Six-year evaluation of selected traits of fruit colour and their interdependences in a set of 24 apricot genotypes

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ABSTRACT: These traits of fruit colour were evaluated in 24 apricot genotypes for six years: basic colour, overcolour, flesh colour and attractiveness. The evaluation involved variability of colour traits and correlations between these traits in a six-year period. The evaluated genotypes were significantly different in colour traits; it will facilitate the selection of commercially interesting genotypes. Highly significant correlation coefficients ($r = 0.56^{++}$ to $r = 0.96^{++}$) were calculated for the rank of the values of particular traits in 1994–1999; it confirmed that the traits are genetically conditioned. As for the correlations between the traits, the closest correlation was found out between basic colour of fruit and flesh colour ($r = 0.53^{++}$ to $r = 0.96^{++}$) and between basic colour and overcolour ($r = 0.45^{++}$ to $r = 0.65^{++}$). In the six-year period fruit attractiveness showed the lowest variability expressed by average coefficient of variation ($v = 14.98\%$) while fruit overcolour had the highest variability ($v = 41.14\%$). The coefficients of variation for basic colour and flesh colour were at a medium level. Harogem and Harlayne were the most interesting varieties by their colour traits. Among the registered and most frequently grown varieties in the CR it was Velkopavlovická LE-6/2. The varieties Lednická M-90-A and Vynoslivyj were the most promising for producers by their colour.

Keywords: apricot; genotypes; traits of fruit colour; variability; correlations

The colour of fruit skin (basic colour and overcolour) in apricots and flesh colour are important descriptive pomological traits as well as quality traits. Colours and their harmony factually influence the market appearance and attraction of fruit to the largest extent. Fruit appearance and attraction based on colour harmony are called attractiveness in this paper. It is also in agreement with English literature where fruit appearance and attractiveness are taken as synonyms. The goal of most breeding programmes for apricots is to breed varieties with different shades of yellow and particularly orange colour. A fruit ideotype for canning use is a fruit with uniform basic colour without colour blush while an ideotype of fresh fruit is a fruit with intensive red colour on a part larger than a half of the fruit (VACHŮN et al. 1981, 1999; BASSI 1999; TZONEVA 2000). Some researchers considered the skin colour of apricots as little variable in the last mid-century (VÁVRA 1955), probably because the assortment of that time belonged to a relatively uniform genotype of *Prunus armeniaca* L. *occidentalis*. Colour traits were previously taken as genetically conditioned. Recently, this assumption was confirmed by the segregation of colour traits in the offspring after crossing e.g. in peaches (YAMAMOTO et al. 2001). Colour traits of apricot fruits were evaluated mainly by the pomologists and workers who collected, evaluated and bred new genotypes, i.e. they developed pomological descriptions of genotypes (DELLA STRADA et al. 1989; KUTINA et al. 1991). The results of any detailed study of colour traits in apricots, particularly their variability and interdependences, have been published scarcely. MIGNANI et al. (1999, 2000) evaluated the influence of two rootstocks (Manicot and GF31) on fruit ripening and quality including flesh colour in six apricot varieties. A specific colour shade can partly be influenced by the conditions of particular years and by other factors. It is known that fruit colour develops during ripening. It is not easy to determine the colour shade objectively. Nevertheless, fruit colour of apricots is used as one of the characteristics to determine an appropriate harvest date. The assessment of fruit colour is used for the identification of varieties, to search for suitable genotypes for breeding of attractive table varieties and for tasting of fresh or processed fruits. Several aids can be used to determine the yellow, orange or red colour shades of apricot fruits objectively (colour tables, nuanceurs, colour charts). It is e.g. RHS Colour Chart (ANONYMUS 2001) or Code de Couleur (ANONYMUS 1994) specifically developed for apricots. Unfortunately, the numerals used to designate colour shades from light yellow through yellow, orange to red are not identical in these published aids. Laboratory instruments were developed for the numeri-

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cal expression of fruit colour using three values L, a, b (HUNTER 1987). Determination of fruit colour is difficult because the shade of basic colour can vary e.g. towards the suture or in dependence on illumination. The shade of overcolour significantly varies towards the edges of so called blush. Colour dots on the edges of the blush were not found to be a fixed trait in by many-year observations (VACHŮN 1965). The Code de Couleur (ANONYMUS 1994) classifies apricot varieties to two colour groups: type a – somewhat lighter (yellower) varieties in general and type b – darker varieties in general (more orange). The objective discriminability and back reproducibility of this classification were already confirmed by studies of apricot collection (VACHŮN 1965). In the Czech Republic a point scale is currently used to designate colour shades of fruits in the studies of apricot genetic resources. Points 1–9 are attributed separately to: flesh colour, basic colour of skin, overcolour of skin and appearance (NITRANSKÝ 1992). The variability and interdependences of these colour traits, based on many-year observations, have not been published yet.

The objective of the paper was to determine point values of selected colour traits, evaluate their variability and objectify their interdependences during a several-year period in fruits of a larger set of apricot genotypes.

MATERIAL AND METHODS

An experimental apricot orchard was established in spring 1991. Five trees of each genotype were planted. Scions for this collection were received from the Czech Republic, Ukraine, Canada and USA. 21 genotypes from a larger collection with complete observations from 1994 to 1999 were used for evaluations. Genotypes designated by the letters LE and M at the beginning of their names are hybrids from a breeding programme of Faculty of Horticulture Lednice, Mendel University of Agriculture and Forestry Brno. These genotypes were chosen as promising by pre-selection in hybrid orchards and propagated for so called station test. The most important of them that are undergoing the registration process are given in this paper under new variety names but their original identification numerical codes with the initial letters LE are given in brackets after the names. It is e.g. the variety Lemeda (LE-962). Velkopavlovická variety, clone LE-6/2, was used as control while an apricot seedling of *P. armeniaca* L. was used as rootstock. The soil texture was sandy loam, soil type Fluvisol. Average annual temperature in the experimental locality Lednice in 1994–1999 was 9.85°C. Average annual precipitation amounted to 526.7 mm in the same period. Average temperature for 80 years (so called standard temperature) is 9.0ºC in the experimental locality. Average annual precipitation (so called standard) was 516.6 mm for the given period. It is evident that the period was warmer and more humid compared to the long-term average. An increase in annual precipitation in 1997 was significant (by 21.3% against the standard). During the growing season from April to September an increase in precipitation against the standard was 36.7%. Average annual temperature of that year was 9.4ºC. From the aspect of risky temperatures for apricots in the phenophases blossoming and small fruits the conditions in 1995 and 1996 were favourable. The conditions in 1999 were excellent, with bumper crop. The conditions in 1994, 1997 and 1998 were less favourable: frost in a blossoming period or worse pollination and fertilization caused by cold rainy weather (VACHŮN 2002). Identical cultural practices and pruning were used in the experimental orchard. Productivity was not regulated by thinning, not even when the fruit set was high.

To evaluate selected traits of fruit colour twenty fruits were randomly collected from each genotype in the years 1994–1999 (at least five fruits from each tree). Collection of specimens and evaluation of fruit traits by assignment of points were carried out using a descriptor list for apricots (NITRANSKÝ 1992) and according to the method of VACHŮN et al. (1995). Scale 1–9 was used for all colour traits when a higher numerical value designates a higher value of the trait (for basic colour from light yellow to rich orange colour, for overcolour from slightly light pink to red). Points for fruit attractiveness indicated better or worse harmony of colours and their attraction. Specimens were collected at the stage of picking ripeness (so called normal harvest) and they were evaluated on the same day. Normal picking ripeness of fruits developing an orange colour (e.g. Velkopavlovická or Bergeron) is harvest at basic colour shade No. 5 (ANONYMUS 1994). The fruit is still firm but elastic, and basic colour shade No. 5 is on the whole fruit, possibly with lighter green-yellow colour in the fruit suture. The genotypes with fruits developing a light yellow colour were harvested at basic colour shade No. 4. Fruits with the higher point evaluation of their colour can have a higher quality of flesh (taste, consistence) but it need not be so. It is evident that e.g. even white or white-yellow varieties can have an excellent taste (e.g. Moniqui variety and others). Flesh quality in the set of apricots was also evaluated, but the results of this evaluation are not presented in this paper. The same person evaluated the traits of fruit colour in apricots in all six years to minimize the effect of a subjective factor. The long-term evaluation made it possible to reduce a certain numerical discontinuity of subjective point evaluation. Common statistical methods were used to evaluate the interdependences between the traits. The calculation of coefficients of variation was based on the particular original values of the trait, not on their average values.

RESULTS AND DISCUSSION

Average fruit attractiveness of the particular apricot genotypes in 1994–1999 ranged from 4.23 ± 0.62 points in LE-SEO-24 genotype to 8.50 ± 0.18 points in Harogem variety (Table 1). Even though fruit attractiveness was influenced by the year to a certain extent, the genotypes maintained a higher or a lower point value of this trait in the period of evaluation. The fact that it is a

Table 1. Means of colour traits in fruits of 24 apricot genotypes in a six-year period (1994–1999)

Genotype	Mean of trait in points and standard error of mean			
	attractiveness	basic colour	overcolour	flesh colour
Harlayne	7.25 ± 0.14	7.40 ± 0.15	5.08 ± 0.28	7.52 ± 0.15
LE-392	6.86 ± 0.26	6.13 ± 0.34	4.38 ± 0.32	5.89 ± 0.21
Priusadebnyj	7.90 ± 0.07	5.80 ± 0.05	6.63 ± 0.36	4.37 ± 0.18
Sem. Bademerik	7.75 ± 0.18	6.88 ± 0.20	6.13 ± 0.29	6.67 ± 0.17
LE-2267	8.17 ± 0.31	6.70 ± 0.14	7.43 ± 0.37	6.77 ± 0.11
LE-390	7.07 ± 0.20	6.07 ± 0.04	4.03 ± 0.29	6.17 ± 0.11
LE-1917	6.72 ± 0.16	4.73 ± 0.37	3.90 ± 0.43	4.28 ± 0.44
NJA-1	6.45 ± 0.15	3.15 ± 0.29	2.93 ± 0.42	2.77 ± 0.15
Arzami aromatnyj	6.98 ± 0.39	4.92 ± 0.23	4.88 ± 0.42	5.32 ± 0.23
Volšebnyj	7.00 ± 0.00	5.14 ± 0.10	2.59 ± 0.38	5.48 ± 0.18
Vynoslivyj	7.68 ± 0.16	6.07 ± 0.13	4.08 ± 0.60	6.10 ± 0.19
M-45	7.73 ± 0.16	6.63 ± 0.16	5.53 ± 0.25	6.13 ± 0.18
M-25	7.53 ± 0.21	6.39 ± 0.13	4.29 ± 0.48	5.83 ± 0.17
Velkopavlovická LE-6/2	8.00 ± 0.23	6.69 ± 0.17	5.30 ± 0.32	6.46 ± 0.18
Harogem	8.50 ± 0.18	7.67 ± 0.17	7.67 ± 0.18	7.60 ± 0.19
LE-2185	7.00 ± 0.28	5.97 ± 0.08	4.33 ± 0.36	5.98 ± 0.14
LE-1580	6.35 ± 0.35	6.06 ± 0.08	3.57 ± 0.41	6.13 ± 0.18
Sabinovska 220	6.70 ± 0.24	6.57 ± 0.20	3.28 ± 0.14	6.42 ± 0.20
LE-1453	7.07 ± 0.39	5.33 ± 0.18	2.80 ± 0.13	5.50 ± 0.18
Lemeda (Le-962)	7.56 ± 0.18	5.98 ± 0.15	1.93 ± 0.27	5.80 ± 0.29
LE-1321	7.63 ± 0.17	6.10 ± 0.11	5.80 ± 0.58	6.57 ± 0.20
Lednická (M-90-A)	8.08 ± 0.05	6.96 ± 0.10	5.64 ± 0.40	6.48 ± 0.14
LE-SEO-118	7.05 ± 0.28	6.21 ± 0.19	4.63 ± 0.55	6.17 ± 0.17
LE-SEO-24	4.23 ± 0.62	2.92 ± 0.63	1.74 ± 0.46	3.40 ± 0.71

genetically conditioned trait is proved by highly significant correlation coefficients between the ranks of point evaluations of fruit attractiveness in the particular years (from $r = 0.56^{++}$ to 0.86^{++}). The relationship between the year 1997 and other years was an exception ($r = 0.29$ to 0.39). It can be explained by the excessively wet year 1997 with above-average precipitation at the time of harvests, which probably influenced fruit attractiveness (e.g. fruit cracking) and decreased the differences between the genotypes. The variability of fruit attractiveness in the evaluated set was on a medium level (coefficient of variation from $v = 11.15\%$ to $v = 17.61\%$). The highest variability in fruit attractiveness was observed in 1998 and 1999 (Table 4). It could probably be caused by the average temperature in the growing season (17.1ºC and 17.2ºC) exceeding by nearly two degrees the eighty-year average (15.4ºC).

The basic colour of fruits in apricot genotypes of the evaluated set expressed by points showed higher variability compared to fruit attractiveness in the six-year period. Coefficients of variation for basic colour were higher than the value $v = 20\%$, i.e. a high level of variability. The year 1997 was an exception (Table 4). Basic fruit colour is an important genotype disposition. The genotypes maintain its shades from light yellow to orange colour in the particular years. It is proved by highly significant coefficients of correlation between the ranks of basic colour expressed by points in the

Table 2. Correlations between flesh colours in fruits of 24 apricot genotypes in 1994–1999, expressed by correlation coefficients

Year	1994	1995	1996	1997	1998
1995	0.87^{++}				
1996	0.90^{++}	0.83^{++}			
1997	0.67^{++}	0.73^{++}	0.68^{++}		
1998	0.87^{++}	0.81^{++}	0.87^{++}	0.66^{++}	
1999	0.93^{++}	0.79^{++}	0.95^{++}	0.64^{++}	0.87^{++}

The level of high significance at $n–2 = 22$ is $r = 0.52^{++}$

Table 3. Correlations between basic colour of fruit (BC) and flesh colour of fruit (FC) in 24 apricot genotypes in 1994–1999, expressed by correlation coefficients

Year	1994(BC)	1995(BC)	1996(BC)	1997(BC)	1998(BC)	1999(BC)
1994(FC)	0.92^{++}	0.92^{++}	0.91^{++}	0.64^{++}	0.86^{++}	0.89^{++}
1995(FC)	0.77^{++}	0.86^{++}	0.77^{++}	0.62^{++}	0.75^{++}	0.74^{++}
1996(FC)	0.93^{++}	0.91^{++}	0.96^{++}	0.70^{++}	0.88^{++}	0.95^{++}
1997(FC)	0.53^{++}	0.59^{++}	0.57^{++}	0.74^{++}	0.54^{++}	0.60^{++}
1998(FC)	0.83^{++}	0.81^{++}	0.83^{++}	0.63^{++}	0.86^{++}	0.83^{++}
1999(FC)	0.91^{++}	0.86^{++}	0.94^{++}	0.65^{++}	0.83^{++}	0.96^{++}

The level of high significance at $n–2 = 22$ is $r = 0.52^{++}$

Table 4. Variability in selected traits of fruits expressed by coefficients of variability calculated from the point evaluations of fruits

Colour trait	Coefficient of variability (%) in						Average
	1994	1995	1996	1997	1998	1999	
Attractiveness	14.18	13.89	15.94	11.15	17.61	17.10	14.98
Basic colour	24.33	25.93	22.21	13.54	22.54	21.05	21.60
Flesh colour	25.08	29.81	23.21	18.47	23.02	21.54	23.52
Overcolour	38.69	42.68	38.26	38.31	49.50	39.37	41.14

years 1994–1999 (from $r = 0.67^{++}$ to $r = 0.96^{++}$). The limit value for high significance at $n–2 = 22$ is $r = 0.52$. The above data suggest relatively good possibilities of genotype selection according to different basic colour of fruits. In this country market demand is higher for the orange basic colour of apricots than for yellow or light yellow to white colours, both for fresh fruits and for canning use as preserved fruits, frozen pulps or nectars. The genotypes that received more than 6 points were the most valuable genotypes in the evaluated set in terms of basic colour. The varieties Harogem, Harlayne, Sem. Bademerik, Lednická (M-90-A) and Velkopavlovická LE-6/2 had the richest orange colour.

The overcolour of apricot fruits, blush of different intensity, increases the attractiveness of fresh fruits sold on the market. On the contrary, marked blush is a disadvantage for canning use. The blush is not maintained in canned fruits, it turns dark and worsens the appearance of canned fruits. It is better to use one-colour varieties without overcolour in the form of blush for this type of processing. The shade of overcolour in the apricot genotypes was very different. The points attributed to the particular evaluations ranged from 1.0 to 8.0 points. The average values of overcolour for the genotypes were in the range of 1.74 points (LE-SEO-24) to 7.67 points (Harogem) (Table 1). Variability of this trait was

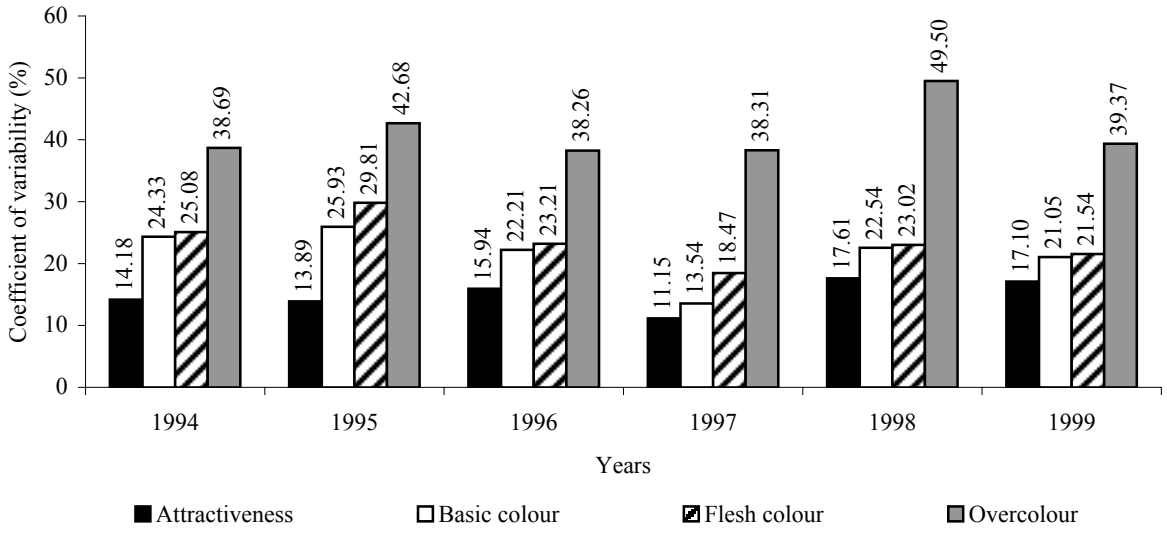

Fig. 1. Variability in colour traits of fruits in 24 apricot genotypes in the years of observations expressed by coefficients of variation

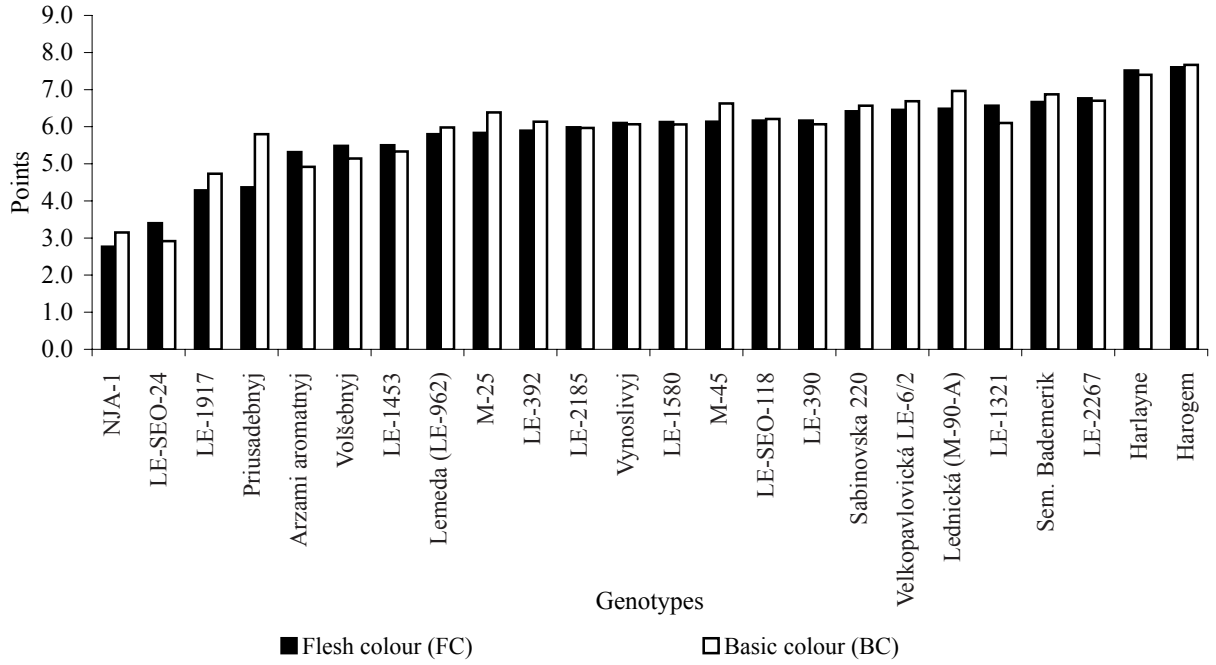

Fig. 2. Flesh colour and basic colour in 24 apricot genotypes in 1994–1999

high. Average coefficients of variation for the particular years were from v = 38.26% to v = 49.50% (Table 4, Fig. 1). The highest variability of this trait was determined in 1999, when a bumper crop was produced. The average coefficient of variation for overcolour for the six-year period was approximately three times higher (v = 41.14%) than for fruit attractiveness (v = 14.98) in the same set of apricot genotypes. In spite of this high variability of the trait in the given set the overcolour can be considered as a variety-specific, genetically conditioned trait. It is proved by highly significant coefficients of correlation ($r = 0.66^{++}$ to 0.91^{++}) between the ranks of the values of this trait expressed in points in the particular years of the six-year period.

The flesh colour of fruits of particular genotypes in the evaluated set was very different over six years. The evaluations in the six-year period ranged from 2.0 to 8.0 points. Average point values for the genotypes were from 3.40 (LE-SEO-24) to 6.77 (LE-2267) (Table 1). The evaluation of flesh colour relations in the set of genotypes in 1994–1999 indicated that flesh colour is a genotype disposition. It was proved by highly significant coefficients of correlation between the ranks of point evaluation of this trait in the particular years (from $r = 0.64^{++}$ to $r = 0.95^{++}$). The limit for high significance at n–2 = 22 was r = 0.52. A significantly positive effect of growing conditions on flesh colour was expressed only in 1997 with a markedly high amount of precipitation. The variability of this trait was lowest in that year. On average for the period of observations the variability of flesh colour can be evaluated as medium high on the basis of coefficients of variation (average coefficient of variation v = 23.52%) (Tables 2 and 4).

Summary evaluation of variability in selected traits of fruit colour in apricots over the six-year period indicated the lowest variability in fruit attractiveness and the highest in fruit overcolour. The coefficients of variation for basic colour and flesh colour had medium-high values. The higher variability of basic colour and flesh colour could be connected with differences in the level of ripeness at the time when the test specimens were collected even though tree ripeness was determined by the same person every time. It can be a problem in varieties with very good appearance of fruits when even an experienced assessor tends to pick fruits earlier than at their actual sufficient ripeness (Fig. 1). The correlations between flesh colour and basic colour of fruits expressed by points were highly significant in the set of genotypes in 1994–1999. Correlation coefficients ranged from $r = 0.53^{++}$ to $r = 0.96^{++}$ (Table 3 and Fig. 2). The point evaluations of basic colour and fruit overcolour in fruit genotypes correlated highly significantly in the particular years of the six-year period. But the values of correlation coefficients were lower than in the previous case, from $r = 0.45^{++}$ to $r = 0.65^{++}$. The interdependences between overcolour and flesh colour were less close. Highly significant, significant and insignificant correlations were determined over the six years (correlation coefficients from r = 0.16 to $r = 0.63^{++}$).

From the aspect of current requirements for colour traits in apricot fruits Harogem and Harlayne are the most interesting varieties in the evaluated set out of the unregistered ones. Among the registered varieties it is Velkopavlovická, and among the varieties promising for production by their colour Lednická M-90-A and Vynoslivyj.

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Šestileté hodnocení vybraných znaků barevnosti plodů a jejich vzájemných vztahů u souboru 24 genotypů meruněk

ABSTRAKT: U 24 genotypů meruněk byly v průběhu šesti let hodnoceny následující znaky barevnosti plodu: základní barva, krycí barva, barva dužniny a atraktivnost. Byla vyhodnocena variabilita znaků barevnosti a korelační vztahy těchto znaků mezi roky v šestiletém období. Hodnocené genotypy se ve znacích barevnosti významně lišily, což dává předpoklad pro výběr komerčně zajímavých genotypů. Pro pořadí hodnot jednotlivých znaků v letech 1994–1999 byly zjištěny vysoce průkazné korelační koeficienty (od $r = 0,56^{++}$ do $r = 0,96^{++}$), což potvrdilo, že jde o znaky geneticky podmíněné. Pokud jde o korelaci mezi znaky, nejtěsnější korelace byla zjištěna mezi základní barvou plodu a barvou dužniny ($r = 0,53^{++}$ až $r = 0,96^{++}$) a mezi barvou základní a barvou krycí ($r = 0,45^{++}$ až $r = 0,65^{++}$). V průběhu šestiletého období byla nejnižší variabilita, vyjádřená průměrným variačním koeficientem, u atraktivnosti plodu ($v = 14,98$ %) a nejvyšší u krycí barvy plodu ($v = 41,14$ %). Variační koeficienty základní barvy a barvy dužniny dosahovaly středních hodnot. Z hlediska znaků barevnosti byly nejzajímavější odrůdy Harogem a Harlayne. Z registrovaných a v ČR nejvíce pěstovaných odrůd to byla Velkopavlovická LE-6/2. Z odrůd pěstitelsky perspektivních byly z hlediska barevnosti vhodné odrůdy Lednická M-90-A a Vynoslivyj.

Klíčová slova: meruňka; genotypy; znaky barevnosti plodu a dužniny; variabilita; vztahy

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