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GENETIC PARAMETERS OF YIELD COMPONENTS AND POMOLOGIC PROPERTIES IN RASPBERRY SEEDLINGS

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Over a three-year period yield components and pomologic properties were studied in 20 raspberry seedlings obtained by open pollination of Meeker`s yellow clone. The primary goals of this research were to determine its variability components, coefficients of genetic and phenotypic variation and coefficient of heritability in a broader sense. The analysis of the components of total variance evidenced that higher proportion of genotypic variance was found with fruit shape index (30.84%) and sucrose content (35.61%). The results revealed that genotypic coefficient of variation were less than its corresponding estimates of phenotypic coefficient of variation for all traits which indicated significant role of environment in the expression of these characters. The values of heritability coefficients, in a broader sense, were high except for number of

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flowers per inflorescens (9.47%), titratable acidity (6.38%) and inverted sugar content (28.88%). Nine characters had h2 in interval from 50 to 80% but for fruit weight and fruit length was greater than 80% which implies the high potential of genetic improvement in those traits.

Key words: Meeker, yellow clone, variability components, genetic and phenotypic variation, heritability

INTRODUCTION

The primary objectives in modern raspberry breeding include structural aspects of fruit construction, skin strength, texture, coherence, flavor, aroma, sweetness, acidity, sugar/acid balance, seediness, appearance, color, shelf life, ability to be transported, shape, uniformity, regularity, shininess, resistance to pests and diseases, environmental resilience, suitability for different uses, and nutritional and pharmochemical attributes (HARRISON *et al.,* 1999; CALLAHAN, 2003). According to PRITTS (2002) significant improvements to yield and growth habit over the long term could be achieve by genetically reconfiguring of the commercial raspberry germplasm to be more stress tolerant while allocating less biomass to roots and vegetative sinks, and more to reproductive sinks. According to HALL *et al. (*2009) major improvements of quantitative traits in raspberries including fruit size, yield, and some important yield components have been achieved by hybridizations with cultivars with enhanced expression of these traits and backcrossing with other cultivars or by intercrossing parents with good expression of the trait in question and recovering transgressive sergeants' exceeding parental performance. MILIVOJEVIĆ *et al.* (2011) also indicate that new raspberry cultivars with high phytonutrients can be obtained through the classical breeding techniques such as hybridization and clonal selection.

Keys for the potential success of floricane-fruiting raspberries are good expression of yield components and excellent fruit quality. For some traits floricane types can be selected in the first fruiting season, but some traits such as yield, vigor, cane numbers, plant health and mature growth cannot be evaluated until the second or third harvest season (HALL *et al*., 2009). Regarding the facts that genetic control of yield components and fruit quality is under multigenic control, that the crosses are made without accurate prediction of progeny performance and that the choice of parents is based on their phenotypic performance, creating of new raspberry cultivars is expensive and time consuming.

The knowledge of the genetic mechanism that controls the inheritance of a character and the impact of genetic and environmental factors on their expression is essential for successful breeding programs (MRATINIĆ *et al.,* 2007). To make progress from selection in a breeding program, there are two important prerequisites, adequate variation and sufficient heritability of that variation. Heritability directly affects the expected gain from every round of selection, and variation must be present for selection to take place (DOSETT *et al*., 2008). Heritability estimates have previously been reported for anthocyanin, antioxidant activity, total phenolic content, color, freeze resistance and resistance to some diseases in raspberry (STEHPENS *et al.,* 2002; CONNOR *et al.*, 2005a, b; MCCALLUM *et al.*, 2010). Unfortunately, studies regarding components of variability and coefficients of genetic and phenotypic variation are lacking.

For all of those reasons, the aim of the present work was to determine the components of variability and the coefficients of heritability for yield components and phonologic properties in promising raspberry seedlings.

MATERIALS AND METHODS

Research was done at the Experimental Station 'Radmilovac' of the Faculty of Agriculture in Belgrade. A raspberry orchard with more than 100 seedlings obtained from open pollination from Meeker`s yellow clone was planted at a distance of 3 x 0.5 m. The measurements were done during three consecutive years (2007-2009). Plants with both red (I-3-2P, I-4-4, I-6-2, I-7-3, I-8-2, I-9-P, II-2-2P, II-3-4P, II-3-PP, II-5-4, II-6-3, II-8-2, II-8-2P, II-PP-2) and yellow (2, 3, 6A, 6C, 9 and 10) fruits were used as a material in this experiment, together with standard cultivar Meeker.

Generative characteristics such as number of fruiting laterals per cane (NFL/C), number of inflorescences per fruiting lateral (NI/FL), number of flowers per inflorescences (NF/I) and number of flowers per fruiting laterals (NF/FL) was carried out by counting fruiting laterals, inflorescences and flowers from each cane. Length of fruiting laterals (LFL) was measured by a tape and expressed in cm. Physical fruit traits were also followed such as fruit weight, length and width, index of fruit shape and number of drupelets per fruit (Table 1). Fruit weight (FW) was measured by scale in g. Fruit length (FL) and width (FWG) was measured by caliper in cm, respectively. Fruit shape index (FSI) was calculated as the ratio between of FL and FWG and number of drupelets (ND) was determined by counting the drupelets from each fruit. Beside yield components and physical fruit properties chemical traits (soluble solids content, titratable acidity, invert sugars and sucrose content) were also analyzed. Soluble solids content (SSC) was analysed by using a digital refractometer (Pocket PAL-1, Atago, Japan). Titratable acidity (TA) was measured by neutralization to pH 7.0 with 0.1 N NaOH and acidity expressed as percent of malic acid equivalent. Invert sugars (IS) and sucrose content (SC) were measured according to Luff - Schoorl method.

The mean values of the studied properties were determined. The obtained results were processed by ANOVA in the statistic program 'Statistica' (StatSoft, Inc.). Components of variability for physical fruit traits were determined based on two-factorial analysis of variance while chemical properties based on monofactorial analysis of variance. The following components of total variance were computed: variance of year (S2y), genetic variance (S2g), variance of year x genotype interaction (S2yg), variance of error (S2e), all expressed in per cent. Coefficients of genetic and phenotypic variation (and), as relative indicator of variability were determined, as well. Coefficient of heritability in broader sense ( ) 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.

RESULTS AND DISCUSSION

In floricane raspberries number of fruiting laterals per cane along with fruit numbers per lateral is especially important to yield. Average of NFL/C in raspberry seedlings for three consecutive years (Table 1) varied from 8.6 to 19.8, whereas the lowest LFL was 9.1 cm and the highest 29.9 cm. The best results concerning NI/FL and NF/FL had seedling 9 (5.7; 13.0, respectively) and the lowest seedling II-5-4 (2.4; 5.3, respectively). The highest FW was recorded in seedling I-3-2P (3.50 g), while the highest FL and FWD were noticed in seedling II-8-2P (19.51 mm; 18.58 mm, respectively). ND, that is presumed to be a good indicator of fruit quality, suitability for harvest, transport, consumption, freezing, and moreover, estimates fruit sensitivity toward pathogen infection or the stage of fungi infestation (HAFFNER, 2002) varied from 67.6 up to 118.9. FSI had narrow range (0.94-1.14). Regarding the chemical components, SSC was in the interval between 10.20% and 13.67%, TA from 0.63-1.60%, IS from 6.22-8.92% and SC from 0.59-1.16%. The highest values for yield parameters (except for LFL) and physical fruit traits were recorded in 2007. In the same year the lowest average values for chemical traits (SSC, IS and SC) were obtained as well. Nevertheless, yield components and physical fruit traits appeared to be the worst in 2009 (data not show).

Table 1. Variability and heritability of pomologic properties and yield components in raspberry seedlings

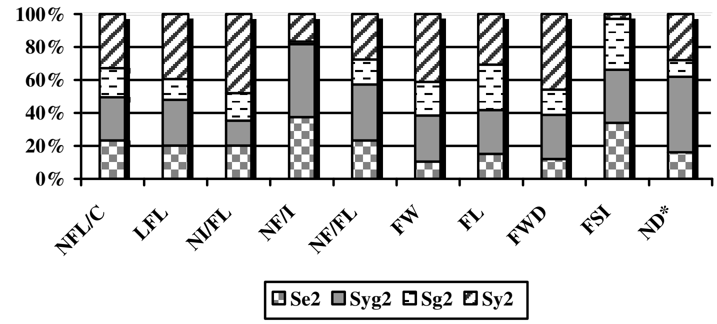
Trait	Min	Mean	Max	CVg	CVf	h2(%)
NFL/Ca	8.6	14.83	19.8	20.92	48.64	69.48
LFL (cm)	9.1	21.51	29.9	17.41	21.61	64.93
NI/FL	2.4	3.92	5.7	19.12	22.66	71.16
NF/I	2.0	2.50	3.3	2.69	8.73	9.47
NF/FL	5.3	9.24	13.0	18.25	22.45	66.08
FW (g)	1.83	2.79	3.50	13.78	14.95	85.17
FL (mm)	14.17	17.51	9.64	6.99	7.61	84.27
FWD (mm)	15.02	17.14	18.58	4.88	5.49	78.94
FSI	0.94	1.03	1.14	4.15	4.85	73.12
ND	67.6	85.9	118.9	7.74	9.61	64.90
SSC (%)	10.20	11.66	13.67	6.17	8.64	50.98
TA (%)	0.63	1.16	1.60	17.27	68.36	6.38
IS (%)	6.22	7.32	8.92	5.29	9.85	28.88
SC (%)	0.59	0.94	1 .16	0.76	12.87	69.90

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

The results from Table 1 revealed that genotypic coefficients of variation (CVg) was less than its corresponding estimates of phenotypic coefficient of variation (CVf) for all traits which indicated significant role of environment in the expression of these traits. Relatively higher estimates of CVg for NFL/C, LFL, NI/FL and NF/FL on one side and close values of CVg and CVf for some pomologic traits on the other side suggest that the selection based on phenotypic values is feasible. Large difference between CVg and CVf in TA (17.27%, 68.36%, respectively) is considerable influenced by weather conditions, which was approved by low heritability estimates variables (6.38%). Genotypic coefficient of variation is not a correct measure to know the heritable variation present and should be considered together with heritability estimates.

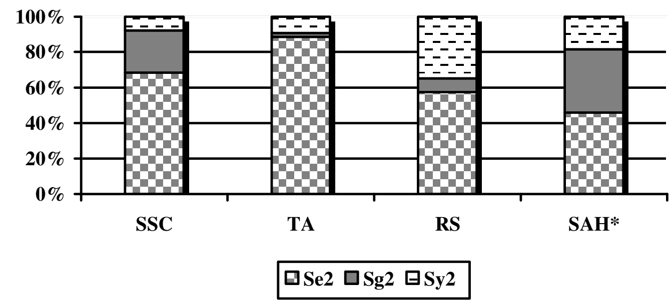
Heritability is another important genetic parameter that measures the relative degree to which a character is transmitted from parent to progeny, and it is more important for the traits related to productivity. A comparison of the data from Table 1 also indicates that the values of heritability coefficients for studied yield components and pomologic traits were moderate to relatively high (50.98 - 85.17%) except for NF/I, TA and IS. It must be however noted that broad sense heritability (h2), that we studied, is of little use for breeders. The narrow sense heritability is of greater importance. Yet, heritability estimates presented in this study are valuable for suggesting potential of investigated seedlings to influence inheritance of studied traits in progeny (MILATOVIĆ *et al.,* 2010). Heritability coefficients were high for FW (85.17%) and FL (84.27%), signifying that these characters are genetically controlled and there could be greater correspondence between phenotypes and breeding value while selecting individuals. Results of our study are not in accordance with CONNER *et al*. (2005a) who determined moderate-high (h2 = 77%) heritability estimates for fruit size in red raspberries. Moderate values for heritability (50-80%) estimates were found in NFL/C (69.48%), LFL (64.93%), NI/FL (71.16%), NF/FL (66.08%), FWD (78.94%), FSI (73.12%), ND (64.90%), SSC (50.98%) and SC (69.90). DOSSETT (2007) found heritability estimates for SSC (38%) and for TA (68%) in black raspberry (Rubus occidentalis L.) which is contradictory with our findings. Selections might be considerably difficult or virtually impractical for a character with low heritability (less than 40%). Such low heritability estimates do not result from genetic identity between parents, but they can be due to non-additive mechanisms, marked environmental effects on these characters, or to a combined effect of these factors (COURANJOU, 1995).

It is becoming increasingly obvious that the future of raspberry production will be largely, perhaps entirely, dependant on breeding efforts. In other words, the solution to current and to future problems will be genetic in nature. Majority of quantitative traits such as yield components and some fruit quality attributes are under multigenic control and are inherited additively with a significant genetic interaction (DAUBENY, 1996). In order to select genotypes for future breeding work it was very important to determine the components of variability and the coefficients of heritability in promising raspberry seedlings.



* for explanation of character symbols, see ''Materials and Methods''

Figure 1. - Components of variability (S2 yg – variance of year x genotype interaction; S2 y – variance of year; S2g - genetic variance; S2e - variance of error and random factors in the experiment) for yield components and morphologic fruit traits



* for explanation of character symbols, see ''Materials and Methods''

Figure 2. - Components of variability (S2 y – variance of year; S2g - genetic variance; S2e - variance of error and random factors in the experiment) for chemical fruit traits

Variability caused by genetic differences between raspberry seedlings ranged in total variability from 1.31% for NF/I to 35.61% for SC (Figures 1 and 2), whereas for plant breeder larger genotypic value of any character is always helpful for effective selection. The variability of NFL/C (S2y = 32.93%), LFL (S2y = 39.52%), NI/FL (S2y = 47.96%), FW (S2y = 41.11%), FL (S2y = 30.70%) and FWD (S2y = 45.85%) were mainly determined by ecological factors (year). The genotype x year interaction between studied seedlings have determined NF/I (S2yg = 44.47%), NF/FL (S2 yg = 34.01%) and ND (S2yg = 45.83%) variability to the highest percentage. Random factors and error account from 10.61% to 88.67% in the total variability of the studied properties. The genetic contribution to NF/I, ND, TA and IS are relatively small (< 10%) and hard to predict, which makes it difficult to develop genotype with large number of flowers per inflorescence, numerous drupelets per fruit, high titratable acidity and inverted sugar content in breeding programs.

CONCLUSION

The results revealed that genotypic coefficient of variation were less than its corresponding estimates of phenotypic coefficient of variation for all traits. Among the studied yield components and pomologic traits, the greatest genetic variance is recorded for the NFL/C and phenotypic for TA. The values of heritability coefficients, in a broader sense, were high except for NF/I, TA and IS. Nine characters had h2 in interval from 50 to 80% but for fruit weight and fruit length was greater than 80% which implies the high potential of genetic improvement in those traits. A wide range of variability and relatively high heritability coefficients values of raspberry seedlings properties studied in this work indicate that the selection of parents for combining breeding can be based on their phenotype. The large magnitude of genotype x year interaction and random factors and error observed with floricane-fruiting seedling indicates that the crop may be unstable over years and locations. Because of that it would make it difficult to recommend seedlings for wide areas of production or choose them as parents in a breeding program. Therefore, it is highly recommended to grow them under different environmental conditions over several years in order to select suitable genotypes for growing or further improvement.

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GENETIČKI PARAMETRI KOMPONENTI PRINOSA I POMOLOŠKIH OSOBINA KOD SEJANACA MALINE

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I z v o d

Komponente prinosa i pomološke osobine kod 20 sejanaca dobijenih slobodnom oplodnjom žutog klona sorte Miker ispitivano je tokom perioda od tri godine. Primarni cilj ovih ispitivanja bilo je da se utvrde komponente varijabilnosti, koeficijenti genetičke I fenotipske varijacije i heritabilnost u širem smislu. Analizom komponenti ukupne varijabilnosti ustanovljeno je da su geneticke razlike medu sejancima u velikom procentu uslovile varjabilnost indeksa oblika ploda (30.84%) i sadržaja saharoze (35.61%). Kod svih osobina takođe je utvrđeno da su koeficijenti genetičke varijacije bili manji u odnosu na fenotipske koeficijente varijacije što ukazuje na značajan uticaj spoljašnjih faktora u ekspresiji ovih osobina. Vrednosti koeficijenta heritabilnosti u širem smislu su bili visoki osima za broj cvetova po cvasti (9.47%), ukupnim kiselinama (6.38%) i sadržaju invertnih šećeria (28.88%). Devet osobina imalo je h^2 u intervalu od 50 do 80%, dok jeza masu i dužinu ploda bio veći od 80% što pokazuje visok potencijal za poboljšanje ovih osobina

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