MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

Hungarian University of Agriculture and Life Science

Growth and yield of plum varieties (*Prunus domestica* L.) on different rootstocks in containers sunk in soil

Anikó, Kajtár-Czinege

Budapest

2024

Name of the
doctoral school: **Doctoral School of Horticulture**

branch of science: **Fruit-bearing plants**

Head of: **Éva, Zámboriné Dr. Németh**

university professor/ DSc

MATE

Institute of Horticulture

Thesis leader: **Károly, Dr. Hrotkó**

professor emeritus/DSc

MATE

Institute of Horticulture

……………………………………….. …………………………………

Approval by the Head of School Approval of the thesis leader

Claude Monet: Flowering plum trees (1879)

1.) BACKGROUND TO THE WORK, AIMS AND OBJECTIVES

Plum is the second most important stone fruit after sour cherry. "It is about 5000 years cultivated plans" (SURÁNYI 1980/b). It has a long tradition of cultivation in its production area. In the last ten years (2013-2023), 30-48 thousand tonnes of plums have been produced in our country, cultivated on an area of about 7 thousand hectares. However, its yield average is outstanding among the stone fruits, with a mean yield of around 5 t/ha. This value could be further increased by increasing the intensity, i.e. by choosing the right rootstock-variety combinations, mulching, modern irrigation techniques with nutrient application, appropriate weed control, and possibly the use of ice nets as climate nets.In Hungary, 50% of the plums produced are for industrial processing and about 50% for fresh consumption (APÁTI, 2020).This would mean that half of the plantations could be grown using semi-intensive technology with vase canopy, on 'Mirobalan' seedling rootstocks that provide strong growth and good anchorage for shaker harvesting.The other half could be grown with intensive techniques, on growth-reducing rootstocks, with (slender) spindle crowns that could be harvested by hand standing on the ground.

Despite this, the use of domestic rootstocks is still rather monotonous, with 95-97% of the rootstocks used by nurseries in Hungary being 'Mirobalan' rootstocks from Cegléd. This situation needs to be changed as soon as possible.

The fruit quality of plums can also be affected by the influence of certain rootstocks on the variety. In our country, 50% of the plums produced are industrially processed into jam, brandy (pálinka) and dried plums, and 50% are sold on fresh markets.

The fresh market needs are served by the large-fruited varieties such as 'Toptaste', 'Jojo', 'Čačanska lepotica', 'Tophit', 'Topend', 'Haganta' or the Japanese plum varieties.

Plums are one of our most outstanding fruits in terms of nutritional value. It is remarkable for its calorie, dry matter (12-15%), carbohydrate (0.4-1.4%), sugar, pectin, fibre and acid content (SZABÓ, 2001), as well as its polyphenol content (ŐRI, 2019).

Plums could also be important for medicinal purposes (TÓTH and SURÁNYI 1980/a; SURÁNYI, 2006, 2019). Our per person consumption of plums in Hungary is 1.0 kg, one tenth of that of apples (10 kg/person/year) (KSH 2020). In Hungary, there is a tradition of plum production, mainly in Szatmár and Bereg (around 10,000 t). However, in recent years (2015-2021), Bács-Kiskun county is the second most important plum producing county, with 7,000-7,500 t of plums produced (KSH, 2021). In the orchards of Bács-Kiskun county, traditional cultivation techniques have been abandoned and the trend is increasingly towards intensive cultivation systems. In Western Europe, approximately 80 plum rootstocks from mahaleb, St.Julien, plum, 'Marianna plum' and other species and hybrids are being studied.(WERTHEIM andKEMP 1998; HROTKÓ 1999; MORENO 2004; JACOB 2007; ACHIM et al. 2010; BOTU et al. 2010;GRZYB et al. 2010;MELAND 2010;PEDERSEN 2010; PINOCHET 2010; SOTTILE et al 2010;MÉSZÁROS et al. 2015;GRAVITE and KAUFMANE 2017; KAJTÁR-CZINEGE 2018/a; RADOVIC 2022;NECAS et al. 2023;). In Hungary, all this research work has so far been carried out with 10 vegetatively propagated breeds, in addition to the Cegléd seedstocks and the vegetatively propagated 'Fehér besztercei' and Kisnánai lószemű" rootstocks from Érd (HROTKÓ et al. 1998; HROTKÓ 1999; HROTKÓ et al 2002;HROTKÓ andMAGYAR 2006/b;CZINEGE 2014; KAJTÁR-CZINEGE 2018/b;KAJTÁR-CZINEGE et al. 2022). Our research examines cultivars of the species domestic plum (*Prunus domestica* L.), myrobalan (*Prunus cerasifera* Ehrh. var. *cerasifera* Scheid. cv. *myrobalana*), 'St. Julien' (*Prunus insititia* Jusl.) and its hybrids, and European plum (*Prunus domestica* L.;).Based on the study of literature data and the analysis of the domestic plum cultivar and rootstock use, I concluded that the evaluation of the new varieties and rootstocks under national conditions is an essential task for the improvement of cultivation technology and cultivar and rootstock use. The aims of our experiment were defined on the basis of the following criteria:

1. Based on the literature data, it is necessary to analyse and select those varieties and rootstocks which, on the basis of foreign data, seem to be perspective for the establishment of intensive plantations under national conditions.
2. We want to study the growth characteristics of the selected varieties and rootstocks, mainly in terms of trunk thickness and crown size, which will allow us to determine their suitability for intensive planting. In addition, shoot growth and the formation of fruiting parts and flower buds, which are important characteristics for fruit set and fertility, are investigated.

3. We investigate the fertility and yield of each rootstock/variety combination based on the yield trends of the trees per year. Productivity is characterised by specific yield in relation to tree size (trunk cross-sectional area, crown volume).

4. We examine the quality parameters (size, fruit content values) of the fruits obtained on different rootstock/variety combinations, which determine their suitability for intensive production.

5. As irrigation is a basic need for intensive plantations in the sandy soils around Kecskemét in the Great Plain, we want to investigate how the amount of irrigation water affects tree growth, fruit quantity, quality and viability of the trees.

6. To summarize our results, we recommend varieties and rootstocks for intensive plum plantations in the Great Plains based on their suitability.

2. MATERIAL AND METHOD

In the spring of 2010, the plant population to be investigated was planted in the Vacsi-közi garden of the then Kecskemét College of Horticulture, located at the present Neumann János University, at 46°91' N and 19°68' E.

Kecskemét is located on the sandy plain of the Danube-Tisza Interfluve, so its soil is sandy soil formed from the Danube alluvium, which is characterised by a low humus content. "The town has alternating loess, loamy sand and quicksand on or near the surface in the back parts of the Kiskunság loess. Vacsi-hegy is loess and loamy sand," says IVÁNYOSI-SZABÓ és HOYK, 2010.

Kecskemét has a warm-dry continental climate. The annual sunshine duration is 2030-2050 hours. The average annual mean temperature in the garden is 10-12°C. The average January temperature is 0 - -1°C, the average July temperature is 21-22°C, the mean temperature during the growing season is 17-18°C. The number of heat days is 16-20 days. The mean annual rainfall is 500-600 mm, but in 2012 it did not exceed 400 mm. According to OMSZ (2022) and KISS (2005), the number of days with snow cover is 30-35 days.

In the spring of 2010, the 1-year-old crown grafted plants purchased from Germany were transplanted. Five cultivars ('Č. lepotica', 'Jojo', 'Topper', 'Toptaste', 'Topfive') were planted on six rootstocks ('Mirobalan', 'St. Julien GF655/2', 'St. Julien A', 'Fereley', 'Wangenheim', 'WaVit'), but not all rootstock/variety combinations, only 16 combinations were planted. I chose the 'Top' varieties for their new value, alongside a more traditional 'Jojo' and a well-known Serbian variety, 'Č. lepotica', for comparison. Among the rootstocks, the well known Mirobalan can be used alongside the St Julien and the foreign promising Wangenheim, WaVit and Fereley, the last one for its early fruiting and high yielding effect. The combinations used in the experiment are shown in Table (1) below. From one combination, 12 trees were planted. 16 combinations, i.e. 192 trees were planted.

Table 1: The used rootstock/variety combinations

The used rootstock / variety combinations

	Mirobalan	St. Julien GF566/2	St. Julien A	Fereley	Wangenheim	WaVit
‚Topper’	X	X		X		
‚Toptaste’	X	X	X	X	X	
‚Topfive’		X	X	X		X
‚Č. lepotica’	X		X			
‚Jojo’	X		X			

The cultivation system used: the trees were planted in a 2.5 x 1.5 m space.

This spatial position allowed manual weed control and limited soil loosening. The crown shape was designed to create a slender spindle-like crown that was easily harvested while standing on the ground. Vertical growth of the trees was stopped at 3.2 m.

Uniform nutrient supply, weed control and plant protection treatments were applied. The grafts were planted in 170 l containers sunk in soil, 60 cm in diameter and 60 cm deep. This was necessary to set up an irrigation experiment, so that watering each tree would not affect the water supply of the next tree.

From 2010 to spring 2012, the trees received one type of irrigation. The irrigation system was completed in spring 2012. From then on, 6 of the combinations of trees received 1x dose of irrigation water, while 6 trees received 2x dose of water. The irrigation system was constructed on a chessboard. This means that the trees received 2 l/h and 4 l/h of irrigation water during the same period.

We measured: trunk circumference, trunk diameter, trunk height, tree height, crown width, shoot growth dynamics, total shoot length, fruit yield per tree, fruit diameter, fruit length, flesh firmness, fruit dry matter content, fruit acidity, soil moisture, irrigation duration, fruit laterals length on sample branch, sugar components, acid components and polyphenol content.

I also made calculations from the measured data.

I calculated: trunk area, crown volume, yield per unit area, specific yield per trunk area (kg/cm^2), specific yield per crown (kg/m^3), fruit shape index and seed/flesh ratio from the measured data.

1.) Trunk cross-sectional area: (TCSA):

$$\mathrm{TCSA}(\mathrm{cm}^2) = \boldsymbol{r}^2 \cdot \boldsymbol{\pi} = \left(\frac{1}{2} \cdot \mathbf{d}\right)^2 \cdot \boldsymbol{\pi}, \text{ where}$$

'd' marks the trunk diameter, half of which is marked by 'r'.

The increase in trunk cross-sectional area can be used to indicate growth vigour, but small changes in trunk cross-sectional area (μm) are also a very good indicator of water stress (INTRIGLIOLO and CASTEL 2004). I was not able to monitor this type of change during the experiment.

2.) **Crown volume (CV):** the crown shape of the trees studied is a spindle, which can be described by a cone, so I calculated the cone volume using the formula

$$\mathrm{CV}(\mathrm{m}^3) = \frac{1}{3} \cdot \mathrm{CA} \cdot \mathrm{M}$$

a M=high of the canopy= (high of the tree - high of the trunk)

- **Canopy area (CA):**

$$\mathrm{CA}(\mathrm{m}^2) = \mathrm{R}^2 \cdot \boldsymbol{\pi} = \left(\frac{1}{2} \cdot \mathrm{D}\right)^2 \cdot \boldsymbol{\pi}; \text{ ahol}$$

az R=a canopy length (canopy diameter *1/2),
a D= canopy diameter

3.) Yield per unit area (ha):

4 x1,5 (1700 piecetree/ha) **Q_1 (kg/ha) = (q_1+…+q_6)/6*1700**

4,5 x2,5 (890 piecetree/ha **Q_2 (kg/ha) = (q_1+…+q_6)/6*890**

where the q =the yield of each tree

4.) Yield per tree: $\mathbf{Y(kg \cdot tree^{-1})}$

- **Cumulative yields:**

$$CY(kg \cdot tree^{-1}) = \sum_{i=2010}^{2016} Y_i$$

5.) specific yields

- **Cumulative specific yield per trunk cross section area:**

$$CYTCSA\ (kg \cdot (cm^2)^{-1}) = CY \cdot (TCSA_{2016})^{-1}$$

- **Cumulative yield per crown volume:**

$$CYCV(kg \cdot (m^3)^{-1}) = CY \cdot CV^{-1}$$

We also looked at the crop rotation index, where the first 3 years' yields were added together and divided by the total cumulative yield and then multiplied by 100 to get a percentage. This index refers to the proportion of tree yields in the first 3 years of the study compared to the total yield per tree.

Precocity index: PI (%) = (Y2010 + Y2011 + Y2012)*[(CY Total) -1]* 100

The precocity index was calculated based on BUJDOSÓ et al. (2019).

6.) Fruit shape index (%)

The stem length, fruit width and length were measured with a ruler, and the shape index of the fruit was calculated from the latter two.

The fruit shape index = fruit length / fruit width.

Next, we measured the weight of the stone, subtracted this weight from the weight of the fruit to get the weight of the flesh, then divided the weight of the seed by the weight of the flesh to get the stone-to-flesh ratio.

7.) Stone-to-flesh ratio (%)

Fruit weight - stone weight = flesh weight

Stone weight (g)/flesh weight (g)= stone-to-flesh ratio (%).

Fruit quality parameters were also measured, such as mean fruit weight, Brix (%), flesh firmness, stone weight.

8.) Morphological observations live and with photographs

Different types of fruiting laterals can be seen on the fruiting twigs (Figure 1), ranging from bouquets to long fruiting canes. These can be identified by their length and bud position. We have classified these parts by type, measured their length and counted the number of buds on them. The drawing below shows the types of each part of the plum.

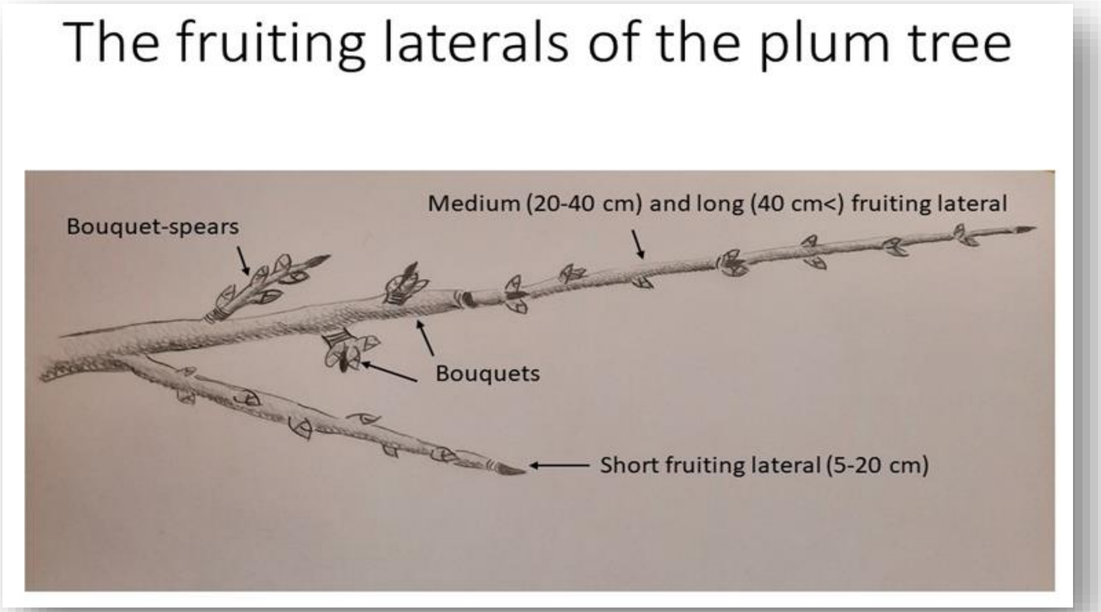


Figure 1. : The fruiting laterals of the plum tree (draw: Kajtár-Czinege,2022)

Data evaluation methods

In evaluating the data, our aim was to show how each of the characteristics tested varied across different groups. When we wanted to compare a trait for two groups, we used a two-sample t-test. When comparing the average of more than two groups for a trait, analysis of variance was used. In both cases, we checked the conditions under which the procedures were performed: normality of the distribution of the trait under test and the agreement of the variance of the trait under test across groups. Normality was tested for using the Kolmogorov-Szmirnov and/or Wilk-Shapiro test, while homogeneity of variance was tested using the Levene test. In several cases in our study, we could not reject normality or homogeneity of variance only at a significance level of 0.01.If the conditions were fulfilled, an analysis of variance or t-test was performed. In the case of analysis of variance, if we rejected the null hypothesis, i.e. we found a significant difference in the mean value of the trait under test across groups, we created homogeneous classes using the modified Duncan's multiple rank test (and marked with a, b, c). If the conditions of the procedures were broken, we performed the non-parametric equivalent of the procedures ANOVA with Welch and Brown-Forsythe tests, and Mann-Whitney test for a two-sample t-test. When comparing means, the significance level was 0.05. Analyses were performed using SPSS (FREUND et al. 2021).

3. RESULTS AND THEIR DISCUSSION

3.1. The survival rate - the effect of rootstocks on tree lifetime

The experiment was maintained for 12 years, although growing in containers does not give a good evaluation of tree lifetime. Nevertheless, our experiments showed that trees of the five varieties survived the first 7 years with a high survival rate of 83-100%, except for the 'Fereley' rootstock (Table 2). Trees of the cultivars 'Topper', 'Toptaste' and 'Topfive' on the rootstock 'Fereley' showed a low survival rate of 33-50% under double watering. The tree mortality of 'Toptaste' and 'Topfive' trees occurred after 2012 when the different irrigation system was in use. The 'Topfive' trees on the 'WaVit' rootstock also showed a lower survival rate of 67%. No mass mortality was observed in the other rootstock-variety combinations (Table 2).

Table 2: Number of trees (2012 and 2016) and survival rate (2016) for different doses of irrigation water (W1 and W2)

	’Topper’				’Toptaste’				’Topfive’			
Rootstocks	2012	2016	W_1 %	W_2 %	2012	2016	W_1 %	W_2 %	2012	2016	W_1 %	W_2 %
’Mirobalan’	6+6	6+6	100	100	6+6	6+5	100	83	-	-	-	-
’GF 655/2’	6+6	6+6	100	100	6+6	6+6	100	100	6+6	6+5	100	83
’St. Julien A’	-	-		-	6+6	6+5	100	83	6+6	6+6	100	100
’Fereley’	6+6	5+3	83	50	6+6	6+2	100	33	6+6	6+2	100	33
’Wangenheim	-	-		-	6+6	6+5	100	83	-	-	-	-
’WaVit’	-	-		-	-	-	-	-	5+6	5+4	83	67

	’Č. lepotica’				’Jojo’				
	2012	2016	W_1 %	W_2 %	2012	2016	W_1 %	W_2 %	
’Mirobalan’	6+6	6+6	100	100	6+6	6+6	100	100	
’St. Julien A’	6+6	5+6	83	100	6+6	6+6	100	100	

There is no support from previous observations, literature, foreign literature for this kind of problem of 'Fereley'. MELAND (2010) observed heavy mortality of about 60% on 'Wangenheim' rootstocks in soils with high organic matter content (4%) and good nutrient supply. In contrast, no tree mortality was observed on 'St. Julien A'.

Vegetative growth - the effect of rootstocks on the growth vigour of trees

The trunk cross-sectional area, i.e. the thickness of the trunk, is the best indicator of growth vigour, although it can be influenced by a number of other factors. The growth vigour of trees as a genetic trait can also be modified over the years by other factors such as the quality of nursery grafting, the growth characteristics of the variety, and the characteristics of crown shaping, fruit set, and yield, - write BLAŽEK and PIŠTĚKOVÁ (2009).

3.2. Thickness of the trunk and crown volume trends observed during our examination

The statistical analysis of the year 2016 based on the trunk cross-sectional areas (TCSA) of 'Topper', 'Topaste' and 'Topfive' (Table 3) showed significant differences in the different rootstocks, and for 'Topaste' the crown volume (CA) was also significantly different. 'Toptaste', 'Topfive' did, while 'Č. lepotica' and 'Jojo' did not differ significantly in trunk cross-sectional area or crown volume. The trees of 'Topper', 'Toptaste' and 'Topfive' showed different performances when TCSA was considered. The highest TCSA and CV values on the 'Fereley' rootstock were obtained on the 'Toptaste' trees, while the 'Topper' on the 'Mirobalan' rootstock had the thickest trunk. The trees of 'Topper' showed no significant difference in crown volume. The TCSA data showed significantly lower values for 'Toptaste'/'Wangenheim' than for the Fereley rootstock. The CV of 'Topfive'/'WaVit' was significantly smaller than that of 'Fereley' rootstock KAJTÁR-CZINEGE et al. (2022).

The mean TCSA results also show that the variety 'Č. lepotica' on 'Mirobalan seedlings' gave tree sizes similar to the 'Topper'/'Mirobalan' combination without significant differences. 'Jojo' trees with 'Mirobalan' and 'St. Julien A' roots showed strong growth overall, while 'Topaste' trees produced trees almost half the size on the same rootstocks. The TCSA and CA development of 'Toptaste' is similar to that of 'Topfive'.

Figure 2 shows that the crown volume evolution of the 'Topper' crown was not as strong as its trunk thickening, but more in line with the 'Toptaste' crown development, which is characterised by a CV of 1.2-1.5 m^3.

Table 3: Average trunk cross-sectional area (TCSA, cm²) and CV (KTF, m^3) in 2016

ROOTSTOCKS	'Topper'		'Toptaste'		'Topfive'	
	TCSA	CA	TCSA	CA	TCSA	CA
'Mirobalan'	18.34 b	1,.22 a	10.59ab	0.74 ab	- -	- -
'GF 655/2'	17.51 b	1.15 a	11.71 b	0.8 b	12.51 b	0.67 a
'St. Julian A'	- -	- -	11.81 b	0.92 bc	13.41 b	0.51 a
'Fereley'	11.16 a	0.93 a	15.47 c	1.06 c	14,.01 b	0.87 b
'Wangenheim'	- -	- -	8.64 a	0.56 a	- -	- -
'WaVit'	- -	- -	- -	- -	7.12 a	0.63 a
	'Č. lepotica'		'Jojo'		MEAN OF ROOTSTOCKS	
	TCSA	CA	TCSA	CA	TCSA	CA
'Mirobalan'	17.36 a	1.57 a	19.27 a	1.60 a	16.51 b	1.30 d
'GF655/2'	- -	- -	- -	- -	13.95 b	0.88 bc
'St. Julien A'	19.32 a	1.63 a	20.16 a	1.44 a	16.20 b	1.12 cd
'Fereley'	- -	- -	- -	- -	13.55 b	0.95 c
'Wangenheim'	- -	- -	- -	- -	8.64 a	0.56 a
'WaVit'	- -	- -	- -	- -	7.12 a	0.63 b

**Note 1: Means are grouped using Duncan's test, different letters show significant difference (p=0.05)*

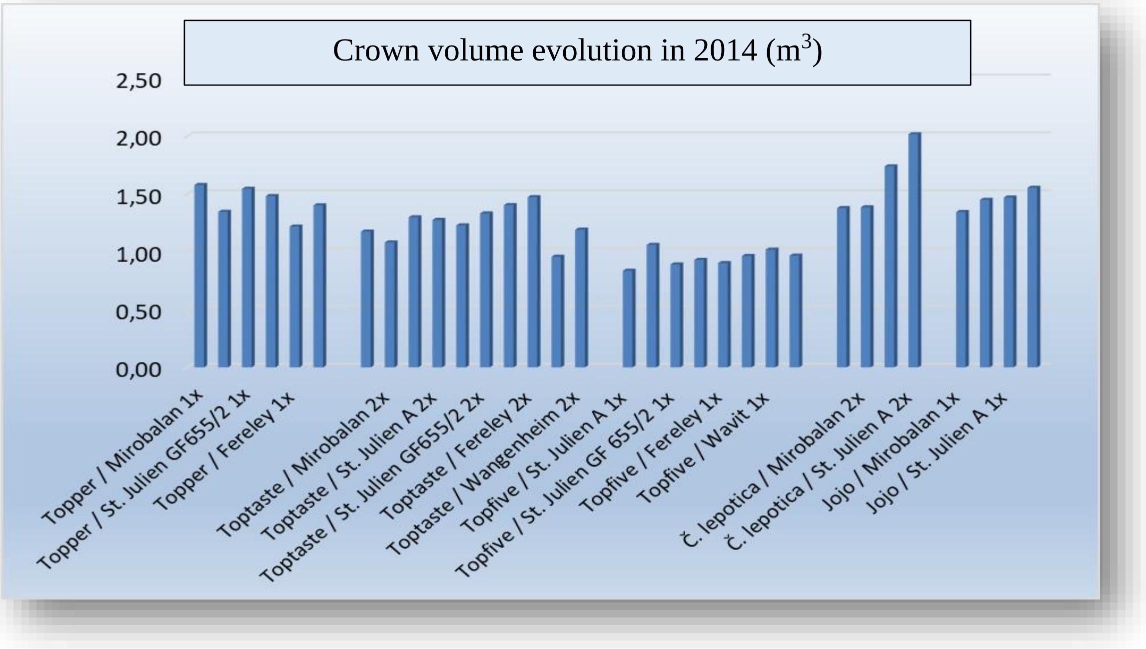


Figure 2: Crown volume evolution in 2014 (m^3)

Statistical analysis was calculated for 1x and 2x irrigation and performed for trunk cross-sectional area (TKT), with significant differences in growing years, but only for 'Č. lepotica' and 'Jojo' (Table 4).

Table 4: Evolution of trunk cross section area for irrigation (cm^2)

	TCSA 2012-2016		
’Č. lepotica’	Ö1	8.71	a
	Ö2	11.94	b
’Jojo’	Ö1	10.41	a
	Ö2	14.33	b

Note 1: Means are grouped using Duncan's test, different letters show significant difference (p=0.05)

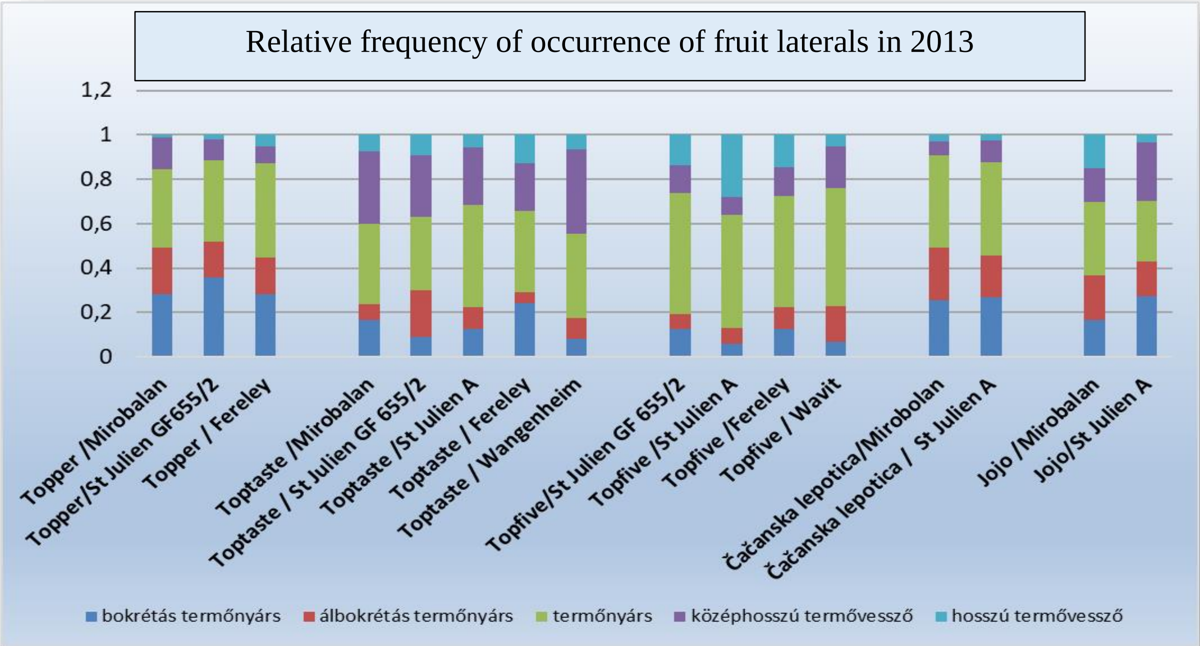
Vegetative growth - development and evolution of fruit laterals

Statistical analysis showed significantly different fruit laterals development for the varieties studied (Table 5). The varieties 'Topper' and 'Č. lepotica' were mainly grown on bouquets (47.44% and 47.13% respectively), 'Topfive' mostly on short fruiting laterals (52.9%), while 'Toptaste' had the highest percentage of long fruiting laterals (41.62%).On 'Topfive', the proportion of bouquets and bouquets spears are significantly different from the short fruit laterals and there is also a significant difference between the medium and long fruit lateral types.In the case of 'Č. lepotica', there was a significant difference between all types of fruiting parts, with 47.7% of the bouquets and bouquets spears , 41% of the short fruiting laterals and 11.3% of the long fruiting laterals.No significant difference was seen between the fruit laterals of 'Jojo' trees, but the proportion of short fruiting laterals was lower. No significant differences were found between the proportions of fruiting parts of the varieties in trees grown on different rootstocks. This characteristic is mainly determined by the variety (Table 5; Figure 3).

Table 5: Evolution of fruiting lateral types for each variety (%)

	Bouquets and boquets spears	Short fruiting laterals	Medium and long fruiting laterals
'Topper'	47.60 c	37.90 ab	14.50 a
'Toptaste'	21.90 a	36.50 ab	41.60 c
'Topfive'	17.30 a	52.80 c	29.90 b
'Č. lepotica'	47.70 c	41.00 b	11.30 a
'Jojo'	36.50 b	29.50 a	34.00 b

**Note 1: Means are grouped using Duncan's test, different letters show significant difference (p=0.05)*



3.Figure 1: Relative frequency of occurrence of fruit laterals in 2013; note: no statistical evaluation

The evolution of the development of fruiting parts according to varieties is also discussed in several Hungarian literatures (GONDA, 2010; SURÁNYI, 2019), but there is no literature on the quantitative proportions of fruiting parts either in Hungary or abroad. The rootstocks had a small effect on the development of the fruiting parts, with no significant differences. The formation of the fruiting part is a very important aspect for the yield formation assessment, both from a quantitative and qualitative point of view. Short fruiting laterals have been observed to produce relatively more fruit than medium or long fruiting laterals, and fruit quality is also more consistent on short and boquets. In our studies, bouquets and bouquets spears are present in 'Topper' and 'Č. lepotica', SURÁNYI (2019) reports the same for 'Ageni', 'Althann ringló', 'Späth Anna', 'Korai kék szilvá'. The tendency of plum trees to produce short fruiting laterals are also influenced by the time factor, with a higher proportion of short fruiting parts observed in the case of ageing trees. This statement is also supported by SURÁNYI (2019).

Generative capacity - turning trees into bearing

Turning to bearing is an important factor for economical cultivation and a quick return on investment. In our plantation, the cultivar 'Topper' already produced a significant yield in 2011, for the rootstocks 'Mirobalan' and 'St. Julien GF655/2', but not for 'Ferely'. (Table 6).

Table 6: Evolution of the Precocity Index (PI %, 2010-2012).

Rootsatocks	'Topper'	'Toptaste'	'Topfive'	'Č. lepotica'	'Jojo'	Mean of rootstock
'Mirobalan'	15.88 b	11.22 a	- -	3.43 a	8.15 a	9.67
'GF655/2'	12.54 b	13.50 a	2.47 a	- -	- -	9.50
'St. Julien A'	- -	12.48 a	1.19 a	2.85 a	4.06 a	5.15
Fereley'	4.60 a	6.28 a	1.68 a	- -	- -	4.19
'Wangenheim'	- -	12.62 a	- -	- -	- -	12.62
'WaVit'	- -	- -	7.62 b	- -	- -	7.62
Means of varieties	11.01	11.22	3.24	3.14	6.11	

**Note: Means are grouped using Duncan's test, different letters show significant difference (p=0.05*

The other varieties only produced significant yields in 2013 or later. For the different rootstocks, significant differences in annual yields were obtained for all varieties in the initial years (2010-2012). The variety 'Topper', which also gave a remarkable fruit yield in the initial years, produced significantly less fruit (0.72 kg/tree) on 'Fereley' rootstocks in 2010-2013 than 'GF655/2' (2.01 kg/tree) or 'Mirobalan' seedling rootstocks (2.33 kg/tree) (Table 21). For the variety 'Toptaste', there are also significant differences depending on the rootstock in the non-bearing years: the yields of trees from 'Mirobalan' and 'Wangenheim' rootstocks (0.35-0.41 kg/ha/year) were significantly lower compared to the other rootstocks 'St. Julien' and 'Fereley'. The variety 'Topfive', 'Č. lepotica' and 'Jojo' had low yields (0.07 - 0.73 kg/wood/year) in the early years without significant differences within the variety. In the fruiting years, the yield averages per tree of plum cultivars on the different rootstocks followed similar trends in proportion to the cumulative yields.

Some of the trees of the five varieties gave their first fruits in 2011. The yields from 2011 to 2016 are summarized: the cumulative yields per tree (CY) are given in Table 7. Statistical analysis showed no significant differences in the annual and cumulative yields of trees irrigated with single (1x) and double (2x) water doses, so the yield results of the two treatments are presented as a combined average of all live and fruiting trees. There were significant differences in the cumulative yields of trees of the same species but on different rootstocks, with different trends between species and rootstock. Exceptions are the rootstocks 'Wangenheim' and 'WaVit', where both 'Toptaste' and 'Topfive' gave the lowest cumulative yield. The 'Topper' variety gave the highest yield on the 'St. Julien GF655/2' rootstock (45.12 kg/tree), similar yields were measured on the 'Mirobalan' rootstock (42.20 kg/tree), while trees of the 'Topper'/'Fereley' combination produced significantly lower (27.29 kg/tree) cumulative yields. The next variety in terms of cumulative yield was 'Jojo', with trees on the 'St. Julien A' rootstock producing the highest yield (42.23 kg/tree), while the 'Mirobalan' rootstock had a significantly lower yield (31.21 kg/tree).For the 'Toptaste' variety, the highest cumulative yield per tree was obtained on the 'Fereley' rootstock (40.27 kg/tree), compared to significantly lower, medium cumulative yields on the 'St. Julien GF 655/2' and 'St. Julien A' rootstocks, while the lowest cumulative yields were observed on the 'Mirobalan' and 'Wangenheim' rootstocks.

The cumulative yield of trees of the variety 'Č. lepotica' on the rootstock 'St. Julien A' was significantly higher compared to those on the rootstock 'Mirobalan'. The cumulative yield of 'Topfive' was about half of the highest yielding rootstock combinations of the other cultivars, with no significant difference between the three medium rootstock trees ('St. Julien GF 655/2', 'St. Julien A' and 'Fereley'). On the other hand, yields were significantly lower (9.45 kg/tree) on the weak growth vigour rootstock 'WaVit'.

Table 7: Cumulative yields per tree 2011-2016.

Rootstocks	**Topper**	**Toptaste**	**Topfive**	**Č. lepotica**	**Jojo**	Means of rootstock
Mirobalan	42.20 b	14.65 ab	- -	30.08 a	32.21 a	29.79
GF655/2	45.12 b	23.79 bc	17.99 b	- -	- -	28.97
St. Julien A	- -	28.57 c	18.59 b	38.37 b	42.23 b	31.94
Fereley	27.29 a	40.27 d	19.83 b	- -	- -	29.13
Wangenheim	- -	9.89 a	- -	- -	- -	9.89
WaVit	- -	- -	9.45 a	- -	- -	9.45
Means of variety	38.20	23.43	16.47	34.23	37.22	

**Note 1: Means are grouped using Duncan's test, different letters show significant difference (p=0.05)*

The differences in fruit quality indicators (Table 8) basically reflect the differences between varieties, and the time of harvesting also influences some parameters, such as Brix. Thus, these are mainly reflected in the factors determining fruit quality. The differences between the rootstocks may be due to the fact that the vegetation of each variety was pushed slightly earlier or later by the rootstock, or the amount of fruit produced by a given graft combination. Fruit quality is significantly influenced by the quantity of fruit, the more fruit on the tree, the slower or more delayed the ripening.

Table 8: Fruit quality indicators (2013)

VARIETY	ROOTSTOCK	FRUIT WEIGHT (g)		BRIX (%)		FLESH FIRMNESS (kg/cm^2)		STONE WEIGHT (g)	
'Topper'	'Mirobalan'	28.78	ab	17.65	bc	1.39	de	1,.74	c
	'GF 655/2'	28.22	ab	16.54	a	1.39	de	1.70	bc
	'Fereley'	26.54	a	16.91	ab	1.40	de	1.71	bc
'Toptaste'	'Mirobalan'	40.76	c	25.09	i	1.53	fg	2.36	f
	'St. Julien A'	40.51	c	21.48	g	1.56	gh	2.46	g
	'GF655/2'	40.69	c	22.96	h	1.53	fg	2.48	g
	'Fereley'	40.45	c	23.29	h	1.54	fgh	2.45	g
	'Wangenheim'	39.81	c	22.70	h	1.45	ef	2.53	g
'Topfive'	'St. Julien A'	31.39	b	19.83	f	1.16	a	1.53	a
	'GF655/2'	30.68	b	19.28	ef	1.30	cd	1.51	a
	'Fereley'	30.91	b	18.13	cd	1.27	bc	1.53	a
	'WaVit'	30.77	b	19.11	ef	1.18	ab	1.64	b
'Č. lepotica'	'Mirobalan'	37.40	c	16.24	a	1.38	de	1.,75	c
	'St. Julien A'	40.67	c	16.12	a	1,.58	gh	1.78	c
'Jojo'	'Mirobalan'	39.70	c	18.72	de	1.52	fg	1.93	d
	'St. Julien A'	44.02	d	17.69	bc	1.64	h	2.10	e

**Note 1: Means are grouped using Duncan's test, different letters show significant difference (p=0.05)*

The mean fruit weight was partly typical of the varieties, with the 'Toptaste' variety yielding the largest fruit (35.79-45.44 g), with no significant difference between the different rootstock trees. Similar fruit size was obtained on trees of the cultivars 'Č. lepotica' and 'Jojo', but the fruit size was opposite on different rootstocks. The fruit of 'Č. lepotica' was significantly larger on the 'Mirobalan' rootstock, while the fruit of 'St Julien A' rootstock was significantly larger on 'Jojo'. Smaller fruit size (24.06-33.11 g) was obtained on the cultivar 'Topfive', where no significant difference was observed between the different rootstocks. Taking the mean, the 'Topper' cultivar had the smallest fruit, with no significant difference in fruit size between the different rootstocks. Fruit weight shows the differences between the varieties very well (Table 8), with a significant difference between them. Similarly, seed weight also reflects varietal characteristics. There is a significant difference in Brix and flesh firmness values among the rootstocks, but this could be explained by the non-uniform fruit ripening. It can be seen that the fruit weight is lower (28.78 g) for the 'Topper' variety than for the other varieties. 'Toptaste' stands out in terms of Brix value (Table 8) (25.09%). The other fruit quality indicators do not differ significantly for 'Mirobalan' rootstocks. The fruit quality of 'Toptaste' on different rootstocks. The fruit characteristics show a high similarity, i.e. there is no difference in the effect on fruit quality among the rootstocks.

4. NEW SCIENTIFIC RESULTS

1) Based on my results in container growing under plain conditions, the rootstocks can be categorized into three groups: 'Fereley' and 'Mirobalan' seedlings are very vigorous, 'St. Julien GF655/2' and 'St. Julien A' are medium vigorous, while 'Wangenheim' and 'WaVit' are weak. The varieties show clear differences in trunk thickness and crown sizes: 'Topfive' and 'Toptaste' are weak-growing, while 'Topper' is medium-growing, 'Čačanska lepotica' and 'Jojo' are strong-growing. My results on growth also confirm that the rootstock-variety combinations have individual behaviour.

2) We found that the proportions of fruiting part types are specific to the varieties, but that this characteristic of the varieties was not significantly influenced by the rootstocks. The 'Topper' and 'Čačanska lepotica' produce mainly bouquets and bouquets spears, whereas the 'Toptaste' variety is characterised by medium and long fruiting laterals cane.

3) The trees with different rootstocks become productive fruit and fruiting is significantly influenced by the rootstocks: 'St. Julien A' and 'St. Julien GF655/2' are more productive, which is independent of the growth characteristics of the develop the fruiting laterals. The 'Mirobalan' seedlings have medium productivity. Contrary to the experience abroad, 'Wangenheim' and 'WaVit' rootstocks had low yields. Values for fruit size and quality indicators showed variation in different rootstock-variety combinations, but no consistent rootstock effect was observed. It was found that fruit of the 'Toptaste' variety gave the highest Brix° values.

4) The two irrigation water levels did not give any significant growth difference in container-grown plants under plain conditions, except for 'Čačanska lepotica' and 'Jojo', where twice the water level gave a stronger growth. On the 'Fereley' rootstock, on the other hand, the double watering resulted in more tree mortality. This phenomenon needs further investigation in comparison with field conditions.

.

Bibliography

1. ACHIM, G., BOTU, I., BOTU, M., PREDA, S., BACIUET, A. (2010): Plum Rootstocks For Intensive Plum Culture. In: *Acta Hortculturae*874: 299-304 DOI: 10.17660/ActaHortic.2010.874.42
2. APÁTI, F. (2020): szóbeli közlés
3. BLAŽEK, J. és PISTÉKOVA, I. (2009): Preliminary Evaluation Results of New Plum Cultivars In A Dense Planting. Horticultural Science, 36(2) 45-54. DOI: 10.17221/3/2009-HORTSCI
4. BOTU, I., BOTU, M., ACHIM, G., BACIUET, A. (2010): Plum Culture In Romania: Present Situation And Perspectives. In: Acta Hortculturae. 874, 365-372 DOI: 10.17660/ActaHortic.2010.874.52. https://doi.org/10.17660/ActaHortic.2010.874.52
5. CZINEGE A. (2014): The study of the vigor of the rootstocks-plum variety combinations. In: Andrea, Ádámné Major; Lóránt, Kovács; Zsolt, Csaba Johanyák; Róbert, Pap-Szigeti (szerk.) *Proceedings of TEAM 2014 : 6th International Scientific and Expert Conference of the International TEAM Society*. Kecskeméti Főiskola GAMF Kar 499 p. pp. 68-70., 3 p.
6. FREUND, R.J., MOHR, D.L, WILSON, W.J. (2021): Statistical Methods; Academic Press.,
7. GONDA, I. (2010): Csonthéjas gyümölcsfák metszése. Debreceni Egyetem. Debrecen. 71.-72., 170-188.
8. GRAVÍTE, I. és KAUFMANE, E. (2017): Evaluation of German Plum Selections in Latvia. In: *Proceedings of the Latvian Academy of Science* 71(3), 166.-172. doi:10. 1515/prolas-2017-0028
9. GRYZB, Z. S., SITAREK, M., ROZPARA, E. (2010): Evaluation of Vigorous and Dwarf Plum Rootstocks in the High Density Orchard in Central Poland. In: F. Sottile Proceedings of the IX.th International Symposium on Plum and Prune Genetics, Breeding, and Pomology. Italy. In: Acta Hortculturae. 874:351-356.
10. HROTKÓ, K. (1999): Alanyhasználat a szilvatermesztésben. In: Hrotkó (szerk.): *Gyümölcsfaiskola*. Mezőgazda Kiadó, Budapest 482.-495. ISBN: 963-9239-30-5
11. HROTKÓ, K. ; MAGYAR, L ; KLENYÁN, T ; SIMON, G. (2002): Effect of rootstocks on growth and yield efficiency of plum cultivars. In: Acta Horticulturae 577, 105-110. DOI:10.17660/ActaHortic.2002.577.15
12. HROTKÓ, K., és MAGYAR, L. (2006/b): Evaluation of Rootstocks and in Row Spacing in Intensive Plum Orchard. Proceedings of International Conference on Perspectives in European Fruit Growing. In: Proceedings of Simpozion: Prezent şi perspectivă în cercetarea pomicolă. Cartea Universitară, Bucures. 31-32.
13. HROTKÓ, K., MAGYAR, L., SIMON, G. KLENYÁN, T. (1998): Effect Of Rootstocks On Growth Of Plum Cultivars In A Young Orchard. In: Acta Horticulturae 478, 95-98 DOI: 10.17660/ActaHortic.1998.478.13.
14. INTRIGLIOLO, D. S. és CASTEL, J. R; (2004): Conrinous Measurment of Plant and Soil Water Status for Irrigation Schedulling in Plum. In: *Irrigation Science*. 23: 93-102.
15. IVÁNYOSI SZABÓ A. és HOYK E. (2010): Kecskeméti táj, kecskeméti tájváltozások In: *Forrás* http://www.forrasfolyoirat.hu/upload/articles/1914/ivanyosi.pdf
16. JACOB, H. B. (2007): Twenty-five Years Plum Breeding in Geisenheim, Germany: Breeding Targets and Previous Realisations VIII. International Symposium on Plum and Prune Genetics, Breeding and Pomology. *Acta Horticulturae*734:341-346.
17. KAJTÁR-CZINEGE, A. (2018a): A Világon elterjedt szilvaalanyok botanikai csoportosítása. In:*Kertgazdaság*. 50(2) 5-16
18. KAJTÁR-CZINEGE, A. (2018b): Szilva alanyok hatása a ‘Toptaste’ szilvafajta növekedésére kecskeméti viszonyok mellett. Effects of the rootstocks on the vigour of the 'Toptaste' variety in Kecskemét. In: *Kertgazdaság* 50(1) 8-15.
19. KAJTÁR-CZINEGE, A., OSZTÉNYINÉ KRAUCZI, É., HROTKÓ, K. (2022): Growth Characteristics of Five Plum Varieties on Six Different Rootstocks Grown in Containers at Different Irrigation Levels. In: *Horticulturae* 2022, 8(9), 819; https://doi.org/10.3390/horticulturae8090819
20. KISS, É. (2005): Magyarország éghajlata Földrajzi atlasz. Pauz Westerman Könyvkiadó. Budapest. ISBN: 963-9432-07-5
21. KSH (2020, 2021): https://www.ksh.hu/mezogazdasag (u. letölt.: 2024 jan. 10.)
22. MELAND, M. (2010): Performance of six European plum cultivars on four plum rootstocks growing in a northern climate. In: Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 60 (4) 381-387. https://doi.org/10.1080/09064710903103917
23. MÉSZÁROS, M., KOSINA, J., LAŇAR, L., NÁMĚSTEK, J. (2015):Long-Term Evaluation Of Growth And Yield Of Stanley And Č. Lepotica Plum Cultivars On Selected Rootstocks. In: *Horticultural Science*, 42 (1) 22-28. DOI: 10.17221/192/2014-HORTSCI
24. MORENO, M. (2004). Breeding and Selection on Prunus Rootstocks at the Estacion Experiamental de Aula Dei. In: *Acta Horticulturae* 658, 519-528.

25. NEČAS, T., WOLF, J., ZEZULOVÁ, E., ONDRÁŠEKET, I. (2023): Evaluation of Nursery Traits in Japanese Plums on Five Different Rootstocks. In: Horticulturae 9(3) 318; https://doi.org/10.3390/horticulturae9030318
26. OMSZ (2022): (Országos Meteorológiai Szolgálat) (National Meteorological Service)., 'Magyarország éghajlata'. https://www.met.hu/
27. PEDERSEN, B.H. (2010): Early Performance Of Two European Plum Cultivars On Thirteen Plum Rootstocks. In: Acta Horticulturae. 874, 261-268 DOI: 10.17660/ActaHortic.2010.874.36ttps://doi.org/10.17660/ActaHortic.2010.874.36
28. PINOCHET, J. (2010): 'Replantpac' (Rootpac R) a Plum-almond Hybrid Rootstock for Replant Situations. In: *Horticultor Science* 45 (2), 299-301.
29. RADOVIĆ, M. M., MILATOVIĆ, D. P., ZEC, G. N., BOŠKOV, ĐORĐE D. (2022): The Influence Of Four Rootstocks On The Growth, Yield And Fruit Quality Of Two Plum Cultivars. In: A*cta Scientiarum Polonorum Hortorum Cultus*, 21(4), 75–81. https://doi.org/10.24326/asphc.2022.4.8
30. SOTTILE, F., BELLINI, E., NENCETTI, V., PEANO, C., PALARTA, U., PIRAZZINI, P., MEZZETTI, B. CAPOCASA, F. MENNONE, C. CATALANOET, L. (2010): Plum production in Italy: State of the art and perspectives. In: *Acta Horticulturae* 874: 25-34. DOI: 10.17660/ActaHortic.2010.874.2
31. SURÁNYI, D. (1980/b): A szilvatermesztés története In: Tóth E.– Surányi D. *Szilva*. Mezőgazdasági Kiadó, Budapest, 100-116.
32. SURÁNYI, D. (2006): A hajtásrendszer és a fenofázisai. In: SURÁNYI D. (Szerk.) Szilva. Mezőgazda Kiadó, Budapest. 131-144. p.
33. SURÁNYI, D. (2019): A házi szilva. Magyarország kultúrflórája. Szent István Egyetemi Kiadó. Gődöllő.
34. SZABÓ, Z., (2001): Szilva In: G Tóth M. (2001) Gyümölcsészet Primom Nyíregyháza 216-233.
35. TÓTH, E., és SURÁNYI, D. (1980/a): Szilva Mezőgazdasági Kiadó. Budapest.
36. WERTHEIM, S., és KEMP, H. (1998): A search for a Dwarfing Plum Rootstock . In: *Acta Horticulturae* 478, 137-141.

Scientific publications on the topic (MTMT2):

PUBLICATIONS

Article with Impakt Factor

1. Kajtár-Czinege, A., Osztényiné Krauczi, É. & Hrotkó, K. Cropping and Fruit Quality of Plum (Prunus domestica) Varieties on Different Rootstocks in a Young Orchard. Erwerbs-Obstbau (2023). https://doi.org/10.1007/s10341-023-00992-8
2. Kajtár-Czinege, Anikó ; Krauczi, Éva Osztényiné ; Hrotkó, Károly (2022) Growth Characteristics of Five Plum Varieties on Six Different Rootstocks Grown in Containers at Different Irrigation Levels. HORTICULTURAE 8 : 9 p. 819 , 14 p. (2022), https://doi.org/10.3390/horticulturae8090819

Publications in peer-reviewed journals (MTA list)

1. KAJTÁR-CZINEGE ANIKÓ1, OSZTÉNYINÉ KRAUCZI ÉVA2, HROTKÓ KÁROLY3 : **Szilvafajták és alanyok növekedése, valamint termőrész-képzése konténeres termesztésben, kétféle öntözéssel.** KERTGAZDASÁG (megjelenés alatt)
2. Kajtár-Czinege, Anikó ; Osztényiné, Krauczi Éva ; Hrotkó, Károly**. Szilvafajták terméshozása különböző alanyokon**; KERTGAZDASÁG 55 : 3 pp. 33-49. , 17 p. (2023)
3. Kajtár-Czinege, Anikó; **A világon elterjedt szilvaalanyok botanikai csoportosítása;** KERTGAZDASÁG (2018) 50 : 2 pp. 5-16. , 12 p. (2018)
4. Kajtár-Czinege, Anikó; **Szilvaalanyok hatása a 'Toptaste' szilvafajta növekedésére kecskeméti viszonyok mellett;** KERTGAZDASÁG (2018) 50 1 pp. 8-15. , 8 p. (2018)
5. Kajtár-Czinege, Anikó; **A szilva művelési rendszereinek fejlődése Magyarországon;** KERTGAZDASÁG 48 : 2 pp. 20-27. , 8 p. (2016)
6. Czinege, Anikó; **Szilva (Prunus domestica) alany-nemes kombinációk fenofázisainak alakulása 2011-2013**; ACTA AGRARIA DEBRECENIENSIS / AGRÁRTUDOMÁNYI KÖZLEMÉNYEK : 55 pp. 25-29. , 5 p. (2014);
7. Czinege, Anikó; **Szilvafajták fenofázisainak alakulása 2012-ben;** ACTA AGRARIA DEBRECENIENSIS / AGRÁRTUDOMÁNYI KÖZLEMÉNYEK : 51 pp. 93-96. , 4 p. (2013)
8. Czinege, Anikó ; Nyéki, József ; Soltész, Miklós; **Különböző szilva alany-nemes kombinációk vegetatív hajtásnövekedése és generatív teljesítménye;** ACTA AGRARIA DEBRECENIENSIS / AGRÁRTUDOMÁNYI KÖZLEMÉNYEK : 47 pp. 25-29. , 5 p. (2012)
9. Czinege, A ; Soltész, M ; Nyéki, J ; Szabó, Z; **The use of rootstocks for European (Prunus domestica) and for Japanese (Prunus salicina) plums**.; INTERNATIONAL JOURNAL OF HORTICULTURAL SCIENCE 18 : 2 pp. 7-14. , 8 p. (2012)
10. Czinege, Anikó**; Szilva (Prunus domestica) alany-nemes kombinációk növekedése;** KERTGAZDASÁG 44 : 4 pp. 8-15. , 8 p. (2012)

OTHER PUBLICATIONS AND PROFESSIONAL ACTIVITIES

Conference Communications(*„full paper" = min 4 pages*)

11. Kajtár-Czinege, Anikó; Kapcsándi, Viktória ; Székelyhidi, Rita ; Németh-Torkos, Anett ; Hanczné, Lakatos Erika; **Cukor- és sav összetevők vizsgálata különböző szilvafajtákban**; GRADUS 7 : 2 pp. 53-58. , 6 p. (2020) ISSN 2064-8014.
12. Kajtár-Czinege, Anikó; Pető, Judit; **Ásványi-anyag tartalom alakulása a szilva gyümölcsében**; GRADUS 7 : 2 pp. 32-36. , 5 p. (2020) ISSN 2064-8014.
13. Kajtár-Czinege, Anikó; **Tenyészedényes szilvafajták fenofázisainak alakulása** Kecskeméten (2011-2016); GRADUS 4 : 2 pp. 295-302. , 8 p. (2017) ISSN 2064-8014.
14. Kajtár-Czinege, Anikó; **Szilva alany-nemes kombinációk generatív teljesítménye kecskeméten 2016-ban** GRADUS 3 : 2 pp. 321-326. , 6 p. (2016) ISSN 2064-8014.
15. Czinege, Anikó; **Szilva-alany nemes kombinációk növekedési erélyének vizsgálata;** GRADUS 1 : 2 pp. 20-25. , 6 p. (2014) ISSN 2064-8014.
16. Czinege, Anikó; **Szilva alany-nemes kombinációk terméshozama;** GRADUS 1 : 2 pp. 26-30. , 5 p. (2014)
17. Czinege, Anikó ; Pető, Judit; **Szilvafajták savtartalmának alakulása 2012-2013-ban;** GRADUS 1 : 1 pp. 257-261. , 5 p. (2014) ISSN 2064-8014.
18. Czinege, Anikó ; Soltész, Miklós ; Nyéki, József **Tenyészedényes szilvafajták– és alanykombinációik fenofázisai (2011-2013);**GRADUS 1 : 1 pp. 251-256. (2014) ISSN 2064-8014.