Variability of 21 apricot (*Prunus armeniaca* L.) cultivars and hybrids in selected traits of fruit and stone

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ABSTRACT: Weight, height, width and diameter of fruits and stones were evaluated in 21 apricot cultivars and hybrids in 1994–1997. Statistically significant differences between the measured values of traits confirmed their applicability for objective characterization of genotypes. The evaluated traits are genetic dispositions. It was also proved by the rank of genotypes arranged according to the values of particular traits in one year that was highly significantly identical in the other years of the evaluated period (correlation coefficient $r = 0.45^{++}$ to 0.87^{++}). The relationship between fruit weight and other traits (stone weight, stone height and stone width) is not linear. Fruit weight increases (or decreases) faster towards the limit values of traits. The average percentage proportion of stone weight in fruit weight ranged from 4.9% to 9.6% in the genotypes over the period of four years. A lower proportion of stone in fruit weight is a positive trait for selection of suitable genotypes for direct consumption and flesh processing. This trait can also be a suitable criterion of genotype selection to breed cultivars with a low proportion of inedible part. Promising cultivar Lemeda is an example of the low stone proportion in flesh weight. A high level of variability was found in the values of stone and fruit weight (coefficient of variation $v = 19.00\%$ and $v = 24.74\%$, respectively). Coefficients of variation for other traits (fruit and stone height, width and diameter) were by more than a half lower.

Keywords: apricot; genotypes; fruit and stone weight; width; height; diameter; relationships and variability

Mensurable traits of fruit and stone (weight, width, height and diameter) in apricots and other drupes are pomological traits used for the description and identification of cultivars and for their inclusion in classes in descriptor lists (NITRANSKÝ 1992). They are also important qualitative traits for selection of the most suitable genotypes for growing, for definition of classes in quality standards and for the sorting of apricot fruits. Only some of the above-mentioned mensurable traits of fruit were evaluated within research in selected sets of genotypes in the past (AKCA, SEN 1995, 1999; OKUT, AKCA 1995; ARZANI et al. 1999; VACHŮN 1965, 1998, 2003). But no long-term observations and evaluations of relationships between the components of drupe have been carried out yet. The objective of this paper is to contribute to the specification of characteristics of some domestic and foreign cultivars and promising apricot genotypes on the basis of many-year observations and to determine the regularities of relationships between the particular mensurable traits of fruit and stone.

MATERIAL AND METHOD

An experimental apricot orchard was established in spring in 1991. Five trees of each genotype were planted. Scions for this collection were received from the Czech Republic, Ukraine, Canada and USA. Twenty-one genotypes in which complete observations were carried out from 1994 to 1997 were chosen for evaluation from a larger collection. The genotypes with the letters LE and M at the beginning of their name are hybrids from a breeding program of the Faculty of Horticulture in Lednice of Mendel University of Agriculture and Forestry in Brno. These genotypes were chosen as promising ones during pre-selection in hybrid orchards and they were propagated for the so called station tests. The most important of them that undergo the process of registration have new varietal names in this paper, and the original identification numerical code with the initial letters LE is given in brackets after the name. It is e.g. the cultivar Lemeda (LE-962). Cv. Velkopavlovická, clone LE-6/2, was used as control. An apricot (*P. armeniaca* L.) seedling was used as rootstock. The orchard was established on Fluvisol of sand-loamy texture. In the period 1994–1997 average annual temperature in Lednice experimental locality was 9.56ºC, average annual sum of precipitation amounted to 537 mm. It was a warmer period than the long-term average. Average temperature over 80 years is 9.0ºC in this experimental locality. Average annual precipitation for this period is

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526 mm. The conditions for apricot productivity were favorable in 1995 and 1996, and less favorable in 1994 and 1997 (frost in a blossom period or worse pollination and fertilization as a result of cold rainy weather). Identical cultural practices and cut were used in the whole orchard. Fruit thinning was not carried out.

To evaluate selected traits of fruit and stone five fruits from each tree were collected in random in the period 1994–1997. The method of collection and evaluation of fruit traits was in accordance with the methodology described by VACHŮN et al. (1995) and descriptor list for apricots (NITRANSKÝ 1992). The whole sample from one genotype contained 20 fruits. This number was lower exceptionally if the trees declined, but it was not lower than 15 fruits. To determine the weight, width, height and diameter of fruit and stone one average fruit was chosen out of five fruits from each tree according to modified methodology (VÁVRA 1955). Five values (exceptionally three values) were obtained for each genotype that were used to calculate the genotype mean. Fruit weight in grams was determined by weighing immediately after harvest. Stone weight in grams was also determined by weighing immediately after stoning, still in fresh condition. Height, width and diameter were measured with a pair of calipers to the nearest 1 mm. In this study the width of fruit and stone is taken to mean a dorsiventral distance in mm from dorsal part to ventral suture, in its equatorial part. The height is taken to mean a distance from the highest point of the pedicel region of fruit or stone to the highest point in the style region of fruit or stone. The definition of fruit width is in accordance with Czech standard for fruit sorting, harmonized with EU standard. Fruit width in mm is a criterion for inclusion in quality classes in this standard. Confidence intervals were determined from all measurements, not only from average values. Current statistical methods and program UNISTAT were used for data processing.

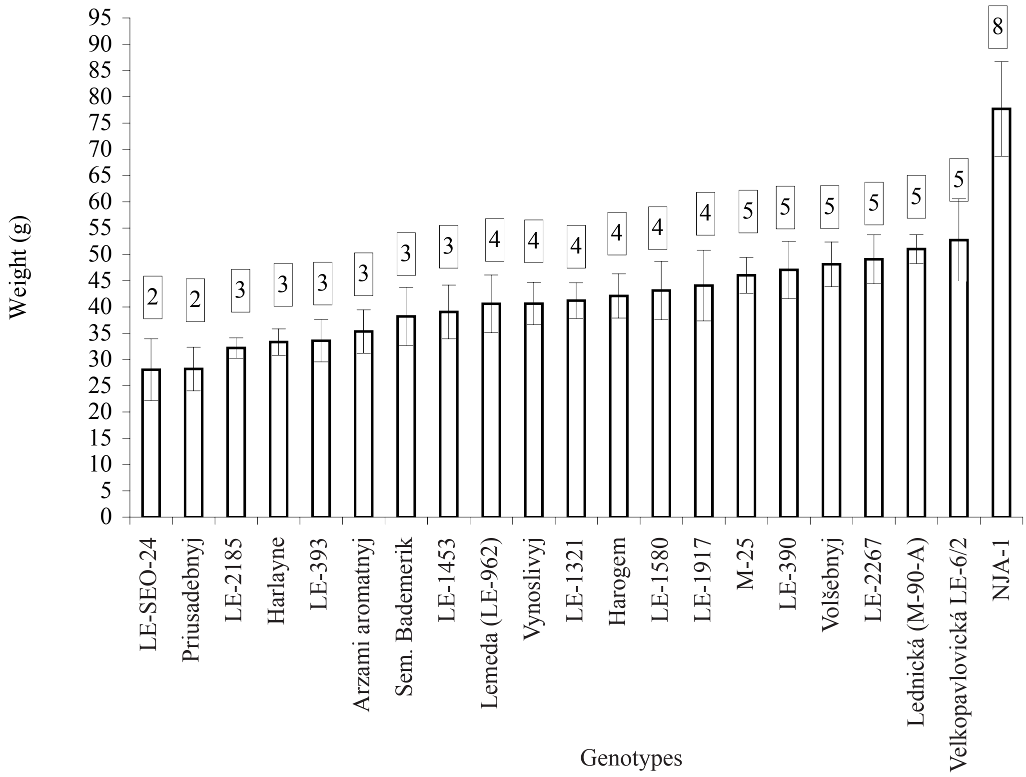
RESULTS AND DISCUSSION

Weight, height, width and diameter of fruit and stone were different in 21 apricot genotypes. These differences resulted from the expression of genotypes in specific conditions of the years of observation (phenotypic expressions). The confidence intervals demonstrated that the differences between the values of traits were significant in a higher number of genotype pairs (Tables 1 and 2, Figs. 1 and 2). The weight of fresh (undried) stone was low; it was maximally 4.3 g (NJA-1) in the evaluated set. Nevertheless, the stone weight was almost three times lower in some genotypes (LE-SEO-24) than in NJA-1 (Table 2, Fig. 3). The percentage proportion of stone in fruit weight ranged from 4% to 9.6% in the particular genotypes over four years. These differences were significant in a higher number of genotype pairs. E.g. the stone proportion in fruit weight was signifi-

Table 1. Means of selected traits of **fruit** in apricot genotypes in 1994–1997

Genotype	Weight (g)	Height (mm)	Width (mm)	Diameter (mm)
Harlayne	33.3 ± 2.5	17.9 ± 1.20	39.1 ± 1.2	35.6 ± 0.82
LE-392	33.6 ± 4.0	18.8 ± 1.64	39.1 ± 1.6	37.9 ± 1.86
Priusadebnyj	28.2 ± 4.2	16.2 ± 2.10	35.9 ± 2.0	33.3 ± 2.19
Sem. Bademerik	38.2 ± 5.5	21.9 ± 2.04	40.4 ± 2.3	38.4 ± 2.45
LE-2267	49.1 ± 4.7	26.9 ± 1.29	45.2 ± 1.4	41.5 ± 1.26
LE-390	47.0 ± 5.5	26.3 ± 1.97	45.0 ± 2.0	39.6 ± 2.76
LE-1917	44.1 ± 6.7	25.4 ± 2.55	43.5 ± 2.4	40.8 ± 2.37
NJA-1	77.7 ± 9.0	43.3 ± 2.65	51.8 ± 2.1	50.0 ± 2.41
Arzami aromatnyj	35.3 ± 4.1	19.7 ± 1.42	37.9 ± 1.8	37.4 ± 1.82
Volšebnyj	48.1 ± 4.2	26.2 ± 1.57	43.1 ± 1.6	42.2 ± 1.50
Vynoslivyj	40.6 ± 4.0	22.3 ± 1.52	43.0 ± 1.8	39.5 ± 1.61
M-25	46.0 ± 3.4	24.7 ± 1.26	43.3 ± 1.2	41.3 ± 1.11
Velkopavlovická LE-6/2	52.7 ± 7.8	30.3 ± 1.58	44.7 ± 1.6	41.7 ± 1.55
Harogem	42.1 ± 4.2	23.1 ± 1.28	42.6 ± 1.6	39.8 ± 1.22
LE-2185	32.2 ± 1.9	17.1 ± 0.65	37.7 ± 0.9	36.0 ± 0.70
LE-1580	43.1 ± 5.6	24.4 ± 2.31	43.0 ± 2.5	39.0 ± 1.93
LE-1453	39.1 ± 5.1	22.1 ± 1.90	40.6 ± 2.0	39.9 ± 2.28
Lemeda (LE-962)	40.6 ± 5.5	23.0 ± 2.46	40.4 ± 2.0	39.3 ± 2.22
LE-1321	41.2 ± 3.4	22.3 ± 2.07	42.8 ± 1.4	37.7 ± 1.17
Lednická (M-90-A)	51.0 ± 2.7	26.9 ± 0.75	45.8 ± 1.1	42.8 ± 0.84
LE-SEO-24	28.1 ± 5.9	17.0 ± 2.64	37.2 ± 2.8	33.9 ± 3.00
Mean	42.44 ± 4.76	23.60 ± 1.75	41.99 ± 1.77	39.40 ± 1.77

Confidence level α 0.05



Genotypes (the numbers above the columns are scores indicating a class on the nine-score scale according to a descriptor list – 1 = very small, 3 = small, 5 = medium, 7 = large, 9 = very large)

Fig. 1. Average fruit weight in apricot genotypes. Confidence intervals at α 0.05 were calculated from the original individually measured values in 1994–1997

cantly lower in cv. Lemeda than in the most frequently grown control cv. Velkopavlovická (Table 3, Fig. 4). Cultivars with largest fruits need not have the highest percentage proportion of flesh. It is evident e.g. from a comparison of the genotypes NJA-1 and Lemeda (LE-962) (Table 1, Fig. 5). The measured values of fruit and stone traits can be used for a pomological description of cultivars, and as an auxiliary criterion for their identification. The percentage proportion of stone is a suitable criterion to select genotypes with a low portion of ined-

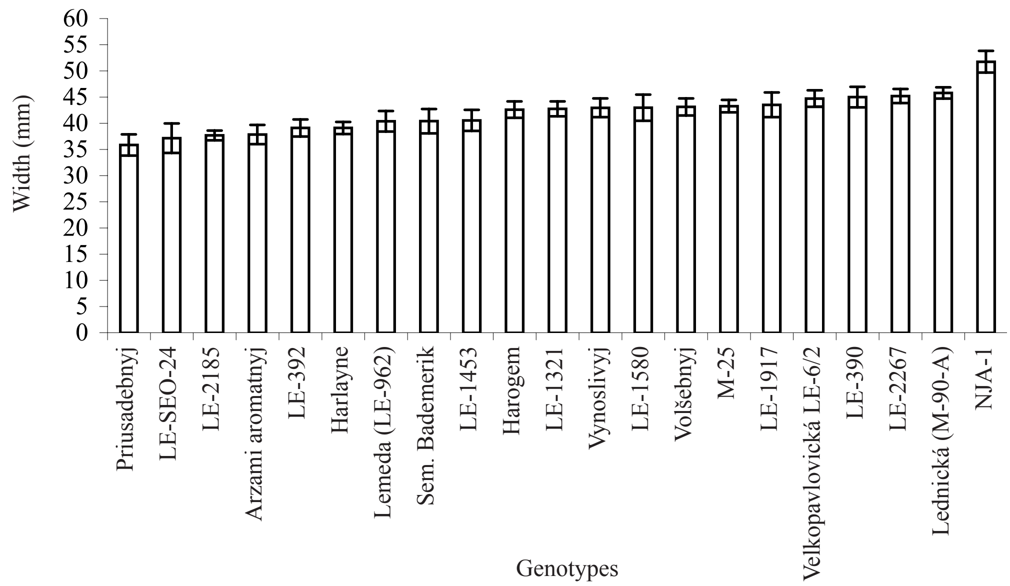


Fig. 2. Average fruit width in apricot genotypes. Confidence intervals at α 0.05 were calculated from the original individually measured values in 1994–1997

Table 2. Means of selected traits of **stone** in apricot genotypes in 1994–1997

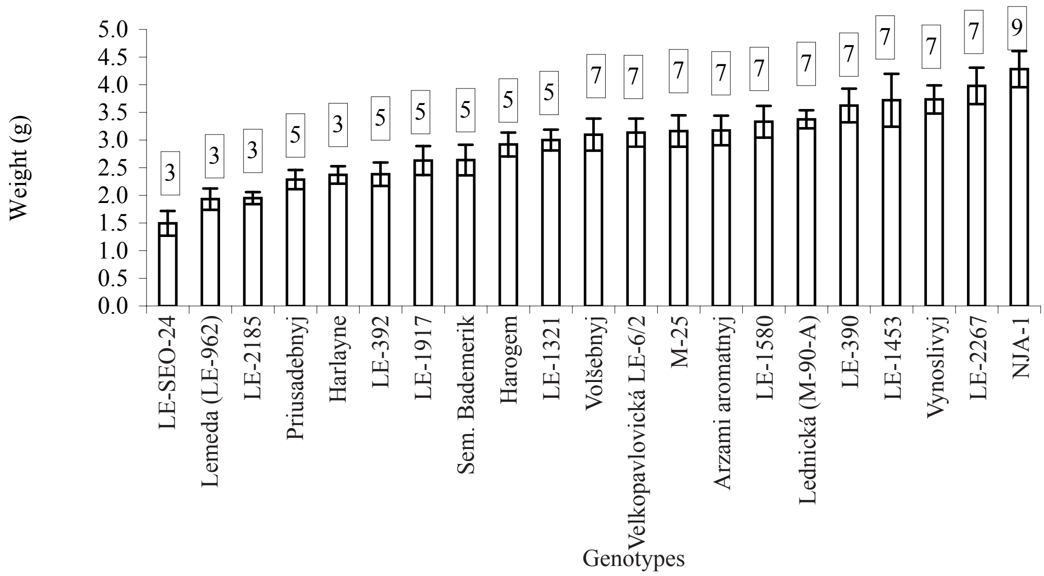
Genotype	Weight (g)	Height (mm)	Width (mm)	Diameter (mm)
Harlayne	2.4 ± 0.2	24.7 ± 0.7	18.7 ± 0.5	10.6 ± 0.30
LE-392	2.4 ± 0.2	22.9 ± 0.5	18.5 ± 0.5	12.2 ± 0.71
Priusadebnyj	2.3 ± 0.2	24.1 ± 0.7	18.9 ± 0.6	11.0 ± 0.39
Sem. Bademerik	2.6 ± 0.3	28.1 ± 1.1	19.1 ± 0.8	11.8 ± 0.55
LE-2267	4.0 ± 0.3	27.9 ± 1.0	22.5 ± 0.9	13.7 ± 0.51
LE-390	3.6 ± 0.3	28.6 ± 1.1	22.7 ± 0.6	12.9 ± 0.67
LE-1917	2.6 ± 0.3	24.1 ± 0.9	19.3 ± 1.0	12.3 ± 0.66
NJA-1	4.3 ± 0.3	27.9 ± 0.6	22.6 ± 0.5	15.0 ± 0.72
Arzami aromatnyj	3.2 ± 0.3	26.7 ± 0.9	22.1 ± 0.9	11.4 ± 0.48
Volšebnyj	3.1 ± 0.3	29.0 ± 1.1	19.5 ± 0.8	12.3 ± 0.49
Vynoslivyj	3.7 ± 0.3	27.4 ± 0.9	23.6 ± 1.5	12.9 ± 0.38
M-25	3.2 ± 0.3	28.1 ± 1.1	21.4 ± 0.4	12.0 ± 0.65
Velkopavlovická LE-6/2	3.1 ± 0.3	27.6 ± 0.9	20.9 ± 0.6	11.4 ± 0.43
Harogem	2.9 ± 0.2	26.7 ± 0.8	21.8 ± 0.6	11.7 ± 0.62
LE-2185	2.0 ± 0.1	25.1 ± 0.7	17.0 ± 0.6	10.5 ± 0.38
LE-1580	3.3 ± 0.3	28.1 ± 0.7	20.5 ± 0.7	12.0 ± 0.24
LE-1453	3.7 ± 0.5	23.5 ± 0.9	20.0 ± 0.5	14.1 ± 0.78
Lemeda (LE-962)	1.9 ± 0.2	23.5 ± 1.0	16.9 ± 0.9	10.2 ± 0.27
LE-1321	3.0 ± 0.2	29.3 ± 1.2	22.7 ± 0.6	11.3 ± 0.35
Lednická (M-90-A)	3.4 ± 0.2	28.0 ± 0.6	22.4 ± 0.4	11.9 ± 0.22
LE-SEO-24	1.5 ± 0.2	22.4 ± 1.2	15.3 ± 1.1	9.6 ± 0.45
Mean	2.96 ± 0.25	26.35 ± 0.89	20.29 ± 0.72	11.93 ± 0.49

Confidence level α 0.05

Table 3. Percentage proportion of stone in fruit weight in apricot genotypes in 1994–1997

Genotype	Year				Mean
	1994	1995	1996	1997	
Harlayne	6.3	7.6	8.1	6.7	7.2 ± 0.50
LE-392	6.6	6.7	9.1	6.8	7.3 ± 0.59
Priusadebnyj	6.3	8.9	10.8	7.6	8.4 ± 0.91
Sem. Bademerik	6.0	6.4	9.6	6.4	7.1 ± 0.88
LE-2267	8.2	8.0	8.5	7.9	8.2 ± 0.33
LE-390	6.7	9.7	7.6	7.5	7.9 ± 0.56
LE-1917	5.3	6.5	8.2	5.1	6.3 ± 0.79
NJA-1	5.0	5.3	5.9	6.7	5.7 ± 0.52
Arzami aromatnyj	8.4	9.7	9.3	9.1	9.1 ± 0.34
Volšebnyj	5.3	6.1	6.6	7.8	6.4 ± 0.45
Vynoslivyj	8.5	10.7	8.1	9.3	9.2 ± 0.81
M-25	6.1	7.2	6.7	7.6	6.9 ± 0.41
Velkopavlovická LE-6/2	4.9	6.5	7.2	6.7	6.3 ± 0.67
Harogem	6.6	8.2	7.0	6.5	7.1 ± 0.47
LE-2185	6.3	6.0	6.1	5.9	6.1 ± 0.26
LE-1580	6.9	7.4	9.8	4.4	7.1 ± 1.08
LE-1453	9.6	9.1	9.2	10.5	9.6 ± 0.48
Lemeda (LE-962)	4.6	4.7	5.9	4.4	4.9 ± 0.36
LE-1321	7.0	6.9	8.3	7.2	7.4 ± 0.35
Lednická (M-90-A)	5.9	6.8	7.1	6.9	6.7 ± 0.25
LE-SEO-24	4.6	4.1	8.3	6.4	5.8 ± 0.93
Mean	6.42	7.26	7.97	7.02	7.17 ± 0.57

Confidence level α 0.05



Genotypes (the numbers above the columns are scores indicating a class on the nine-score scale according to a descriptor list – 1 = very small, 3 = small, 5 = medium, 7 = large, 9 = very large)

Fig. 3. Average stone weight in apricot genotypes. Confidence intervals at α 0.05 were calculated from the original individually measured values in 1994–1997

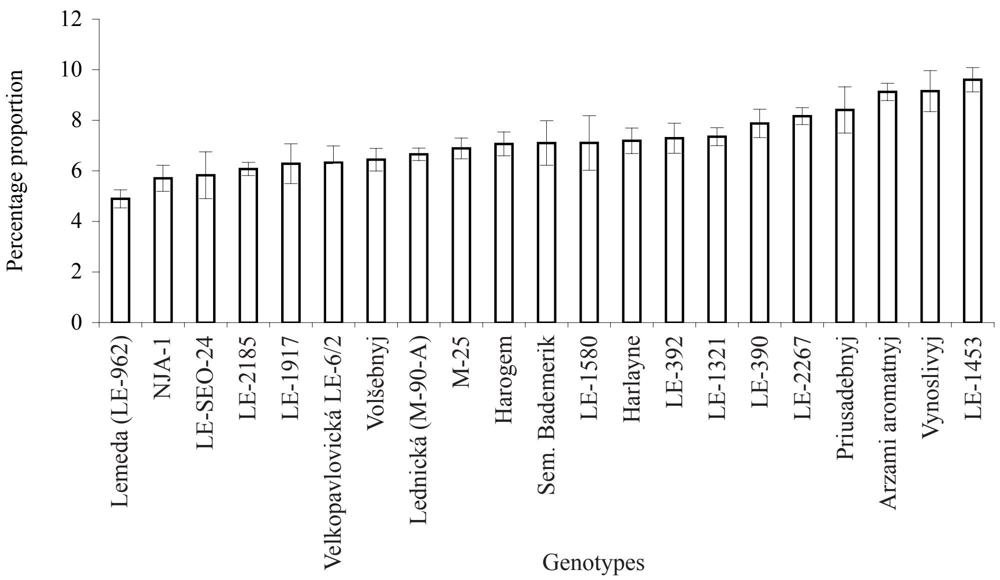


Fig. 4. Percentage proportion of stone in fruit weight in a set of apricot genotypes. Average values for 1994–1997. Confidence intervals at the level α 0.05

ible part. A lower proportion of stone in fruit weight is a positive trait for the selection of suitable genotypes for direct consumption and flesh processing. An almost five percent difference in the flesh proportion in fruit weight is worth mentioning when candidates of new cultivars are selected and when suitable parental pairs are searched in a breeding process. The fact that weight of fruit and its other parameters are genetic dispositions is proved by the rank of genotypes arranged according to the values of particular traits in one year correlating highly significantly with their rank in the other years of the evaluated period (correlation coefficient $r = 0.45^{++}$ to 0.61^{++}). Highly significant coefficients of correlation between the rank of trait values in the pairs of years in the evaluated period were calculated for other traits, i.e. stone weight, width, height and diameter of fruit and stone. The values of these correlation coefficients ranged from $r = 0.50^{++}$ to $r = 0.87^{++}$. Hence the relationships were differently close, but significant. The relationship between stone weight and fruit weight was not fully linear in the set of genotypes in the period 1994–1997. There was a change in the rate of an increase in fruit weight in relation to stone weight towards the limit (lowest and highest) values. Average fruit weight increased faster than average stone weight (Fig. 6). A similar tendency was determined for the relationship between fruit weight and stone height ($y = –0.0046x^2 + 0.5828x + 10.453$, $R^2 = 0.49$) and

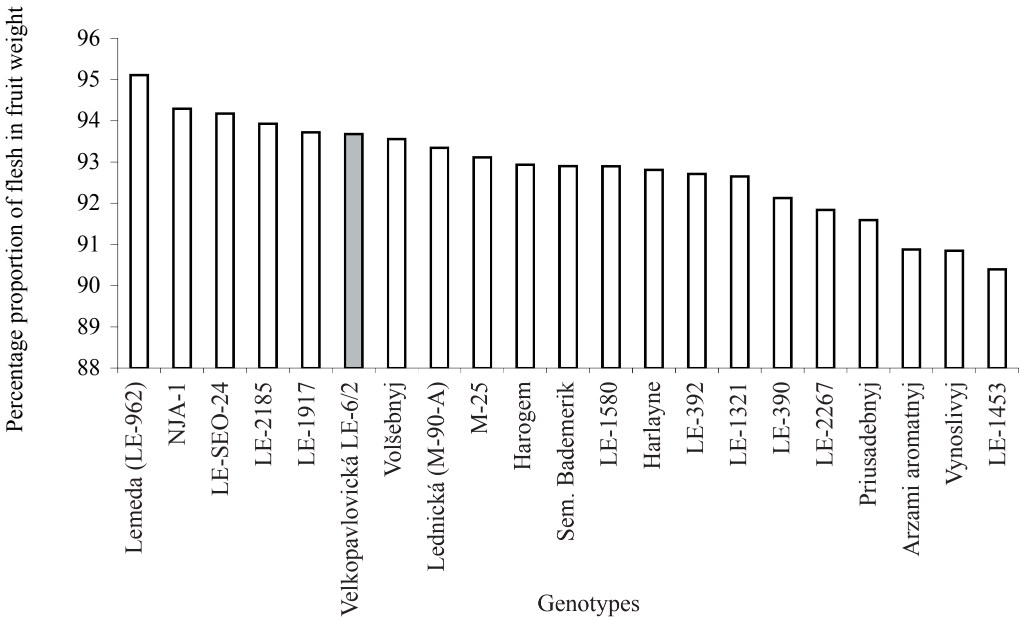


Fig. 5. Percentage proportion of flesh in fruit weight in a set of apricot genotypes. Average values for 1994–1997

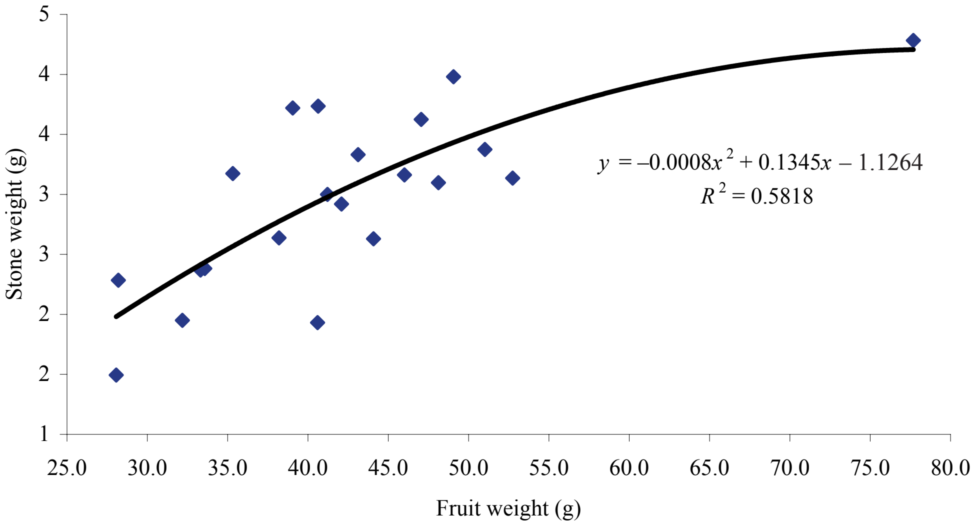


Fig. 6. Relationship between stone weight and fruit weight in a set of 21 apricot genotypes in 1994–1997

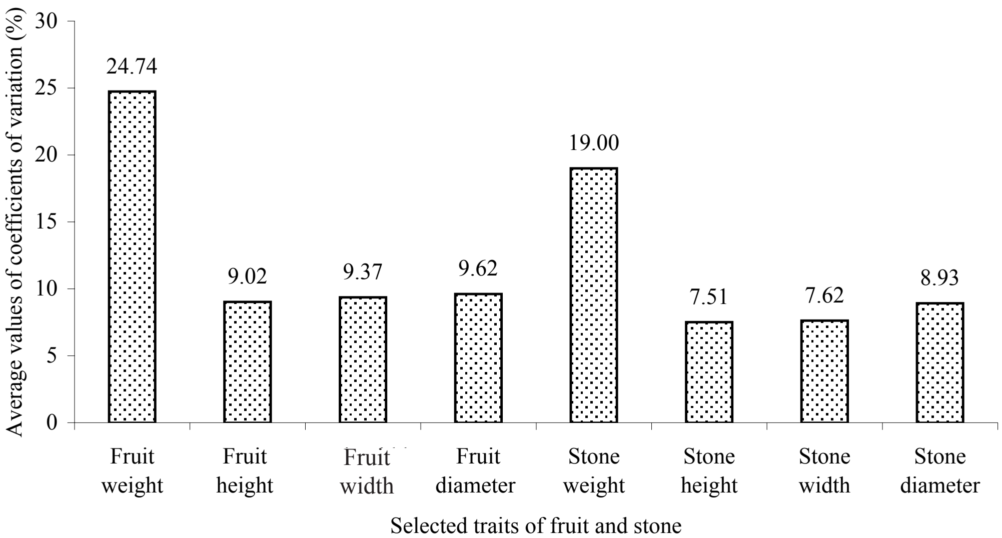


Fig. 7. Average values of coefficients of variation for selected traits of fruit and stone in a set of 21 apricot genotypes in a four-year period

Table 4. Correlations between fruit weights in a set of apricot genotypes in 1994–1997 expressed by correlation coefficients. Calculated from the original measured values

Year	1997	1996	1995
1994	0.46**	0.61**	0.59**
1995	0.50**	0.45**	
1996	0.47**		

**highly significant correlation coefficient

conditions are more sensitive in fruit weight and stone weight than in the other traits such as fruit and stone height, width and diameter. E.g. the flesh or the kernel can have a higher or lower water content in dependence on moisture conditions. Increased variability of stone weight can be caused by the occurrence of less developed kernels. For a more detailed statistical evaluation of the share of year × cultivar interaction in total variability of the given traits it is advisable to use a higher number of measured fruits and stones in further experiments.

Table 5. Coefficients of variation for selected traits of fruit in apricot genotypes in 1994–1997. Calculated from the original individually measured values

Genotype	Coefficient of variation							
	Fruit weight	Fruit height	Fruit width	Fruit diameter	Stone weight	Stone height	Stone width	Stone diameter
Harlayne	17.20	6.67	6.79	5.28	15.13	6.75	5.84	6.42
LE-392	26.87	9.58	9.21	10.97	19.88	5.14	5.80	12.98
Priusadebnyj	33.65	12.79	12.90	15.02	17.19	6.98	7.73	8.06
Sem. Bademerik	29.43	9.94	11.75	9.93	21.38	7.67	8.65	9.54
LE-2267	21.68	6.58	6.83	6.93	21.01	8.21	9.18	8.90
LE-390	26.59	10.08	9.91	15.92	19.17	8.53	6.44	11.77
LE-1917	33.03	12.41	11.50	12.64	20.83	7.67	11.26	11.68
NJA-1	24.48	10.94	8.40	10.15	16.56	4.45	4.96	10.28
Arzami aromatnyj	25.72	7.79	10.80	10.51	19.19	7.58	8.95	9.39
Volšebnyj	19.60	7.39	8.40	7.88	21.08	8.45	8.61	8.89
Vynoslivyj	16.69	8.35	9.34	9.14	15.25	7.71	8.34	6.52
M-25	14.75	5.81	5.74	5.68	18.46	7.90	3.71	10.66
Velkopavlovická LE-6/2	31.42	7.47	7.43	7.59	16.48	6.90	6.17	7.76
Harogem	22.76	6.78	8.39	7.02	16.87	7.20	6.80	12.17
LE-2185	12.66	3.31	5.14	4.11	11.56	5.61	7.78	7.62
LE-1580	27.74	10.95	12.31	10.47	18.41	5.05	6.95	4.17
LE-1453	29.81	11.13	11.27	10.21	29.29	9.82	6.07	12.58
Lemeda (LE-962)	29.30	12.44	10.79	12.24	21.98	9.13	10.89	5.58
LE-1321	18.73	9.88	7.62	7.07	14.35	9.47	6.25	7.09
Lednická (M-90-A)	16.86	5.37	7.35	5.93	15.00	7.14	5.83	5.75
LE-SEO-24	40.52	13.82	14.88	17.29	29.95	10.40	13.89	9.64
Mean	24.74	9.02	9.37	9.62	19.00	7.51	7.62	8.93

fruit weight and stone width ($y = -0.038x^2 + 0.5075x + 6.0856$, $R^2 = 0.44$). The relationship between fruit weight and stone diameter ($y = -0.0003x^2 + 0.1084x + 7.8112$, $R^2 = 0.48$) resembled a linear one to the greatest extent.

The variability of fruit and stone traits in the particular genotypes was different. A difference in the variability of fruit weight and that of stone weight was significant. Average values of the coefficient of variation for these two traits in the whole set of genotypes were $v = 24.74\%$ and $v = 19.00\%$, respectively. They demonstrate a high degree of variability. The variability of other traits (fruit and stone height, width and diameter) was relatively low (coefficient of variation lower than 10%) (Table 5, Fig. 7). It could be explained by the fact that the responses of particular genotypes to the same changes in

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Variabilita vybraných znaků plodu a pecky meruněk a jejich vzájemné vztahy z hlediska identifikace a selekce

ABSTRAKT: V letech 1994–1997 byly hodnoceny hmotnost, výška, šířka a tloušťka plodů a pecek u 21 meruňkových odrůd a hybridů. Statisticky průkazné rozdíly mezi zjištěnými hodnotami znaků potvrdily jejich použitelnost k objektivní charakterizaci genotypů. Hodnocené znaky jsou genetickými vlohami. Prokázala to i skutečnost, že pořadí genotypů seřazených podle úrovně hodnot jednotlivých znaků v jednom roce bylo vysoce průkazně stejné i v ostatních letech hodnoceného období (korelační koeficient $r = 0{,}45^{++}$ až $0{,}87^{++}$). Vztah mezi hmotností plodu a dalšími znaky (hmotnost pecky, výška pecky a šířka pecky) není lineární. Směrem k okrajovým hodnotám znaků se hmotnost plodu zvětšuje (či zmenšuje) rychleji. Průměrný procentuální podíl hmotnosti pecky na hmotnosti plodu u genotypů za období čtyř let se pohyboval od 4,9 % do 9,6 %. Menší podíl pecky na hmotnosti plodu je pozitivním znakem při výběru vhodných genotypů pro přímý konzum a zpracování dužniny. Tato vlastnost může být rovněž vhodným kritériem výběru genotypů pro vyšlechtění odrůd s malým podílem nekonzumní části. Příkladem malého podílu pecky na hmotnosti dužniny je perspektivní odrůda Lemeda. Vysoký stupeň variability byl zjištěn u hodnot hmotnosti pecky a plodu (variační koeficient $v = 19{,}00$ %, resp. $v = 24{,}74$ %). Ostatní znaky (výška, šířka, tloušťka plodu a pecky) měly variační koeficienty více než o polovinu menší.

Klíčová slova: meruňka; genotypy; hmotnost; šířka; výška; tloušťka plodu a pecky; vztahy a variabilita

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