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INCREASING THE EFFICIENCY OF PLUM BREEDING IN FAMILY ORCHARDS BY INTRODUCING INTO THE VARIETAL ASSORTMENT OF SOME UNIVERSAL VARIETIES WITH VALUABLE PHYSICOCHEMICAL PROPERTIES

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Abstract

The research was carried out in an orchard from Cenad village, Timis County, throughout 2021, and compared five recently introduced varieties (Topend Plus®, Topfive®, TopHit , Toptaste®, Amers) with a control variety (President). Some physical and chemical characteristics of the fruits (major diameter, minor diameter, length, weight, total soluble solids, carbohydrate content, pH, and vitamin C) as well as plum production were monitored and measured. The plum components and economic indicators differ significantly between the varieties evaluated. In the majority of the examined indicators, all five newly introduced varieties outperformed the control, indicating the necessity to change the plum varietal assortment not only to satisfy market demands, but also to meet the suitability for industrialization and obtaining jams, juices or compotes, an important criterion given the net downward trend in demand for alcoholic products derived from plums. Economic indicators must be considered for fruit breeding success, particularly in light of current market trends caused by increases in labor costs, fertilizers or pesticides.

Key words*: plum trees, varieties, weight, firmness, yield, assortment, orchards.*

INTRODUCTION

The great adaptability to different climate and soil conditions has made the plum to grow and produce spontaneously or cultivated, with the area of spread and the variety of varieties being practically limitless (Käthner et al., 2017; Svanes and Johnsen, 2019). The plum tree is found all over the world, particularly in temperate climates of the northern hemisphere (Dimitrova et al., 2021). With around 1.7 million ha and a total production of approximately 13.5 million tons, the species ranks 11th in the world after apples, citrus fruits, bananas, peaches, and pineapples, and second in temperate areas after the apple (Ukar et el., 2022). Asia produces the most plums, followed by Europe, North America, South America, Africa, and Oceania (Afanador-Barajas et al., 2023). China, the United States, Turkey, Argentina, Yugoslavia, and Romania are the world's top producers (Wang et al., 2023). Former Yugoslavia, Romania, Germany, Bulgaria or France, are European major producers countries. In this context, Romania has become the Balkan and European country with the highest plum production, as well as a major exporter of fresh or dehydrated fruit (Zagrai et al., 2022).

The large number of plum varieties, which exceeded 2,000 at the beginning of the twentieth century, is the result of an ancient culture whose beginnings are lost in antiquity (Suranyi, 2019). However, in recent years, a severe decrease in the cultivated areas with plum trees has been noticed, even though there are currently programmes that support the establishment of new orchards (Kaufmane et al., 2019).

Romanian fruit growers have recently turned their attention to crops that are more profitable (apricot, peach, cherry) or easier to manage (hazelnut, walnut), even in good and highly favourable places for plum orchards (Gitea et al., 2019). Nonetheless, due to its adaptability and economic value, plum culture will undoubtedly retake its former position in Romania's fruit-tree crop hierarchy.

The plum varietal assortment in western Romanian orchards is relatively limited to two varieties: Stanley and Anna Spath. This assortment has recently begun to be slightly diversified by the introduction of new cultivars with high economic value. This diversification, however, must be of good quality, offering truly valuable cultivars compatible with the pedoclimatic conditions of each orchard location (Woznicki et al., 2019).

Plums are known to be consumed fresh but also dehydrated (dried plums), and they are used to make jams, marmalade, compotes, jellies, liqueurs, and last but not least the famous Romanian plum liqueur (Varga et al., 2022). Plum blossoms are an important source of honey and provide a spectacular view for entire regions (Hasnain et al., 2023; Fotirić Akšić et al., 2022).

When compared to other fruits, plums have the highest nutritional value. Plums have diuretic, laxative, depurative, nerve stimulant, and liver decongestant properties, with a sugar content of 16-20% (malic acid and in small amounts citric and benzoic acids) (Lin et al., 2023).

Fresh plums contain all of the microelements that humans require for normal life, such as potassium 170 mg%, Ca 12 mg%, Mg 10 mg%, P 18 mg%, Na 1mg%, Fe 0.5 mg%, Cl 1.5 mg%, and so on (Tomić et al., 2022). Among the most representative vitamins are: vitamin C under 4.0 mg%, carotene 0.9 mg%, B 10.83 mg%, B1 0.03 mg%, PP 1.0 mg% and others (Panahirad et al., 2019). As a result, plums are balanced foods in terms of vitamins, minerals, carbohydrates, and other nutrients or regulatory substances of human metabolism (Li et al., 2023). The world trends regarding the improvement of varieties are common, and they propose the preservation of valuable varieties, that respond to the local pedoclimatic and agrotechnical requirements on the one hand and to commercial and consumer ones on the other, with good economic results (Kuchay et al., 2022). The trees must produce abundantly and constantly from the first years, with significant adaptability to the various pedoclimatic zones, be rustic, quite resistant to diseases (Seethapathy et al., 2022).

The fruits must be large (over 40 g), attractively colored, with a pleasant taste, sugar, acidity, and tanoid substances in a well-balanced ratio, and a rich content of vitamins and mineral substances useful for the human body (Park et al., 2021).

The study's objective was to evaluate the physical and chemical parameters of several plum varieties cultivated in the environment of western Romania.

MATERIALS AND METHODS

The research was conducted during the year 2021, in an orchard located in the Cenad area, Timis County. The characteristics of some varieties recently introduced into the area's varietal assortment (Topend Plus®, Topfive®, TopHit, Toptaste®, Amers) were monitored. The observations and determinations were made in comparison to the President variety, which is grown in the area and provides good to very good results.

The study focused on the phenology, physical, and chemical characteristics of the fruits, such as length, width, weight, soluble dry matter, pH, carbohydrate, malic acid, and vitamin C content, fruit firmness, and plum production. BBCH codes were used to evaluate the phenophases of flowering and harvest maturity. The soluble sugar content was measured with the digital refractometer, the pH was determined using a pH metre, the firmness of the fruits was determined using a penetrometer, and the acidity was determined by titration. The HPLC method was used to separate vitamin C by high-performance liquid chromatography.

Statistical analysis

The XLSTAT software was used to analyse data from experiments designed in accordance with specific statistical designs (by Addinsoft, 2018, Statistical and Data Analysis Solution Version 2018.7.5). P values ($p \leq .05$; $p \leq .01$ $p \leq 0.001$) were used to estimate the source of variation.

RESULTS AND DISCUSSIONS

The recent climatic variability has influenced the success of plum culture in many circumstances, which is why fruit growers have changed their strategy to varieties with later flowering or are experimenting with various methods to induce a phenophase delay of at

least a few days (Florea et al., 2019). The investigated varieties flowered later than the control variety, both in terms of phenophase initiation (BBCH 61) and phenophase ending (BBCH 65) (Meier, 2018).

Early flowering varieties are more vulnerable to late spring frosts than later ones. Late frosts have a greater negative impact on production when the climatic incident happens in BBCH 65, as compared to BBCH 61. Toptaste® and Topend Plus® varieties reached the BBCH 65 phenophase 6 and 5 days later, respectively, than the control variety. TopHit and Amers varieties, which reached the BBCH 65 stage at the same time as the President variety, were at the opposite pole (Table 1).

Table 1. Flowering stage code

Variety	Beginning of flowering BBCH 61	Full flowering BBCH 65	Difference to control (days) BBCH 65
Topend Plus®	15.04	21.04	5
Topfive®	13.04	19.04	3
TopHit	9.04	16.04	-
Toptaste®	15.04	22.04	6
Amers	10.04	17.04	1
President (C)	9.04	16.04	-

Table 2. Plums maturity stage - BBCH 87

Variety	August			September			October
	1-10	10-20	20-30	1-10	10-20	20-30	1-10
Topfive®	8.08						
Toptaste®		12.08					
TopHit				7.09			
Amers					12.09		
President (C)					19.09		
Topend Plus®							8.10

Regarding harvest maturity, it is preferable that the chosen assortment be planned over a longer period in order to avoid production peaks, better manage the required labour force, and ensure the consumption and storage of fresh fruit for as long as possible. The Topfive® variety was the first to reach harvesting maturity (BBCH 87) among the varieties studied, followed by the Toptaste® variety 4-5 days later (Table 2). These two varieties ensure early production, which benefits from higher prices at the start of the season, for plums in the first half of August. TopHit reached harvest maturity around 12 days earlier than the control variety in the first decade of September. Topend Plus® was the only variety that achieved harvesting maturity later than the control variety, allowing a late consumption of plums towards the end of the season when prices become competitive again. The chosen assortment ensures that the plum production is distributed over a long period of time, around 60 days, allowing for both an easier distribution of the production and a decrease in the pressure on the processing activities.

Table 3. Plums length and width measurements

Variety	Major diameter (L)		Minor diameter (l)		Difference to control (mm)	
	mm	%	mm	%	L	L
Topend Plus®	45.68	104.48	42.78	104.06	1.96^{ns}	1.67^{ns}
Topfive®	39.22	89.70	36.12	87.86	-4.5^{**}	-4.99^{*}
TopHit	50.92	116.46	48.25	117.36	7.2^{***}	7.14^{***}
Toptaste®	41.89	95.81	38.95	94.74	-1.83^{ns}	-2.16^{*}
Amers	49.74	113.76	44.22	107.56	6.02^{***}	3.11^{***}
President (C)	43.72	100.00	41.11	100.00	-	-

*t significant at p ≤. .05; **t significant at p ≤ .01;***t significant at p ≤. .001

Table 4. Main physical parameters of six plum varieties

Variety	Length		Weight		Difference to control (mm)	
	mm	%	g	%	Length	Weight
Topend Plus®	53.64	103.09	61.12	113.10	1.61^{ns}	7.08^{***}
Topfive®	53.11	102.07	57.23	105.90	1.08^{ns}	3.19^{*}
TopHit	61.12	117.47	76.38	141.33	9.09^{***}	22.34^{***}
Toptaste®	50.17	96.42	52.26	96.70	-1.86^{*}	-1.78^{ns}
Amers	54.11	103.99	59.21	109.56	2.08^{ns}	5.17^{**}
President (C)	52.03	100.00	54.04	100.00	-	-

*t significant at p ≤. .05; **t significant at p ≤ . 01;***t significant at p ≤. .001

Like other fruits, buyers choose plums mostly based on how they look; the largest plums with the most appealing skin are always in demand. The success of the product's marketing is assured if the physical traits are combined with palatable flavour qualities and a non-sticky pulp. It is desirable that most of the production be valued through direct fresh consumption that ensures immediate income. Therefore, all the researched varieties have large, attractive fruits, with a plus for the TopHit and Topend Plus® varieties, which, compared to the control, have a statistically significant higher fruit weight. The only variety that, both in terms of fruit length and weight, had lower values than the control was Toptaste® (Tables 3, 4). In similar research done on 10 varieties of plum, Tomić et al. (2022) found an average plum weight ranging from 26.9 to 57.9 g. Dimitrova et al. (2017) after the research of fresh fruits of 10 cultivars, found an average shorter length of plums among 33.26 and 47.8 mm.

Table 5. Chemical properties of plums varieties

Variety	Total soluble solids (TSS)		Carbohydrates		Difference to control (mm)	
	(% Brix)	Content	%	Content	Total soluble solids	Carbohydrates
Topend Plus®	19.27	98.52	18.16	98.64	-0.29^{ns}	-0.25^{ns}
Topfive®	19.84	101.43	18.59	100.97	0.28^{ns}	0.18^{ns}
TopHit	19.23	98.31	18.11	98.37	-0.33^{ns}	-0.3^{ns}
Toptaste®	20.09	102.71	18.88	102.55	0.53^{*}	0.47^{*}
Amers	20.11	102.81	18.93	102.82	0.55^{*}	0.52^{*}
President (C)	19.56	100.00	18.41	100.00	-	-

*t significant at p ≤ .05;

Besides appearance, the taste and chemical composition of plums are important, especially when the fruits are processed (Table 5). Total soluble solids were comparable between varieties, ranging from 19.27 to 20.09% Brix. Toptaste® and Amers were the only varieties that outperformed the control with statistically significant differences. Plocharski and Konopacka (2003) found in two Polond plum varieties a lower total soluble solids amount between 11.8 and 16.9%.

Plum varieties had very similar carbohydrate content, with limits ranging from 18.11 to 19.93%; the differences in carbohydrate content between the Amer and Toptaste® varieties compared to the control were also statistically significant.

In addition to the dry matter and carbohydrate content, the pH, malic acid content, and vitamin C content are important parameters that contribute to balanced overall plum content (Table 6).

The ph level for all varieties was generally close, with limits ranging from 3.55 for the control variety to 3.86 for the Amers variety. It should be noted that the pH recorded slightly significant values for the control variety in all varieties investigated. Larger and higher limits of Vitamin C (4-11 mg/100 g) were found in Poland plums by Walkowiak-Tomczak (2008).

Table 6. Plums pH and malic acid content (% or mg/100 g fresh matter)

Variety	pH	malic acid (% or mg/100 g fresh matter)	Vitamin C (mg/100 g)
Topend Plus®	3.75	0.74	3.94
Topfive®	3.62	0.67	3.88
TopHit	3.57	0.63	3.65
Toptaste®	3.59	0.66	3.73
Amers	3.86	0.62	3.57
President (C)	3.55	0.71	3.91

Table 7. Firmness in plums variety

Variety	Firmness (kg/cm^2)	Relative value (%)	Difference to control
Topend Plus®	2.42	109.50	0.21^{*}
Topfive®	1.98	89.59	-0.23^{*}
TopHit	1.85	83.71	-0.36^{*}
Toptaste®	1.94	87.78	-0.27^{*}
Amers	2.09	94.57	-0.12^{ns}
President (C)	2.21	100.00	-
*t significant at p ≤. .05;			

The malic acid content was also within normal limits, with close relative values between the varieties, ranging between 0.62 for the Amers and 0.74 for the Topend Plus® variety.

Plums are known to be vitamin C-rich fruits, with the content ranging between 3.57 mg/100 g for the Amers variety and 3.94 mg/100 g for the Topend Plus® variety.

The only variety that recorded higher values than the control for vitamin C content was the Topend Plus® variety.

Table 8. Plums production parameters

Variety	Plum production			Difference to control
	kg/tree	kg/ha	%	(kg/ha)
Topend Plus®	32.3	20187.5	110.6	1937.5^{***}
Topfive®	28.2	17625.0	96.5	-625.0^{*}
TopHit	29.4	18375.0	100.7	125.0^{ns}
Toptaste®	26.5	16562.2	90.7	-1682.8^{**}
Amers	31.6	19750.0	108.2	1500.0^{**}
President (C)	29.2	18250.0	100.0	-
*t significant at p ≤. .05; **t significant at p ≤ .01;***t significant at p ≤. .001				

Fruit firmness is an essential variable that impacts the shelf life of the product, transport resistance, and handling (Table 7). Firmness values ranged from 1.85 for the TopHit variety to 2.42 for the Topend Plus® variety, which was also the only variety with significantly better firmness than the control variety. Topfive®, TopHit®, Toptaste®, and Amers varieties are not considered less popular despite having lower firmness values than the control.

Finally, the plum production obtained is the most important indicator that has a significant impact on the economic results and profit of each orchard. The researched varieties produced favourable results, with yields ranging from 26.5 kg/tree for the Toptaste® variety to 32.3 kg/tree for the Topend Plus® variety, yielding 16562.2 kg/hectare and 20187.5 kg/hectare, respectively (Table 8).

Although the Topfive® and Toptaste® varieties have early fruit ripening, they have reached satisfactory levels of production per hectare, which, coupled with higher prices since the beginning of the consumption season, make these varieties attractive variants within the assortment of varietals. Topend Plus® and Amers, the most productive varieties, were the only ones that outperformed the control with statistically significant differences. These are also the latest varieties, ensuring an extension of the plum consumption season and, as a result, off-season prices.

CONCLUSIONS

Plum culture is very common in Romania, from the plains to the sub-Carpathian areas and even to the highlands. However, for unknown reasons, there has been a significant decrease in the ratio of newly established plum orchards to those of other fruit tree species in the past few years. With the development of new plantations

of other fruit tree species, like hazelnut, walnut, and cherry, areas planted with plum have been limited in the western part of the country.

In the west of the country, the plum varietal assortment is relatively small, with the Stanley and Anna Spath varieties predominating in a significant proportion. This assortment no longer meets the consumer's current demand for more diverse products, ranging from fresh plums to dehydrated plum consumption, juices, nectar, and other processed products. As a result, it is necessary to expand the varietal assortment by introducing valuable varieties with clearly different appearance and quality characteristics that are suitable for multiple applications. The new varieties introduced into the assortment must be adaptable to the pedoclimatic resources of the area while also being resistant to diseases and pests, requiring fewer treatments, or even being cultivated in order to achieve financial efficiency, in an organic system that has been successfully implemented in Romania in recent years. Climate change has caused significant production losses in recent years, including in plum orchards; therefore, the later the varieties bloom, the less likely they will be destroyed by late spring frosts. Toptaste® and Topend Plus® are recommended in this regard because they bloom 5-6 days later than the control. The studied varieties responded favorably to the natural conditions of the cultivation area, yielding positive results for the commercial quality standards, the physico-chemical composition, and plum production.

Due to the distribution of fruit maturity over a period of about 60 days, the plum assortment chosen ensures a long period of fresh fruit and benefits from good prices from the beginning (Topfive® and Toptaste®) to the end of the season. All five investigated varieties are also suitable for processing, particularly as juices and nectar, due to their sugar, acidity, pH, and malic acid content.

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