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HEIRLOOM VALUABLE LOCAL CULTIVARS THREATENED WITH EXTINCTION IN THE CENTRAL BALKAN MOUNTAIN REGION IN BULGARIA

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Abstract

The study was conducted in the towns of Troyan and Apriltsi and the nearby villages and hamlets in the Central Balkan Mountain. During the expedition research, heirloom local apple cultivars and forms threatened with extinction were discovered, marked and described. Their reproductive characteristics were studied. A large genotypic diversity of the genus Malus, L. have been observed. The complex of agroecological conditions favours the growth, and longevity of the apple trees*. Most discovered and described trees are more than 100 years old, more than 15 m tall and more. The trees bear fruit abundantly, but there is a tendency to alternate their fruit bearing. The subject of the present study are 11 late-ripening valuable cultivars with large-size fruit threatened with extinction, such as 'Kandile' - 129.51 g, 'Sadova Perusha' - 108.07 g, etc., with the aim of studying their morphological, pomological and reproductive characteristics. It has been found that most of them are distinguished by an attractive appearance, intensely coloured fruit skin and valuable nutritional and dietary qualities. Their long-term storage under home conditions is also a valuable quality.*

Key words: *apple, gene pool, local cultivars and forms, biometric, physicochemia of fruit.*

INTRODUCTION

In the recent and distant past, apples were consumed fresh and mostly processed, dried or made into cider, vinegar or applesauce. People have cultivated cultivars specially suited for specific purposes. The fruits range from crispy to floury, from very tart to extremely sweet, from juicy to dry, and each has its best application. If the skin of an apple is tough and waxy, or brown and rough, it keeps well because this prevents the flesh from drying out. Today, some old 'Golden Delicious', 'Jonathan' and 'McIntosh' cultivars are on the market as more widely available, but there is not enough demand for most heirloom apples to make commercial production worthwhile. For example, apples that are red, with spotted skin, rust, or completely covered with a rough texture are not considered pretty, but the taste of many of them is amazing. The bad news is that the number of apple cultivars considered at risk of being lost to the wild and from the food table is greater than for any other type of food. To reverse this trend of loss of diversity in the market for one of our most beloved fruits and ensure that generations from now do not think of 'Red Delicious' (or even the much-hyped 'Honeycrisp') as everything an apple can be in terms of taste, texture, shelf life and use, work must be done to restore apple diversity to our farms, backyard orchards, restaurants and home tables.

Despite historical losses, unique apples are still being found. Historic North American apple (*Malus domestica*) orchards that flourished in the late 19th and early 20th centuries, with cultivars different from today's orchards, are disappearing. There are several reasons for this loss: tree aging, tree maintenance costs, and urbanization. Many groups have compiled local knowledge of apple history and horticulture using both phenotypic and genotypic identification methods, as (1) some characteristics are highly variable with location, tree age, rootstock, etc.; (2) many cultivars are phenotypically similar; (3) there are many cultivar synonyms (i.e., same cultivar but different names) that are not fully realized until genotypically proven; (4) information is missing or scarce for some heirloom cultivars (Wallis et al., 2023).

The interest in preserving the apple diversity requires to find the places where the cultivars remain unique and growing them *in situ* or e*x situ*.

Kiprijanovski et al. (2020), presents the pomological, qualitative and organoleptic properties of 13 autochthonous cultivars, such as: 'Kolačara', 'Ciganka', 'Kojče', 'Crveno pote', 'Pašinka', 'Karapaša', 'Šareno blago', 'Alamanka', 'Pariska palma', 'Djulabija', 'Zvečarka', 'Tetovka' and 'Avajlija', with the cultivar 'Golden Delicious' as reference. Some of them deserve to be grown in traditional orchards in typical rural areas, with reduced use of chemicals and in environmental protection programs. Others of these cultivars do not have much economic and agronomic value, but this local gene pool is of great sociocultural importance and the cultivars should be preserved in *in situ* collections.

Duralija et al. (2021) reported the long tradition of fruit growing in the Republic of Croatia, due to its geographical location, climatic conditions and high quality of fruit crops, there is a growing demand for functional foods obtained from autochthonous and traditional plant sources, as they are recognized as a very valuable source of healthy bioactive ingredients. Heirloom apple cultivars (*Malus domestica* Borkh.) are characterized by good morphological and pomological properties, less need for chemicals during cultivation and a higher proportion of biologically active compounds (BACs). They have better sensory acceptability compared to commercial cultivars. However, their nutritional and biological potential, as well as their ability to be processed into functional food, is underestimated. Conserving heirloom apple cultivars and their cultivation importance through innovative strategies can successfully incorporate them into future selection programs.

Musacchi & Serra (2018) assessed the impacts and potential of both environmental conditions and agronomic factors. Environmental and agronomic factors throughout the vegetation have a strongly impact on the final quality of apples, including nutritional aspects. Temperature and light modify colour quality and dry matter accumulation, but can also cause the unwanted effect of sunburn. Orchard design, shaping, and pruning can dramatically affect fruit skin colour and fruit maturity. Crop load and thinning can determine physiological adjustments that favour fruit dry matter accumulation. Watering and nutrition can change the colour and chemical composition of fruit flesh.

For apple storage, it is known that the later the ripening period, the firmer the fruit flesh and the better and longer the fruit will be stored. Early ripening apples have soft flesh and do not store well. Fruits that are not fully ripe are selected for storage when the seeds are just starting to colour, as for best results temperature and humidity conditions are controlled.

With the spread of commercial apple cultivars since the second half of the last century, hundreds of different local cultivars quickly disappeared from orchards, and the specific quality characteristics of these fruits are still at risk of being lost today. From the 1920s to the 1960s, they were the main part of the apple cultivar type in Bulgaria. As a result of the introduction of new cultivars of American and European selection, their cultivation and distribution is decreasing and they are threatened with almost complete extinction. These cultivars are very well adapted to the agroecological conditions of the Central Balkan Mountain region, the fruits are large-sized with very good taste qualities, good attractive appearance, suitable for long-term storage, relatively resistant to diseases and enemies, which requires them to be sought out, stored and studied. They are suitable for non-conventional orchards, family farms, as well as for selection programs, to improve some of their qualities (Vitkov, 2015; Dzhuvinov et al., 2016).

This genetic diversity is a huge resource that could be used in selection programs that seek high yields, good fruit characteristics, tolerance to diseases and pests, as well as to abiotic environmental factors. To exploit this wealth, efforts should be made to survey different areas to select desirable types for establishing gene stocks (Ercisli et al., 2006).

The objective of the present research is the preservation and study of the valuable local apple cultivars, adapted to the agroecological conditions of the Central Balkan Mountain

region, with large-sized fruits, with very good taste qualities, suitable for fresh consumption and processing and resistant to diseases and enemies.

MATERIALS AND METHODS

During the expedition research in the Central Balkan Mountain region, the towns of Troyan and Apriltsi and their adjacent villages and hamlets, at an altitude of 600 to 1100 m, old local apple cultivars threatened with extinction were discovered, marked and described.

The trees are over 100 years old, with a large trunk circumference (over 1.5 m), crown height over 15 m, with good vitality. They are grafted at a height of 30-40 cm from the ground, and some species at 1.20-2.00 m. The shape of the crowns varies from globose to freely growing cone-shaped. The trees bear fruit abundantly, but there is a distinct alternateness. Marked trees are found as a seperate specimen or in abandoned old orchards, along small hamlets, often overgrown with forest vegetation, without application of agrotechnical and pomological measures. Drying is often observed on the trunk and crown.

The following indicators are taken into account:

- Reproductive - fruit weight (g), fruit size (mm) (height and average diameter) and fruit stalk (mm)

The terminal (king) fruit should be excluded from the sample (UPOV 2005) Observations on the fruit should be made on 10 typical fruits taken from a minimum sample of 20 fruits, at the time of ripeness for eating.

- Dry matter - with refractometer RHB-32 with a range of 0.0-32.0% (Brix %)
- Density (firmness) of fruit flesh (kgf/cm^2) - determined with a digital penetrometer FHT-15 (3.5 mm), by measuring both sides of 25 randomly selected fruits. The fruit skin of the measured fruits was removed.
- Pomological characteristics –

− sensory analysis (taste, aroma)

− colour coordinates L - colour brightness; +a - red color; -a - green color; +b - yellow color -b - blue colour measured with Color meter CM-200S, reported according to the CIE Lab system of the fruit skin. A/b colour tone quality indicator was calculated.

- A visual assessment was made of the attitude of the observed cultivars to the economically significant diseases, such as apple scab and powdery mildew on leaves and fruits. Low susceptibility based on single spots or absence of spots by the apple scab on leaves and fruit was reported and no powdery mildew symptoms were detected.

RESULTS AND DISCUSSIONS

According to the Guidelines for the Conduct of Tests for Distinctness, Uniformity and Stability (UPOV 2005), the determination of fruit size is divided into 9 groups. The cultivars included in the present study are large-sized in the categories from medium (5) 'Cox's Orange Pippin') to very large (8) 'Bramley's Seedling').

The fruits of 'Red Winter Calvil' (229.7 g) and 'Winter Green' (196.2 g) had the largest size, followed by 'Bukhavitsa' and 'Perusha' (about 187 g). 'Garden Feather' and 'Ribstone Pippin' had the smallest fruit (108 g). Accordingly, fruit height was 68 mm in the largest, but the largest average diameter was registered in 'Red Winter Calvile' (82 mm), whereas in 'Winter Green' it was only 46 mm, which gives an elongated shape to the fruit of this cultivar. 'Perusha' (81.4 mm) and 'Gankovata' (76.3 mm) had a larger average diameter. According to UPOV (2005), the shape of the fruits of most of the studied cultivars is (**7**) obloid, for example, 'Sadova Perusha', 'Ribston Pippin', 'Red Winter Calville'. The fruit shape of the cultivars 'Kandile', 'Buhavitsa' is (6) globose, 'Winter green' is (2) conic (Table 1).

The length of the fruit stalk is a characteristic pomological indicator for each cultivar. It is significant for the better appearance of the fruit, it gives a better opportunity for exposure to the sun and a longer time remaining on the tree. Apples with a longer stalk are more preferred by traders, as it favours storage capability. The fruits of 'Winter green' and 'Chardachka' had the longest stalks (20-22 mm) (Table 1).

Table 1. Biometric characteristics of fruits

Cultivar	Fruit weight (g)	Height (mm)	Diameter (mm)	Fruit: general shape	Fruit stalk length (mm)
	X ± St. Dev.	X ± St. Dev.	X ± St. Dev.		X ± St. Dev.
Candle	129.50±27.58	55.15±4.89	48.81±4.13	Globose (6)	13.84±4.41
Sadova perusha	108.07±29.02	53.46±6.08	64.48±4.81	Obloid (7)	9.87±2.58
Buhavica	185.79±29.50	63.90±2.49	76.62±3.03	Globose (6)	18.59±4.13
Perusha	187.08±37.61	62.82±4.38	81.42±5.58	Obloid (7)	9.10±1.19
Ribstone Pepin	108.45±12.3	54.51±4.44	63.34±1.78	Obloid (7)	15.77±1.19
Red Winter Calville	229.71±73.94	67.76±6.62	82.24±7.20	Obloid (7)	16.74±5.30
Winter green	196.19±10.50	68.03±2.07	46.16±0.87	Conic (2)	22.01±6.60
Chardachka	112.53±11.34	54.86±2.52	70.22±2.69	Conic (2)	19.73±2.92
Gankovata	145.83±4.73	59.05±0.83	76.36±0.23	Obloid (7)	15.61±2.35
Chichovata	115.79±19.40	53.16±4.03	67.42±3.54	Globose (6)	12.59±4.72
Tsar Alexander	153.34±42.08	56.35±5.90	72.92±6.49	Globose (6)	15.92±3.76
LSD 0.05	*43.67*	*5.86*	*5.66*		*5.10*
LSD 0.001	*76.74*	*10.3*	*9.94*		*8.96*

A main characteristic of the sensory analysis is the colour of the fruit skin. The cultivars, such as ‘Kandile’, ‘Perusha’, ‘Winter green’ and ‘Chichovata’ have a green main colour, some of them with white dots (‘Perusha’ and ‘Winter green’), and others with a blush on the exposed side (‘Red Winter’ ‘Calvil’ and ‘Gankovata’), as ‘Perusha’ is with more pronounced rusts.

The cultivars ‘Buhavitsa’, ‘Ribston Pippin’ and ‘Chardachka’ have a red main colour (Table 2). Skin colour is fundamental in apple production as a grading criterion. Many of the most cultivated apple cultivars are two-tone skin color, with a varying range of intensity and quality of red rind colour. Most of the world's apple production is based on mutations of original cultivars such as ‘Gala’, ‘Delicious’ or ‘Fuji’ (Musacchi & Serra, 2018). In automated fruit sorting, machines are usually set to sort based on the percentage of red colouring on the surface of the fruit, such as 'Modi®' and 'Demi Rouge™', with more than 70% dense red and 40 to 70% shades of over colour. For some cultivars, such as ‘Granny Smith’ and ‘Golden Delicious’, excessive red colour is an undesirable quality for the market and highly red apples decrease their commercial value (Musacchi & Serra, 2018).

The fruit flesh is usually white (1 ‘Akane’, ‘Spartan’) - ‘Kandile’, ‘Perusha’, ‘Chardachka’, ‘Tsar Alexander’; in the rest it is greenish (4 ‘Gloster’, ‘Granny Smith’) and rarely cream-coloured (2 ‘Jonagold’) (UPOV 2005), which is characteristic of the newer selected cultivars. The fruit flesh of ‘Kandile’, ‘Buhavitsa’, ‘Ribston Pippin’, ‘Chichovata’ is dense, whereas the rest of the cultivars are soft. The fruits of the observed cultivars are distinguished by juicy flesh. It is rather acidic in ‘Sadova perusha’ and ‘Winter green’ to sweet in ‘Chardachka’ and ‘Chichova’.

The cultivars, such as ‘Kandile’, ‘Tsar Aleksandar’, ‘Chichovata’ have a pronounced intense aroma, whereas ‘Buhavitsa’, ‘Perusha’, ‘Ribston Pippin’ are without aroma.

The researched cultivars satisfy both tastes of both types of consumers of acidic and sweet fruits.

Table 2. Pomological description of the cultivars

Cultivar	Colouring of fruit, taste qualities
Kandile	Fruit skin: green with blush and red non-broken vertical strikes, thick. Fruit flesh: white, juicy, grainy structure, dense, slightly acid without a pronounced aroma, refreshing.
Sadova perusha	Fruit skin: green with blush, dense, thick. Fruit flesh: greenish, soft, juicy, rather acid, without aroma.
Buhavica	Fruit skin: red broken and non-broken darker stipes, with waxing coat, dense, tough, not very thick. Fruit flesh: grenish, crispy, dense, comparatively tender with crystalline structure, juicy, slightly acid, without aroma.
Perusha	Fruit skin: yellowish-green with grey spots and rust around the stalk, thick with wax coating. Fruit flesh: white, soft, slightly floury, dry, sweet, without aroma.
Ribston Pippin	Fruit skin: red with broken vertical darker stripes with white spots and a green cloud around the bottom part. Thick, tough, dense. Fruit flesh: greenish, dense, slightly juicy, slightly fibre-like, firm, rather acid without aroma.
Red Winter Calville	Fruit skin: yellowish-green with an intense red over color and darker non-broken vertical red stripes, sprinkled with white dots, relatively thick, dense with a light wax coating. Fruit flesh: yellowish-green, juicy, crispy, slightly acid, with very good taste.
Winter green	Fruit skin: green with white spots, thick, covered with a wax coating. Fruit flesh: green with grain structure, juicy, rather acid but not tough.
Chardachka	Fruit skin: red in non-broken stripes with white spots, glossy, thin, tough. Fruit flesh: white, soft, slightly floury, dry, sweet, without aroma.
Gankovata	Fruit skin: yellow with a blush on the sunlit side, thin, dense, tough. Fruit flesh: white, soft, slightly mealy, juicy, sweet with an interesting aroma.
Chichovata	Fruit skin: green with red clouds and darker red non-broken stripes, thick, firm. Fruit flesh: green, dense, slightly tough, juicy, sweet with aroma.
Tsar Alexander	Fruit skin: red with dark red broken stripes and yellowish colouring on the dark side. Fruit flesh: white, soft, tender, fine, juicy, aromatic, slightly acid.

In the present study, the colour coordinates L - colour brightness were measured; +a - red colour; -a - green colour; +b - yellow colour; -b - blue colour (Table 3).

Table 3. Fruit colour parameters

	L	a	b	a/b
Kandile	57.73	9.14	40.88	0.32
Sadova perusha	71.74	-6.09	63.42	7.92
Buhavica	57.58	11.92	51.44	0.28
Perusha	74.68	1.95	119.22	*0.02*
Ribston Pippin	52.14	18.60	52.48	0.43
Red Winter Calville	56.79	11.38	57.49	0.24
Winter green	66.26	-1.61	79.88	-0.02
Chardachka	52.27	14.34	48.56	0.34
Gankovata	62.55	0.78	62.85	0.01
Chichovata	62.36	-0.48	44.88	0.04
Tsar Alexander	66.08	2.43	39.27	0.11
LSD 0.05	*11.70*	*11.93*	*14.04*	
LSD 0.01	*15.62*	*19.03*	*16.04*	

Regarding the brightness of the skin, the highest value was recorded for the fruits of 'Perusha' (L = 74.68), in which the yellow colour (b = 119.22) was the most dominant. High brightness values are also found in 'Sadova perusha' (L = 71.74), Winter green and 'Tsar Alexander' (L = 66), and with the lowest value L = 52.14 are the fruits of 'Ribston Pippin', in which the red color (a = 18.60) is the most pronounced. The 'Sadova perusha' cultivar had the largest negative value (-a = 6.09), defining the 'Green colour'.

The qualitative indicator colour tone a/b (dominant wavelength) had the highest value for the fruits of 'Sadova perusha' (7.92).

Soluble dry matter (Brix%) was recorded in two periods - after fruit harvesting and 10 days after storage in uncontrolled conditions. The highest values (16.8 and 17% were recorded for 'Perusha' and 'Gankova', as after their storage they also had the highest values, but the change is very small (0.5% to 1%), compared to cultivars that have increased the dry matter after storage to more than 3%. These are 'Winter green', 'Chichovata' and 'Kandile' (Figure 1).

According to Hoehn (2003), soluble solids content, firmness, and acidity are important factors determining the nutritional quality of apples. Tests with consumers have confirmed that acceptance can be predicted by instrumental measurements of total soluble solids (refractometer). 'Golden Delicious' of acceptable eating quality should reach a minimum of 12° Brix for total soluble solids.

The highest values for fruit firmness were measured in the 'Chichovata' with 14.44 (kgf/cm^2) and 'Gankovata' with 13.48 (kgf/cm^2) varieties (Figure 1), which corresponds to the sensory analysis according to Table 2. An intermediate position is occupied by 'Red Winter Calville', 'Chardachka' and 'Ribston Pippin', as with the smallest value for fruit firmness are 'Kandile' and 'Sadova perusha'.

High dry matter cultivars also have firmer fruit, except for 'Kandile', which has 17% dry matter and a firmness of 7.62 kgf/cm^2.

Softer fruits have a lower percentage of soluble solids. Based on this density, cultivars are defined as transportable and suitable for longer term storage.

The importance of combining instrumental methods (objective) with sensory methods (subjective) in the assessment of fruit quality, gives reliable and efficient information about how they are perceived by the consumer. Harker et al. (2002) considered that consumer acceptance of 'Gala' and 'Elstar' appeared to be less dependent on firmness, soluble solids content and acidity, but dependent on flavour quality and juiciness. In this regard, future storage optimization should take into account aroma aspects.

Tests with consumers have shown that liking can be predicted by instrumental measurements of total soluble solids (refractometer), titratable acidity and hardness. 'Golden Delicious' can be accepted if it reaches a minimum of 12° Brix, a minimum acidity of 3.2 g/l and a minimum hardness reading of 44 N. For 'Elstar', hardness should exceed 46 N and soluble solids should be above 12° Brix. 'Elstar' with acidity below 4.0 g/l or high acidity (> 6.5 g/l) did not appeal to consumers (Hoehn et al., 2003).

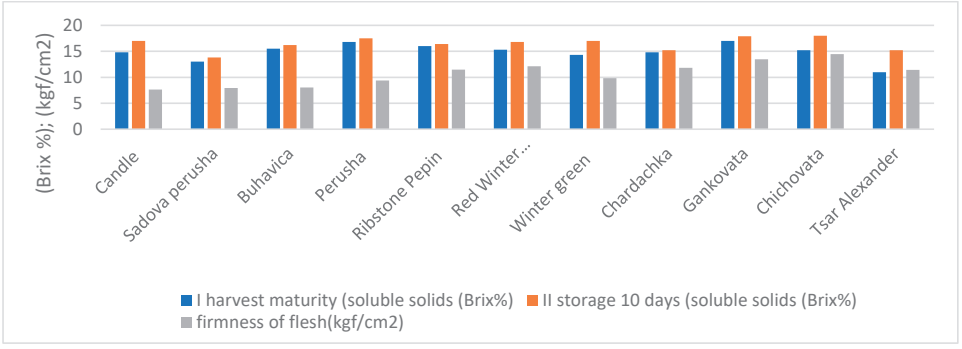

Figure 1. Soluble dry matter (Brix %) and fruit flesh firmness (kgf/cm^2)

A visual assessment was made of the attitude of the observed cultivars to the economically significant diseases, such as apple scab and powdery mildew on leaves and fruits. Low susceptibility based on single spots or absence of scab spots on leaves and fruit was reported and no powdery mildew symptoms were detected.

CONCLUSIONS

Based on the results of the present study, it was found that the 11 apple cultivars studied in terms of their fruit quality characteristics (size, weight, flesh firmness, appearance, taste, etc.) were not inferior to the standard 'Golden Delicious' and 'Granny Smith' cultivars.

The largest are the fruits of the 'Red Winter Calvil' (229.7 g) and 'Winter Green' (196.2 g), the shape of the fruit of most cultivars is obloid, the main colour of the fruit skin varies from green, yellowish-green to red. The fruit flesh is mainly white and green and their shades, some varieties have a pronounced aroma, others are without aroma.

The highest values of dry matter with 16.8 and 17% were reported in the fruits of the 'Perusha' and 'Gankova' cultivars, during ripening stage and after storage for 10 days, and for fruit firmness in the 'Chichovata' with 14.44 (kgf/cm^2) and 'Gankova' with 13.48 (kgf/cm^2).

The 'Winter green' cultivar could successfully replace the most common, cultivated and preferred 'Granny Smith' apple, in small family farms for sustainable and organic farming and non-conventional plantations.

We recommend the cultivarss we are considering to complement the apple assortment under the conditions of the Pre-Balkan Mountain. Their inclusion in selection programs can influence their biological potential and deservedly gain a wider distribution.

We identified promising cultivars best suited for fresh consumption and commercial cultivation, such as 'Tsar Alexander', 'Winter Green', 'Red Winter Calvil'. The rest are suitable both for fresh consumption and for processing (drying, sweet, distillates), and all cultivars of the group are subject to long-term storage, with the exception of 'Tsar Alexander'.

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