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STABILITY OF YIELD AND FRUIT QUALITY IN PROMISING PEACH CULTIVARS

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ABSTRACT

Yield and fruit quality (fruit weight, reducing sugar content, sucrose content and total acids content) were studied in 20 introduced peach cultivars. To evaluate the stability of those characteristics in the agro-ecological conditions of Belgrade surroundings, bi and S^2di were applied. 'Adriana' had the highest yield and content of reducing sugars, 'Aurelia' the highest fruit weight, 'Pegaso' the highest sucrose content, and 'Croce del Sud' the highest total acids content. Values of bi coefficient indicated that 'Sirio' had the highest stability of yield 'Iris Rosso' the highest stability of fruit weight and content of reducing sugars, 'Aurelia' the highest stability of sucrose content, and 'Emilia' the highest stability of total acids content. Values of S^2di, despite being relatively high, did not show any statistical significance, which indicates a more significant deviation from regression and unsatisfactory stability of the studied genotypes. The results of the present work confirm that bi, being a stability parameter, is more important than S^2di in heterozygous genotypes, the genotype of a majority of fruit cultivars, therefore of peach itself.

KEY WORDS: Fruit quality, Peach, Stability parameters, Yield

INTRODUCTION

Peach Prunus persica (L.) Batsch. is one of the most important fruit species. Among the deciduous fruit trees, peach is ranked third for its production in the world, and in Serbia it is ranked fifth after plum, apple, pear and sour cherry production [11]. A dynamic change in the number of cultivars is a prominent characteristic of peach, since new cultivars are being created round the world all the time. According to some biological and pomological characteristics, numerous peach cultivars have been arranged into three groups: peaches, nectarines and clingstone peaches. The basic difference between peach and nectarine is in hairy skin pubescence [9]. In addition to such difference, nectarine fruits have lower fruit weight, are less firm and their skin is of more intensive red color than of peach fruits [16]. Clingstone peach fruits are characterized by firm-consistency flesh that has grown together with a stone. They are not suitable for direct use because their flesh is difficult to chew, and they have a specific sweetness index due to considerably lower content of acids [10].

All peach cultivars grown across the world today come as the result of breeding, whose intensity has led to reduced genetic variability within this species [14]. However, despite tremendous progress in the selection of peach there is still no cultivar with marked positive characteristics, and genetic limit has not been reached yet, and hence further activities in selection of this fruits are necessary. Over the past years, modern breeding programs of peach, apart from yield, direct attention to fruit quality and its aesthetic values.

Most papers dealing with peach fruit quality focus on the content of soluble solids and content of total acids, or pH values. However, peach fruit quality is conditioned not only by content but also by well-balanced various components that are the result of metabolic activities, changing during fruit growth and maturation [8]. Multivariate analysis showed that peach fruit quality is conditioned by a great number of factors, contents of sugars and acids being the most prominent determinants of fruit quality [7]. Correlation between contents of certain matter and fruit quality was also found by Esti et al. [4] who studied in 21 cultivars of plain peach and nectarine the correlation between contents of sugars and acids, on one hand, and sweetness and acidity determined by organoleptic evaluation, on the other hand, and found that content of the majority of chemical parameters correlates with organoleptic evaluation. Nor should the reports of Scorza and Sherman [15] be disregarded, who point out that fruit weight is certainly one of the most important peach characteristics, since it is important component of both fruit quality and yield.

Creating new peach cultivars with improved fruit quality is very difficult because a great number of characteristics are involved. It is therefore recommendable to study some of fruit quality components. This may contribute to better utilization of the existing genetic potentials and provide for identification of parents suitable for further selection and involvement in breeding programs [1].

When evaluating newly created cultivars, concerning the fact that one genotype can be grown at various locations, from practical aspect, adaptability component is very important i.e. stability of characteristics in studied genotypes under various agro-ecological conditions. There have been elaborated a number of procedures for determining stability parameters and their application in the analysis of selection material of various grown plants. One of the first works of this type, based on regression analysis, was produced by Yates and Cochran [18], and then by Finlay and Wilkinson [6], Plaisted and Peterson [13] elaborated the procedure that provides for assessment of each genotype and environment interaction share in total variance of genotype x environment interaction.

Model of regression analysis developed by Yates and Cochran [18] was modified by Eberhart and Russell [3]. Their model is based on computations of linear regression (bi) for each genotype against environmental conditions and deviation from regression (S^2di).

When evaluating newly created peach cultivars from the aspects of production or potential parents in combined breeding, it is necessary, apart from knowledge about phenotypic expression of characters, to evaluate the behavior of cultivar under certain ecological conditions. Therefore, the aim of investigations was to study yield, fruit quality and stability of those characteristics in 20 introduced promising peach cultivars under ecological conditions of Belgrade surroundings.

MATERIAL AND METHODS

The material comprised twenty peach cultivars. The experiment involved seven peach cultivars (‘Gold crest’, ‘Iris Rosso’, ‘Domiziana’, ‘Emilia’, ‘Aurelia’, ‘Padana’, ‘Flaminia’), nine nectarine cultivars (‘Mayfire’, ‘Weinberger’, ‘Croce del Sud’, ‘Pegaso’, ‘Venus’, ‘Nectaross’, ‘Andromeda’, ‘Vega’, ‘Sirio’) and four clingstone peach cultivars (‘Romea’, ‘Villa Adriana’, ‘Villa Ada’ ‘Villa Giulia’). Collection orchard planted in 1996 is located at “Fruit Plantations” in Boleč, belonging to Agriculture Combine. It is of experimental character and contains a larger number of each cultivar of peach fruit tree. Planting was done at 4 x 2.5 m row spacing. The training system is spindle bush and the rootstock used for grafting peach cultivars was vine yard peach

Table 1. Mean value of yield and fruit weight in 20 peach cultivars for 3-year period

Cultivar	Yield (kg/tree)				Fruit weight (g)			
	2000	2001	2002	Average	2000	2001	2002	Average
Gold crest	1.4	12.1	2.4	5.3	67.0	71.3	60.4	66.2
Iris Rosso	1.3	7.1	1.8	3.4	130.0	109.2	131.3	123.5
Domiziana	7.8	4.8	3.3	5.3	106.4	114.2	137.8	119.5
Emilia	6.3	29.3	8.3	14.6	197.8	110.4	217.5	175.2
Aurelia	3.7	16.5	5.4	8.5	173.6	134.9	226.9	178.5
Padana	5.5	21.2	2.9	9.9	179.8	112.7	168.7	153.7
Flaminia	4.9	21.1	2.7	9.6	164.7	104.9	134.1	134.6
Mayfire	1.6	11.0	1.8	4.8	73.9	61.5	47.5	61.0
Weinberger	1.8	12.9	1.8	5.5	99.5	69.6	75.5	81.5
Croce del Sud	1.7	9.4	1.6	4.2	132.3	85.9	116.4	111.5
Pegaso	2.7	20.6	6.1	9.8	126.5	76.4	125.2	109.4
Nectaross	3.5	14.9	1.7	6.7	99.2	99.3	112.0	103.5
Venus	2.1	31.0	3.4	12.2	107.8	110.4	125.6	114.6
Andromeda	2.3	18.7	4.5	8.5	105.6	97.8	110.2	104.5
Vega	4.5	19.7	2.0	8.7	136.4	101.1	120.0	119.2
Sirio	2.4	13.6	3.1	6.4	118.5	112.8	123.5	118.3
Romea	11.7	17.1	10.6	13.1	77.7	64.2	155.9	99.3
Villa Adriana	8.2	25.1	11.1	14.8	105.8	78.8	120.9	101.8
Villa Ada	6.2	20.9	4.9	10.7	152.8	99.2	158.1	136.7
Villa Giulia	4.8	19.4	11.5	11.9	128.6	80.4	152.7	121.9
Average	4.2	17.0	4.5	-	124.1	94.1	131.3	-
LSD_C 0.05			1.88				7.55	
0,01			2.49				9.97	
LSD_Y 0,05			0.73				2.92	
0,01			0.96				3.86	
LSD_{CY} 0,05			3.26				13.07	
0,01			4.31				17.28	

seedling. Of each cultivar, three fruit trees were separated and marked, and they were unit of observation for all characteristics.

Investigations carried out in 2000, 2001 and 2002, apart from yield (kg/tree) to evaluate fruit quality, involved monitoring of characteristics as follows: fruit weight (g), content of reducing sugars (%), sucrose content (%), and content of total acids (%).

Yield was established by weighing all fruits from a fruit tree. Fruit weight was determined using a sample of 20 fruits per tree. In those cultivars and in those years when the number of fruits per tree was less than 20 all fruits from the tree were used as a sample.

After harvest, approx. 1 kg of fruits of each cultivar was frozen and kept in a freezer, and thus prepared fruits were used for chemical analyses.

Content of reducing sugars was determined by Bertrand [2], method, while sucrose content was obtained by computing the difference between content of total and reducing sugars, and then multiplied by coefficient 0.95.

Content of total acids was found by titration method of neutralization with 0.1N NaOH. Multiplication by coefficient 0.0067 results in representing those acids as malic acid.

In addition to mean values, significance of effects of the studied factors of cultivar, year and cultivar x year interaction on variability of analyzed characteristics was determined by variance analysis. Both tests, F-test and LSD-test, were applied for risk levels of 5% (*) and 1% (**). Stability parameters were computed for all characteristics, using Eberhart and Russell [3], method. The first stability parameter is standardized regression coefficient (bi) which is standardized relative to unity. Statistical significance of bi coefficient was determined by t-test. The second stability parameter is standard deviation from regression (S^2di), whose significance was found by F-test. Also, simple correlations were done between mean values for characteristics and bi coefficient, and their testing was performed by t-test.

Table 2. Mean value of reducing sugars content, sucrose content and total acids content in 20 peach cultivars for 3-year period

Cultivar		Reducing sugars (%)				Sucrose (%)				Total acids (%)			
		2000	2001	2002	Average	2000	2001	2002	Average	2000	2001	2002	Average
Gold crest		3.15	3.18	2.93	3.09	5.38	5.79	4.67	5.28	0.90	1.05	0.88	0.94
Iris Rosso		2.43	2.64	3.14	2.74	6.68	4.83	5.70	5.73	0.90	0.83	1.48	1.07
Domiziana		2.68	3.71	4.58	3.66	5.59	5.48	4.44	5.17	1.41	1.40	1.20	1.34
Emilia		2.58	3.14	4.32	3.35	6.36	6.45	4.92	5.91	1.05	1.10	1.30	1.15
Aurelia		2.92	3.02	3.95	3.30	6.84	5.87	4.97	5.89	1.16	1.03	1.08	1.09
Padana		3.35	3.49	3.87	3.57	6.90	6.08	5.20	6.06	1.06	1.01	1.22	1.10
Flaminia		3.25	2.87	2.80	2.97	6.51	5.89	4.50	5.63	0.97	0.88	1.11	0.99
Mayfire		3.42	3.47	3.56	3.48	5.38	5.88	4.00	5.09	0.97	1.01	1.23	1.07
Weinberger		2.16	2.30	2.92	2.46	5.62	5.44	3.75	4.94	1.30	1.17	0.91	1.13
Croce del Sud		2.40	2.80	4.15	3.12	6.05	5.90	4.15	5.37	1.64	1.52	1.09	1.42
Pegaso		2.52	2.88	4.24	3.21	8.48	7.37	4.77	6.87	1.20	1.10	1.24	1.18
Nectaross		4.06	3.87	3.25	3.73	6.01	5.76	4.73	5.50	1.03	1.04	1.07	1.05
Venus		2.55	2.94	4.50	3.33	7.10	6.37	5.04	6.17	0.98	0.91	1.43	1.11
Andromeda		2.89	3.35	2.87	3.04	5.37	5.61	3.79	4.92	0.92	0.94	0.88	0.91
Vega		3.27	3.49	3.06	3.27	5.41	5.87	3.98	5.09	0.93	0.96	1.01	0.97
Sirio		3.06	2.57	2.65	2.76	5.59	5.52	4.31	5.14	1.02	1.17	0.92	1.04
Romea		2.24	2.15	3.09	2.49	5.99	5.80	4.58	5.46	0.83	0.72	1.02	0.86
Villa Adriana		4.01	3.82	4.12	3.98	5.90	5.08	5.39	5.46	0.93	0.83	1.41	1.06
Villa Ada		2.46	2.55	3.17	2.73	6.80	6.24	5.10	6.05	0.86	0.80	1.54	1.07
Villa Giulia		3.19	3.72	2.81	3.24	7.36	6.20	4.32	5.96	0.93	0.85	1.39	1.06
Average		2.93	3.10	3.09	-	6.26	5.87	4.62	-	1.04	1.01	1.16	-
LSD_C	0.05		0.361				0.491				0.083		
	0,01		0.478				0.649				0.110		
LSD_Y	0,05		0.143				0.190				0.032		
	0,01		0.185				0.251				0.043		
LSD_{CY}	0,05		0.626				0.850				0.144		
	0,01		0.828				1.125				0.191		

RESULTS AND DISCUSSION

It is evident from data in Table 1 that for 3 study years, on average, 'Iris Rosso' had the lowest yield, 3.4 kg/tree, while 'Adriana' the highest yield, 14.8 kg/tree. On average, the lowest yield for all cultivars was in 2000 (4.2 kg/tree), and the highest in 2001 (17.0 kg/tree). It stems from this that yield varied more per year than between peach cultivars. In 2001 average yield was several times higher compared to study year before and year after. Such varying trend in yield is characteristic of the majority of peach cultivars, except for 'Domiziana' and 'Romea'. It is in 'Domiziana' that highest yield level was found in the first study year (7.8 kg/tree), however, in subsequent years it declined (4.8 kg/tree and 3.3 kg/tree). It is characteristic of 'Romea' that differences in yield per year (11.7kg/tree, 17.1 kg/tree, 10.6 kg/tree) are not so high like in the majority of peach cultivars studied in the present work.

Fruit weight varied from 61.0 g ('Mayfire') to 178.5g ('Aurelia'), but per year it ranged from 94.1 g, in 2001 to 131.3 g, in 2002. Variations in fruit weight per year were in contrast to variations in yield level. The lowest average fruit weight was exactly in 2001 when yield level was highest, whereas in the other two study years, when yield level was significantly lower, fruit weight was higher by approx. 30-40% (Table 1).

On average, 'Weinberger' had the lowest (2.46%) content of reducing sugars and 'Villa Adriana' the highest (3.98%) (Table 2). On average, 'Andromeda' had, the lowest (4.92%) sucrose content, while 'Pegaso' had the highest (6.88%). In the majority of peach cultivars, sucrose content was relatively similar in the first and second year but considerably lower in the third year. For all peach cultivars, on average, the content of reducing sugars was increasing (2.91%; 3.10%; 3.16%), while sucrose content was decreasing (6.31%; 5.85%; 4.62%) per study year. 'Romea' had, on average, the lowest content of total acids (0.86%) and 'Croce del Sud' the highest (1.15%). Content of total acids per year ranged from 1.01% to 1.15%.

The highest yielding cultivars proved to be those of clingstone peach followed by peach cultivars, while nectarine cultivars are the lowest yielding. Fruit weight in peach cultivars was considerably higher than fruit weight in nectarine and clingstone peach cultivars. As for content of reducing sugars and sucrose content, no big difference was noticed between cultivars of peach, nectarine and clingstone peach. However, content of total acids was lowest in clingstone peach cultivars but appreciably higher in cultivars of peach and nectarine. Results obtained for content of chemical components in a fruit of peach cultivars are in partial agreement and disagreement with results of Wen et al [16] who report that nectarines had a significantly higher content of total sugars, sucrose, sorbitol and total acids than peach, while glucose and fructose contents were approximately identical.

Results of variance analysis (Table 3) indicate that differences in genetic basis of cultivars have significantly conditioned variability of all studied characteristics. Also, differences manifested in study years in all characteristics were very important. Specific response of a cultivar i.e. its genotype to ecological factors over a 3-year period was confirmed by the results of F-test, which proved that cultivar x year interaction was also a significant source of variability in all characteristics.

Very important effects of ecological factors and cultivar x year interaction on variability of all characteristics studied in the present paper were used as a starting point for studying the stability of those characteristics. The paper also involves reports by Eberhart and Russell [3] who point out that analysis of stability parameters makes sense only in cases when variability of characteristic is significantly affected by environmental (year, location) and eco-factors x genotype interactions. Using regression coefficient and deviation from regression, the said authors have established a method for evaluating stability of genotypes grown under various conditions. A stable cultivar is considered to be the one that has regression coefficient approx. 1 and standard error of regression as low as possible. Genotypes in which bi>1 respond better to more favorable growing conditions, whereas genotypes

Table 3. Mean square from analysis of variance for yield and fruit quality properties

Source of variation	d.f.	Yield	Fruit weight	Reducing sugars	Sucrose	Total acids
Replication (tree)	2	8.47*	3.209	0.026	0.019	0.001
Cultivar (C)	19	122.99**	12550.392**	1.568**	2.363**	0.154**
Year (Y)	2	3612.34**	24256.394**	6.569**	53.033**	0.535**
C x Y	38	57.06**	1285.659**	0.888**	0.885**	0.092**
Error	118	4.07	65.377	0.150	0.277	0.008

Table 4. Stability parameters (*bi* and *S²di*) of yield and fruit quality in 20 peach cultivars

Cultivar	Yield		Fruit weight		Reducing sugars		Sucrose		Total acids	
	b_i	S^2d_i	b_i	S^2d_i	b_i	S^2d_i	b_i	S^2d_i	b_i	S^2d_i
Gold crest	0.857	17.474	1.078	16.706	-0.391**	-0.047	0.524	0.126	3.306**	-0.002
Iris Rosso	1.153	0.653	1.052	-5.406	1.094	-0.047	0.257*	1.689	3.342**	-0.003
Domiziana	0.415**	1.356	0.609	-12.256	1.643	-0.047	0.704	-0.073	3.879**	-0.002
Emilia	1.278	3.466	1.072	838.869	2.668**	-0.020	0.930	0.040	1.135	0.000
Aurelia	2.105**	-1.341	0.275	101.335	1.701	-0.042	0.995	0.107	2.945**	-0.003
Padana	0.039**	-0.705	1.921	1927.874	0.813	-0.049	1.635	-0.073	1.967**	-0.001
Flaminia	0.809	-1.377	0.258	-17.553	-0.541**	0.002	1.143	-0.074	-1.071	0.003
Mayfire	1.137	0.912	1.601	24.349	0.213	-0.049	0.960	0.378	3.497**	-0.002
Weinberger	1.210	4.389	0.664	245.774	1.224	-0.049	1.145	-0.048	0.762	-0.002
Croce del Sud	1.144	-0.461	0.401	-20.940	2.766**	-0.048	1.160	-0.039	-0.205**	-0.003
Pegaso	1.653**	-1.051	2.826**	-4.242	2.732**	-0.049	2.125**	-0.046	1.384	0.004
Nectaross	0.582**	-1.258	0.986	305.721	-1.279**	-0.049	0.761	-0.090	-2.939**	0.020
Venus	-0.078**	8.356	0.379	387.286	3.115**	-0.049	1.153	-0.044	-1.215**	-0.002
Andromeda	0.769	-1.270	-0.250	-11.464	-0.306**	0.079	1.039	0.160	-0.680	0.007
Vega	1.213	1.670	1.376	79.372	-0.479**	0.007	0.991	0.336	0.567	0.003
Sirio	0.910	1.598	0.248	37.481	-0.420**	0.050	0.791	-0.055	0.626	-0.002
Romea	0.697	-1.332	-0.171	303.797	1.515	-0.010	0.856	-0.079	1.482	0.000
Villa Adriana	0.895	-0.875	2.127	586.494	0.293	-0.023	0.467	0.240	0.301	0.005
Villa Ada	1.525**	0.413	0.680	-18.164	4.593**	0.065	0.965	-0.071	0.171	-0.002
Villa Giulia	1.689**	11.923	2.227*	76.377	-0.594**	0.170	1.691	0.055	0.730	0.000
SEbi	0.160	-	0.571	-	0.419	-	0.347	-	0.450	-

in which bi<1 respond better to adverse environmental conditions.

According to the values of regression coefficients (bi) given in Table.4, 'Sirio' had the most stable yield (b=0.910), 'Aurelia' responded best to favorable growing conditions (b=2.105**), while 'Venus' responded best to adverse production conditions (b=-0.078). 'Nectaross' had the most stable fruit weight (b=0.986), 'Pegaso' responded best to favorable growing conditions (b=2.826**), while 'Andromeda' to unfavorable conditions (b=-0.250). 'Iris Rosso' demonstrated the most stable content of reducing sugars (b=1.094), 'Villa Ada' responded best to favorable growing conditions (b=4.593**), while 'Nectaross' to adverse growing conditions (b=-1.279**). 'Aurelia' had the most stable sucrose content (b=0.995), 'Pegaso' responded best to more favorable environmental conditions (b=2.125**), while 'Iris Rosso' responded best to unfavorable production conditions (b=0.257*). The lowest variability of total acids content was registered in 'Emilia' (b=1.135), and in favorable production conditions the best results will be achieved by 'Domiziana' (b=3.879**), while in adverse environmental conditions this characteristic will be possessed by 'Nectaross' (b=-2.939**).

When observing values of S^2bi for all studied characteristics (Table 4), it is evident that none of the values of this parameter is statistically significant. Despite this fact, values of S^2di are relatively high, which indicates a more significant deviation from regression and unsatisfactory stability of the studied genotypes, because values of this parameter do not tend to zero. Studying heterogeneous and heterozygous genotypes (populations, synthetic cultivars and hybrids), Fakorede and Mock [5] concluded that regression coefficient is more significant than deviation from regression line. The results of the present paper confirm that bi, being a stability parameter, is more significant than S^2bi in heterozygous genotypes the genotype of the majority of fruits, therefore of peach itself.

Correlation coefficients between mean values and bi coefficients (Table 5) for the majority of characteristics, except for sucrose content, are very weak and are not statistically significant. This shows that peach cultivars possessing good genetic potential for high yield level and high quality fruit are not characterized by high adaptability. Only for sucrose content very significant correlations (r=0.564**) were found between mean values and stability of this characteristic in peach cultivars. Fakorede and Mock [5] point out that the most common phenomenon is that higher yielding genotypes demonstrate better response to environmental conditions and vice versa, which is not confirmed by these studies.

Petrović et al. [12] found both positive and negative correlation coefficients of yield level and value of regression coefficient, which was also confirmed by our works.

Table 5. Coefficients of correlation between mean value and stability parameter (*bi*)

Traits	r_{xbi}
Yield	-0.114
Fruit weight	0.037
Reducing sugars	-0.163
Sucrose	0.564**
Total acids	0.051

CONCLUSION

The highest yield and content of reducing sugars had 'Adriana', the highest fruit weight 'Aurelia', the highest sucrose content 'Pegaso', and the highest total acids content 'Croce del Sud'.

Variability of yield and fruit quality were significantly influenced by cultivar genotype. In addition, variability of those characteristics was significantly conditioned by ecological factors and interaction between genotype and environmental factors

Values of bi coefficient indicated that 'Sirio' had the highest stability of yield 'Iris Rosso' the highest stability of fruit weight and content of reducing sugars, 'Aurelia' the highest stability of sucrose content, and 'Emilia' the highest stability of total acids content.

Values of S^2di, despite being relatively high, did not show any statistical significance, which indicates a more significant deviation from regression and unsatisfactory stability of the studied genotypes. The results of the present work confirm that bi, being a stability parameter, is more important than S^2di in heterozygous genotypes, the genotype of a majority of fruit cultivars, therefore of peach itself.

The absence of clear relations between mean values of characteristics and their stability indicate that further breeding activities should focus on creating peach cultivars that will possess at the same time high yield level and fruit quality but also good adaptability i.e. ability of having these characteristics stable under various growing conditions.

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