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Original scientific paper

ESTIMATION OF VARIATION AND CORRELATION ANALYSIS FOR YIELD COMPONENTS IN BLACK CURRANT CULTIVARS

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Creating genotypes that will be characterized by high yields, good quality and other favorable agronomic characters is a major objective of most currant breeding programs worldwide. For easier and faster achievement of these goals and identification of superior genotypes suitable for use as parents in future hybridization programs, study of genetic parameters seems to be obligatory. In this regard, the aims of our study were to estimate components of variability and heritability, and do correlation analysis for yield components in order to determine efficient strategies for improving yield in black currant breeding programs. Significant differences between cultivars were established for all studied traits. A high proportion of genotypic variance was found with bush width, no. of shoots per bush, bunch weight and berry weight indicating that genetic improvement for these traits through breeding was achievable. Opposite, seasonal variance was high for bush height, no. of bunch per bush and yield. The high heritability coefficients (0.80-0.94) detected for all traits studied reflect the close agreement between their phenotypic and genotypic values. Also, most pairs of traits were similarly correlated at both phenotypic and genotypic levels. So, yield was significantly and positively correlated with bush height, no of bunch per bush and bunch weight. These results imply a rapid response of black currants to selection.

Keywords: Components of variability, heritability, phenotypic and genotypic correlation, genetic gain, *Ribes nigrum* L.

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INTRODUCTION

The black currant (*Ribes nigrum* L.) is an important fruit crop produced commercially in moderate temperature regions encompassing many countries of the world (PLUTA *et al.*, 2012). Compared with other fruit types, black currant has stringent requirements in terms of growing, and allows a rapid return of investments and profit-making. Black currants are mainly grown on intensive large-scale mechanized farms for industrial use like making juices and nectars, jams and other products while only small amounts are consumed freshly (BRENNAN, 2008). In recent years, research obtained by TABART *et al.*, (2006), CIORNEA *et al.*, (2009), DJORDJEVIĆ *et al.*, (2010, 2014), MILIVOJEVIĆ *et al.*, (2013) that are showing high contents of taste- and health-related compounds are increasing demand for this berry fruit.

The breeding of black currant is now focused on the production of fruit with elevated levels of nutritional components and other favorable agronomic characters that can be grown in low input cropping systems. This can be achieved by using unrelated and diverse parents (UKALSKA *et al.*, 2006). Parental genotypes are usually selected on the basis of their phenotypic value for important traits. Phenotypic variation of a trait assumed in quantitative genetics to be a sum of variance of genetic, environmental and genotype by environment interaction effects (TOKER, 2004) For easier and faster achievement of breeding goals and identification of superior genotypes suitable for use as parents in future hybridization programs, study of genetic parameters seems to be obligatory. According to RAKONJAC *et al.*, (2011) progress in breeding programs depends on the knowledge of traits, genetic systems controlling their inheritance, and genetic and environmental factors that influence their expression. Also information on levels of variability can be very useful for determining on which material to begin genetic improvement through breeding programs.

There is limited information on the evaluation of genetic basis for yield and quality attributes in black currant (MADRY *et al.*, 2010). To develop breeding strategies and maximize genetic gain, breeders need reliable information such as coefficient of variation components of variability and coefficients of heritability. Heritability coefficient determines how much of the differences in phenotypic expression of a trait on selection units are as due to their genetic effects (HOLLAND and CERVANTES-MARTINEZ, 2003). This measure is usually applied to assess in what extent the phenotypic variation of a trait affected by genetic effects and, then, is explained by their variation. Their values depend on magnitude of genetic and environmental variance components.

Improvement programs often considered more than one trait. The knowledge of correlations within the traits is useful in order to predict how the changes in one traits will affect the other. So, just as the phenotype of an individual has both a genetic and environmental component, a phenotypic correlation between two traits can be the result of genetic or environmental effects or both (LUBY and SHAW, 2009). Also, correlation analysis is necessary in case when selection target is complex traits such as yield. Yield is considered as quantitative trait affected by a number of factors such as genetic and environmental factors, physiological processes, influence of pests and diseases or other causes (MADRY *et al.*, 2005). By indirect selection through yield components, characteristics that are highly correlated with yield and more heritable can easier be improved.

Therefore, present study undertaken to estimate the extent of genotypic and phenotypic variability, heritability, genetic advance and genotypic and phenotypic correlation coefficient for yield components in black currant cultivars collection.

MATERIALS AND METHODS

Investigations were carried out in a currant collection orchard, the property of the “Omega” nursery (Mislodjin village, near Belgrade). Experimental field was situated between 44° 30′ and 44° 45′ N and 20° and 20° 20′ E. Altitude is between 80 and 90 m. Plantation was planted on sandy loam soil type with average pH 6.3. The orchard was planted in 2006, with 1-year nursery plants, using the hedge system (a bush form), at 1.8 x 0.8 m spacing. The bushes were under non-irrigated standard cultural practices. The experiment was set as a randomized complete block design with five replicates. Each replicate was presented with five bushes.

Thirteen European black currant (*Ribes nigrum* L) commercial cultivars were used as material in this investigation. During three consecutive years (2007-2009) bush height (BuH), bush width (BuW), shoots number (SNo), cluster number (CNo), berry weight (BeW), cluster weight (CW) and yield (Y) were evaluated. BuH and BuW were measured by ruler in m, respectively. SNo and CNo were determined by counting and are expressed as the number per bush. BeW and CW were measured with digital balance on 30 randomly sampled samples and expressed in g. Y was presented as kg/bush.

The obtained results were processed by two-factorial analysis of variance (ANOVA) and LSD test with P< 0.05.in the statistic program ‘Statistica’ (StatSoft, Inc.). From the results of ANOVA, the total variance of each traits was partitioned into the variance components associated with genotype (Vg), year (Vy), genotype by year interaction (Vgy), and variance of error (Ve), Coefficients of genetic and phenotypic variation (GCV and PCV), as relative indicator of variability were determined, as well. Coefficient of heritability in broader sense (H^2) was calculated as a ratio between genetic and phenotypic variance. All values of components of variability, coefficients of variation and coefficients of heritability were expressed in percentage. All values of components of variability, coefficients of variation and coefficients of heritability were expressed in percentage. Phenotypic and genotypic covariance obtained by covariance components analysis was used to calculate correlation coefficients. Direct genetic gain (ΔGn) for all traits studied and indirect genetic gain (ΔGyn) for yield, over the studied traits at 20% selection intensity (i = 1.40) was calculated following FALCONER (1996).

RESULTS AND DISCUSSION

Variance analysis and means comparison

The analysis of variance showed that effects of the cultivar (genotype) and the years were significant (P<0.05) for all traits included in the study. A large number of significant differences for all traits were found between black currant cultivars (Table 1). Cultivar Malling juel is the most vigorous since it had the highest bush height (BuH) and widt (BuW) whereas the smallest vigor was detected in cultivar Ben sarek. The range in variation was 2.3-10.9 for shoot number (Sno) and 88.7-251.2 for cluster number (CNo). Compared to other cultivars, significantly higher berry (BEW) and cluster weight (CW) had cultivar Bona. The highest yield (Y), which was much higher than in other cultivars was recorded in the cultivars Malling Juel and Tsema while varieties Ojebyn and Triton had significantly the lowest yield. KRÜGER *et al.*, (2011) also detected significant differences for yield and berry weight between black currant cultivars. Highly significant differences among black currant cultivars studied in this paper indicate the presence of adequate natural variation which could be improved by various breeding approaches.

Differences in climatic conditions have a considerable effect on the year-to-year performance of all traits studied (Table 1). The lowest values for most traits except for BEW and CW were detected in the first year. Large variation by age is especially expressed for BuH, CNo and Y, where the values in 2007 were several times less than in the other two years. In addition, significant differences between all three years was detected for BuH, BeW, CW and Y.

Table 1. Mean performance of 13 black currant cultivars and of three years for yield component and yield

Main factor	BuH[a,b]	BuW	SNo	CNo	BeW	CW	Y
Cultivar							
Ben Sarek	76,9f	72,9i	7,0cd	170,9de	1,40bc	8,89cd	1,46cd
Ben Nevis	89,5d	91,8gh	8,5b	156,7ef	1,48b	6,50g	1,02f
Bona	93,9d	83,7h	7,9b	138,3g	1,85a	12,69a	1,75b
Ben Lomond	125,1b	138,3b	6,2de	226,0b	0,91ef	7,66e	1,67bc
Ometa	108,6c	98,7fg	3,9ghi	156,6ef	0,84f	6,88fg	1,07f
Tenah	90,6d	100,5f	10,9a	135,4gh	1,38c	9,04cd	1,22ef
Silmu	119,7b	117,4cd	4,3fgh	191,4cd	0,96e	7,47ef	1,40de
Titania	108,5c	107,1ef	7,6bc	193,7c	1,11d	9,87b	1,83b
Malling Juel	133,2a	158,1a	2,9ij	226,2b	1,08d	9,56bc	2,06a
Ojebyn	80,3ef	103,4f	4,9fg	88,7i	1,08d	6,64g	0,55g
Tsema	117,7b	124,8c	5,3ef	251,2a	1,08d	9,44bc	2,28a
Triton	87,4de	120,8cd	3,3hij	114,1h	0,92ef	7,68e	0,74g
Čačanska crna	103,0c	114,9de	2,3j	145,4fg	0,93ef	8,56d	1,17f
Year							
2007	67,7c	98,9b	5,2b	63,1b	1,18b	9,56a	0,61c
2008	110,9b	113,8a	5,5b	222,5a	1,30a	9,15Bb	2,05a
2009	129,4a	117,8a	6,6a	220,9a	0,98c	6,88c	1,54b

[a] for explanation of trait symbols, see ‘‘Materials and Methods’’

[b] Mean separation within columns for two main factors by LSD test at $p \leq 0.05$

Due to the fact that majority of quantitative traits such as yield components and yield are under multi factorial control it was very important to determine the components of variability. The variance components calculated for the traits studied are presented in Figure 1. The variance of genotype (Vg) was highest in BuW (67%) and BeW (62%), followed by SNo (46%) and CW (44%). The variance of among years (Vy) was the highest in BuH and CNo (68%) and Y (56%).

Although effects of the genotype x year interaction were statistically significant (data not shown) this effect expressed as a component of variability (Vgy) (Vgy) was negligibly small from most traits, except for SNo, and ranging from 1 to 11%. This show that responses to changing yearly climatic conditions are similar in all cultivars and according to SHIRAISHI *et al.*, (2012), suggest that changing pattern of each trait over the years is valid for the selection of breeding programs. Slightly higher contribution caused by Vgy observed with SNo (29%)

indicates that this property may be unstable over years and locations or probably due differences in cultivation conditions.

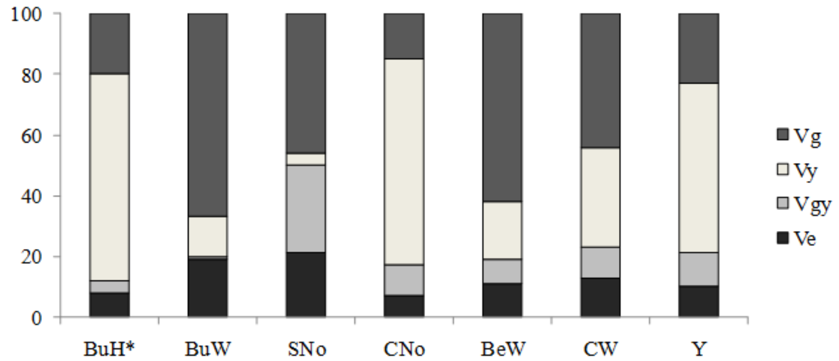

Figure 1. - Components of variability (Vg - genetic variance; Vy - variance of year; Vgy – variance of genotype x year interaction; Ve - variance of error and random factors) for yield components and yield in black currant cultivars,
[*] for explanation of trait symbols, see ''Materials and Methods''

The extent of variability present among black currant cultivars estimated in terms of phenotypic and genotypic coefficient of variation (Table 2). The magnitude of PCV and corresponding GCV were almost identical in expression for all the traits which indicates that the effect of genetic factors in the expressed variability was predominant. The PCV and GCV were high for SNo (43.4% and 39.1%, respectively) and Y (36.3% and 33.3%, respectively) while it was found low for BuH (17.4% and 16.7%, respectively). According SINGH *et al.,* (2011) properties having greater amount of GCV, like SNo and Y in this study, present a better possibility and potential of improvement through hybridization and selection.

Table 2. Coefficients of variability, heritability and genetic gain of yield components and yield in black currant cultivars

Parameters	BuH[a]	BuW	SNo	CNo	BeW	CW	Y
Average	102,6	110,2	5,8	168,8	1,16	8,53	1,40
PCV	17.4	20.6	43.4	28.0	25.1	19.9	36.3
GCV	16.7	20.4	39.1	25.0	24.5	19.0	33.3
H^2	92.5	98.0	80.9	79.7	94.8	91.4	84.3
ΔGn	23.1	31.2	2.85	52.7	0.39	2.16	0.60
ΔGyn	0.49	0.25	0.08	0.51	0.06	0.44	-

[a] for explanation of trait symbols, see ''Materials and Methods''

ΔG_n - Genetic gain in direct selection (in traits units)

$\Delta G_{y.n}$ - Genetic gain in yield (y) via the traits (n)

Coefficients of heritability estimated as Vg/Vp ratio were high for all traits under study (Table 2). The highest heritability coefficients (>90%) were identified for BuH, BuW, BeW and

CW, whereas slightly less but still high heritability coefficients (79.7-84.3%) detected for SNo, CNo and Y Results of our study are in accordance with UKALSKA *et al.*, (2006) and SINGH *et al.*, (2011) who estimates high heritability for yield in strawberry. Also, high heritability coefficient for fruit weight in red raspberries determined by FOTIRIĆ AKŠIĆ *et al.*, (2011). STEPHENS *et al.*, (2009) found high heritability for berry weight i nisku heritabilnost za yild kod maline in raspberry which is partly in accordance with our results. ZURAWICZ *et al.*, (1996) and MADRY *et al.*, (2005) identified low to moderate heritabilities for bush size, berry weight and fruit yield per bush in black currant which is contradictory with our findings. The differences may be explained by the fact that the values are determined in different plant material, the assessment is carried out in different environmental conditions, and finally by the use of a different model for approach. Differences may arise due to the fact that we set the broad sense heritability, which is always greater than the narrow sense heritability. It must be noted that, broad sense heritability is of little use for breeders. Yet, heritability estimates presented in this study are valuable for suggesting potential of investigated cultivars to influence inheritance of studied traits in progeny (MILATOVIC *et al.*, 2010).

The relatively high heritability coefficients detected in this study for yield components as well as yield ndicate that these characters were less influenced by environment demonstrating either these were simply inherited characters governed by additive gene effect (VERMA *et al*., 2013). Also, high values of heritability reflect the close agreement between their phenotypic three-year means and genotypic values for the cultivars represented by this collection and indicate that a reliable selection can be made for these traits.

As shown in Table 2 expected direct genetic gain for all traits was positive and relatively high. The genetic advance as percentage of mean was high (>40%) for SNo and Y, medium for BeW, CNo and BuH while it was low (<25%) for CW and BuH. The values of expected genetic gain in yield by indirect selection through yield components were less than direct genetic gain. BuH (0.49 kg), CNo (0.51 kg) and CW (0.44 kg) were distinguished as the components through which indirectly can achieve the highest yield increase. It should be noted that the genetic gain and the relative efficiency of indirect selection are calculated based on the total genetic variance and so that the values of these parameters is somewhat higher than the actual.

According to the results of this study the largest effect of yield increasing is expected as a result of direct selection. However, bearing in mind that this is a very complex trait and taking into account that the values of correlation coefficients, coefficients of heritability and expected gain from indirect selection, this goal can be achieved with great success through the bush height and cluster weight.This is in agreement with MADRY *et al.*, (2000) that found that plant and cluster size were the main factors influencing fruit yield in black currant. STEPHENS *et al.*, (2012a) also observed highest expected genetic gain of total yield per breeding cycle in rapsberry was from indirect selection through fruit weight.

The inter-relationship among yield components and yield was analyzed to determine the direction and magnitude of association at the genotypic and phenotypic level (Table 3). Genotypic and phenotypic correlations ranged from negligible to highly negative or positive. The correlation coefficients at genotypic level were higher in magnitude than of the corresponding phenotypic correlation coefficients. This indicates the apparent association of two traits is not only due to genes but also due to influence of environmental interactions. But, the meager differences between values for the phenotypic and genotypic correlation coefficients revealed that the effect of the genotype is stronger.

Table 3. Genotypic (over diagonal) and phenotypic (under diagonal) correlation coefficients for yield components and yield in black currant cultivars

Traits	BuH[a]	BuW	SNo	CNo	BeW	CW	Y
BuH	-	0.833**	-0.480	0.970**	-0.479	0.107	0.784**
BuW	0.801**	-	-0.591*	0.617*	-0.635*	-0.098	0.390
SNo	-0.406	-0.524	-	-0.034	0.807**	0.283	0.131
CNo	0.804**	0.537	-0.081	-	-0.303	0.231	0.870**
BeW	-0.454	-0.599*	0.683**	-0.222	-	0.598*	0.108
CW	0.100	-0.089	0.254	0.199	0.588*	-	0.697**
Y	0.661*	0.360	0.074	0.862**	0.146	0.650*	-

[a] for explanation of trait symbols, see ‘‘Materials and Methods’’

* Significant at at $p \leq 0.05$, ** Significant at $p \leq 0.01$

Bush height had positive and significant correlation with yield at phenotypic and genotypic levels. Similar findings were also reported by MADRY *et al.,* (2000) in black currents and KUMAR *et al.,* (2011) in *Withania somnifera* berries. Further Y was closely associated on both phenotypic and genotypic level with CNo and CW. STEPHENS *et al.,* (2012b) also found significant genetic and phenotypic correlation with yield for berry weight and number of fruit in red raspberry. Correlations between yield and BuW, Sno and BeW were positive but nonsignificant. This is partly in accordance with the results MADRY *et al.,* (2005) who also reported that the correlation between yield and shoots number is weak, while the relationshiph between yield and berry weight was strong but negative correlated.

Some of yield components were significantly correlated with one another. However, BuH expressed a significant positive correlation with BuW and CNo. BuW were significantly correlated with CNo at genotypic level whereas phenotypic correlation between this to traits was also positive but no significant. Further, SNo were strongly associated with BeW, while BeW were significantly correlated with CW. Genotypic and phenotypic correlations between BuW and BeW and between BuW and SNo were significant and negative indicating that the same set of genes controls these traits in opposite directions.

CONCLUSIONS

The study shows that great level of phenotypic variability for all traits studied exists in black currant cultivars collection. Bush width, shot number, berry and cluster weight had greater amount of Vg and therefore, present a better possibility and potential of improvement through hybridization and selection. The high heritability coefficients (0.80-0.94) estimated for all traits studied reflect the close agreement between their phenotypic and genotypic values and indicated that superior parents can be selected by direct observation of their performance. Bush height, no of bunch per bush and bunch weight are the most important yield components that can be separated as traits that were significant, positively, phenotypic and genotypic correlated with yield. In the breeding process yield increase can be achieved by direct selection or indirect selection through bush height and weight cluster with equal success. These results imply that we can expect a rapid response of black currants to selection.

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PROCENA VARIJABILNOSTI I KORELACIONA ZAVISNOST KOMPONENTI PRINOSA KOD SORTI CRNA RIBIZLA

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Izvod

Stvaranje genotipova koje će karakterisati visok prinos, dobar kvalitet ploda i druge agronomski poželjne osobine je glavni cilj većine programa oplemenjivanja ribizle širom sveta. Za lakše i brže ostvarivanje ovih ciljeva kao i za identifikaciju superiornih genotipova pogodnih za korišćenje u svojstvu roditelja u budućim programima hibridizacije, proučavanje genetičkih parametara je neophodno. U tom smislu, cilj našeg istraživanja je bio da se utvrde komponente varijabilnosti i heritabilnost, i uradi korelaciona analiza za komponente prinosa kako bi mogla da se preporuči efikasne strategije za poboljšanje prinosa crne ribizle. Veoma značajne razlike između sorti su ustanovljene za sve ispitivane osobine.Visok udeo genotipske varijanse utvrđen je za širinu žbuna, broj izdanaka po žbunu, masu grozda i masu bobice što ukazuje da je znatan genetički napredak ovih osobina kroz programe oplemenjivanja ostvariv. Nasuprot tome, ekološka varijansa je bila visoka za visinu žbuna, broj grozdova po žbunu i prinos. Visoke vrednosti koeficijenataheritabilnosti (0.80-0.94) detektovane za sve ispitivane osobine odražavaju povezanost njihove fenotipske i genotipske vrednosti. Takođe, korelacionom analizom je ustanovljeno da je i na fenotipskom i na genotipskom nivou većina parova osobina korelisana na sličan način, pri čemu je prinos bio značajno, pozitivno korelisan sa visinom žbuna, brojem grozdova po žbunu i masom grozda. Dobijeni rezultati ukazuju da je kod crne ribizle moguće ostvariti značajnu dobit od selekcije.

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