macro (www.cimmyt.cgiar.org/biometrics).

Results and discussion

From the breeders' point of view, location is fixed factor, and yield consistency over time is the only relevant component of genotypes yield stability (Annicchiarico, 2002). The expression of oil yield, as one of the most important rape seed quantitative traits, is greatly influenced not only by genotype, but also by environment and complex genotype x environment interactions (Habekotte, 1997; Sidlauskas and Bernotas, 2003). Therefore, it is always attempted to test the stability or consistency of each genotype in wide range of different environments. The obtained data is very useful in selection of the best genotypes, making this kind of research quite important for breeders and growers alike (Tuck et al., 2006).

This approach enables determination of the genotypes that would achieve satisfactory oil yield when growing in different environments, if it is confirmed that genotype x environment interaction has significant effect on expression of the trait (Table 1).

These genotypes can differ in oil yield, but they are characterized by $b_i \approx 1$ and low w_i and s^2_{di}. In this investigation this was the case with lines UM-10, UM-12, UM-13, UM-14, UM-6, as well as with registered varieties 'Falcon'

Table 1. ANOVA and AMMI model for rapeseed oil yield across all growing seasons

Effect	df	SS	MS	Variance (cm)	Variance (%)
E	5	25.4517	5.090341**	-	
Block (E)	12	4.202586	0.350215	-	
G	18	6.217062	0.345392**	0.01356	
GEI	90	9.173625	0.101929**	0.01759	
IPCA1	22	4.2405	0.19275**		51.89
IPCA2	20	2.604387	0.130219**		35.05
GEI Residual	48	2.328744	0.048516		13.06
Residual	216	10.5875	0.049016	0.04902	
Total	341	55.63248	0.163145		

** F test significant at P<0.01 level

Table 2. Stability and adaptability of rapeseed oil yields in all growing seasons

Genotype	Yield ($t\ ha^{-1}$)	w_i	b_i	s^2_{di}
Sremica	1.027	0.08	1.35	0.01
Banacanka	0.918	0.09	0.86	0.02
Samuray	0.605	0.18	0.65	0.05
Falcon	0.978	0.16	1.02	0.04
Jet Neuf	0.926	0.11	0.82	0.02
Oktavija	0.718	0.89	0.16	0.14
Jana	0.824	0.07	0.72	0.01
B-009	0.826	0.20	0.62	0.04
Average	0.852			
UM-1	0.967	0.14	1.21	0.03
UM-2	1.118	0.19	1.15	0.05
UM-5	0.900	0.30	1.26	0.07
UM-6	1.015	0.03	1.16	0.00
UM-8	0.925	0.00	1.02	0.00
UM-9	1.060	0.26	1.49	0.04
UM-10	0.979	0.05	0.99	0.01
UM-11	1.139	0.03	0.97	0.01
UM-12	0.717	0.03	1.04	0.01
UM-13	0.819	0.14	1.09	0.04
UM-14	0.920	0.10	1.03	0.03
Average	0.960			

Table 3. Correlation coefficients among rapeseed oil yield and stability parameters and among stability parameters

Stability parameters	Oil yield	w_i	b_i
w_i	-0,332		
b_i	0.629**	-0.533	
s^2_{di}	-0.370	0.963**	-0.494*

** F test significant at level P<0.01; ** F test significant at level P<0.05

and 'Banacanka' (Table 2). Beside high stability for oil yield, these genotypes also may be considered as wide adaptable for the most important trait of rapeseed and recommended for planting in different environments.

Strong and highly significant positive correlation was estimated between oil yield and regression coefficient

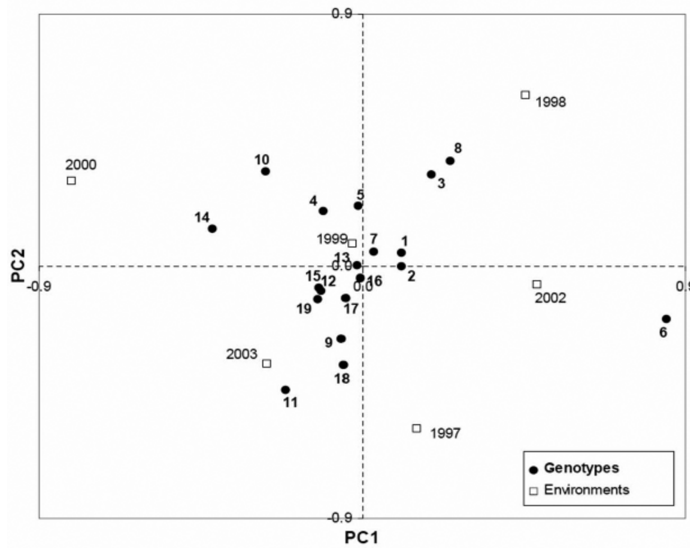

Figure 1. Biplot of principal components (PC) axis 2 vs. 1 for oil yield in 19 cultivars winter rapeseed grown at six environments

(0.629**), but non-significant negative between oil yield and ecovalence as well as between oil yield and deviations mean square (Table 3). A complete, negative, highly significant correlation between ecovalence and deviations mean square points out that either of these two parameters could be used independently from each other without affecting accuracy of estimation.

The stability of the genotypes is also shown in a biplot (Figure 1). Stable genotypes are concentrated around the center presenting a group of genotypes with average oil yield near to the mean value (0.915 $kgha^{-1}$). Different value of the IPCA-1 influences the positioning of the genotypes in the different sectors of the graph, near the y axis. This is a result of their diverse reaction on the environmental conditions. The genotypes 'Samuray' and 'B-009' belong to the group that is characterized with lower average oil yield and positive correlation with year 1998. Genotypes located in the highest spots of different sectors of the graph have best results in the ecological conditions in the same sector (Yan, 2001). It should also be noticed that registered hybrids and varieties had slightly lower oil yield but very high stability. This is probably one of the main reasons why they are so widely present in the winter rapeseed growing area. The lines UM-2 and UM-9 expressed very high positive association of oil yield and year 2000, and negative with the year 2003. These genotypes have similar origin influencing similar variability of oil yield. Grouping of rapeseed genotypes according to their average value and interaction, which can be explained with their common origin, is presented by other researchers (Shafii et al., 1992; Marjanovic-Jeromela, 2005). High yielding genotypes had positive correlation with years suitable for rapeseed production. On the contrary, low yielding genotypes were in association with inappropriate years. Similar results are given by Vargas et al. (1999) and Sudarić et al. (2006). Knowing the favorable environmental factors for specific genotypes, makes easier their choice for particular regions and growing conditions.

The lines UM-8 and UM-11, according to their IPCA1 value close to 0, were the most stable and with high average oil yield in all six years of investigation. Such lines could be recommended for implementation in future breeding programs for growing in this region.

Conclusions

Environmental effect as well as GEI had the strongest effect on oil yield expression.

For experimental lines higher oil yield was estimated, whereas registered varieties showed higher stability for the same trait.

Use of the graphic AMMI model analysis in biplot form alleviated selection of stable and high yielding genotypes for oil yield.

The results of this investigation alleviate selection of appropriate genotypes for particular growing conditions. Lines UM-8 and UM-11 showed high and stable oil yield in the performed investigation. Therefore, both lines can be recommended for planting in South-Eastern Europe. Moreover, these lines should also be included in further breeding programs of rapeseed.

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