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ROOT SYSTEM ARCHITECTURE IN 'VÂLCEAN' VARIETY (*PRUNUS DOMESTICA* L.) DEPENDING ON ROOTSTOCKS AND TRUNK

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Abstract

European plum (Prunus domestica) is one of the fruit tree species cultivated around the world for fresh consumption, prunes (dried fruits), smoked plums, in jams or jellies, juices, plum purée as a baby food, liqueur, distilled into a 'brandy' or spirits, having also a large potential for rural and metropolitan zones landscaping. The experiment was conducted during 2020 year to individual trees in a randomized compete block design in four replicate blocks (10 plum trees/block) within a private plum orchard in the proximity of Craiova city, Dolj county, Romania and included 'Vâlcean' plum variety and four rootstocks (Oteşani 8, Pixy, Miroval, Roşior văratic). The study assessed the architecture of root system, in thickness and variable depths, at 1 and 2 meters away from trunk. For 0-3 mm root thickness category Miroval rootstock has developed the highest roots number (104 roots) at 1m distance from the trunk, while at 2 m trunk distance the best root system development was noticed in Roşior văratic rootstock (58 roots). Among all plum rootstocks included in the experiment Miroval had the most performant root system.

Key words*:* architecture, *Prunus domestica*, rootstock, root, plum variety.

INTRODUCTION

The European Plum (*Prunus domestica*) has been known in Europe for more than two thousand years, being originated in eastern Europe or western Asia around the Caucasus and the Caspian Sea. Nowadays, aside other spontaneous and cultivated plants and trees in temperate regions, plums are cultivated in many European countries, being suitable to be grown in light (sandy), medium (loamy) and heavy (clay) soils over a wide range of climatic conditions (Răduțoiu et al., 2012; Bonciu, 2019b; Butac et al., 2019; Cosmulescu et al., 2020; Gaši et al., 2020; Răduţoiu, 2020; Răduțoiu and Cosmulescu, 2020; Butac et al., 2021; Durău et al., 2021; Nesheva et al., 2021, Răduțoiu and Băloniu, 2021; Velea et al., 2021).

Within hexaploid European plum (*Prunus domestica*) there are many varieties and hybrids, varying from red, purple to yellow and green skin or pulp, being suitable for fresh consumption, dried prunes, smoked plums, jams or jellies, juices, plum purée, liqueur, spirts (brandy). Plums are also a great source of vitamins (vitamin C, A, K) and minerals (Ca, Mg, K, P) and other phytochemicals influencing human and preventing many diseases (heart diseases, Alzheimer`s disease, lung and oral cancer, reducing blood sugar, protecting bones, muscular degeneration, improving memory) (Arjmandi et al., 2002; Byrne et al., 2009; Stacewicz-Sapuntzakis, 2013; Birwal et al., 2017; Wallace, 2017; DiNardo et al., 2018; Gill et al., 2019; Mohammadi-Moghaddam et al., 2020 a, b). However, the nutraceutical effects of food or parts of food were underlined previously by many authors, being of great importance nowadays (Lever et al., 2015; Igwe and Charlton, 2016; Sadler, 2016; Soare et al., 2016; Chiu et al., 2017; Shamloufard et al., 2017; Mirza et al., 2018; Al-Dashti et al., 2019; Alsolmei et al., 2019; Tomić et al., 2019; Bonciu, 2020a; Khorrami et al., 2020; Dodier et al., 2021). Despite breeding progress, nutritional components in fruits, vegetables and field crops are affected by abiotic and biotic constrainers (Saleem et al., 1970; Labusca et

al., 2012; Popa et al., 2013; Bonciu, 2018; Bonciu, 2019a; Bonciu, 2019c; Bonciu, 2020b, Cotuna et al., 2020; Paraschivu et al., 2020; Bonciu et al., 2021; Paraschivu et al., 2021).

Among all European Union countries, Spain is the main supplier, Germany is the largest destination market for fresh imported plums, while France is one of the main plum-consuming ones.

Most plums imported by these countries are originated from Romania which is, accordingly to production statistics, the largest plum producer in Europe with over 500.000 tons annually and the highest yield in 2018 year (830.000 tons) (CBI, 2020).

Worldwide the rootstocks are essential in modern breeding programs due to their capability of adapting a plum variety to different environmental conditions, cultural practices and to improve the scion tolerance to biotic (pests and pathogens) and abiotic constrainers (high soil salinity, drought, heat, etc.) (Meland, 2010; Assimakopoulou et al., 2011; Font i Forcada et al., 2020).

On the other hand, the rootstocks have a great impact on plum trees vigour, canopy structure, fruit maturation period, yield and fruits quality (Beckman and Lang, 2003; Grzyb and Rozpara, 2012; Sidorova et al., 2018; Milatović et al., 2019; Bouzari et al., 2021; Gerbi et al., 2021; Hamdani et al., 2021; Stefanova et al., 2021).

In Romania the plum breeding activity was oriented towards obtaining new cultivars and rootstocks as result of specific ecological conditions (climatic change and poor soils) in various areas, beside high productivity, fruit quality, tolerance to Sharka disease (*Plum Pox Virus*). The plum rootstock assortment contains Romanian bred ones, which are more adapted to the specific soil conditions from the plum growing areas then the foreign rootstocks (Botu et al., 2012a; Botu et al., 2012b; Butac et al., 2013; Butac et al., 2019).

Rapid progress in breeding has leaded to a large number of valuable rootstocks, but still many nurseries are propagating only the most popular ones: Myrobalan type ones (several selections such as: 'Miroval', 'Mirobolan C163', 'Mirobolan galben', etc); 'Roşior văratec' and 'Oteşani 8' (*P. domestica*), 'Oteşani 11' and 'Voineşti B' (*P. insititia*).

Over 85% of the plum trees sold in Romania are grafted on Myrobalan. Other rootstocks like: 'Pixy', 'St. Julien A', 'Rival', 'BN 4Kr' are rarely used.

Among the factors that increase plum trees demand include new varieties and rootstocks, population growth, products that meet healthy lifestyle, food diversification and rising incomes.

The present study aim was to assess the architecture of root system of Vâlcean plum variety and four rootstocks (Oteşani 8, Pixy, Miroval, Roşior văratic) in the agro-environmental conditions of Dolj county, Romania.

MATERIALS AND METHODS

The experiment was conducted during 2018-2020 to individual plum trees in a compete block design in four replicate blocks (10 plum trees/block) within a private plum orchard in the proximity of Craiova city, Dolj county, Romania and included 'Vâlcean' plum variety and four rootstocks (Oteşani 8, Pixy, Miroval, Roşior văratic), resulting four biosystems graft/rootstock:Vâlcean/Oteşani8,Vâlcean/Pixy, Vâlcean/Miroval şi Vâlcean/Roşior văratic.

The orchard was grown on brown reddish silt loan soil (pH = 5.5-6.6, 0.78-2.35% organic matter, high potassium and phosphorus rate), under non-irrigation conditions, at a planting distance of 4 m between rows x 4 m between trees on row.

For the assessment of the root's development pattern of each variety/rootstock biosystem it was used the Oscamp-Dragavţev within a soil profile of 100 x 100 m size, which was oriented at the trunk at the distance of 1m and 2 m. Depending on their thickness, the roots were divided into 3 categories: roots up to 3 mm in diameter; roots with a diameter between 3 to 5 mm; roots with a diameter of more than 5 mm.

It was quantified the number of branch roots and their ramification capacity on the depth interval of 10 to 10 cm, within 100 cm.

The primary recordings were processed through the use of biometrics indicators and synthesized in a quantified form summarizing the main characteristics of the root system.

The biometrical measurements of the tree-roots were performed by the metric frame. The assessment of development of the biosystems variety/rootstock pattern was done take into consideration: canopy size (CS), tree height (TH) and canopy volume (CV).
The experimental data were calculated and analysed, using MS Office 2019 facilities, while the structure of variability of the assessed traits were statistically processed by Duncan's multiple range test.

RESULTS AND DISCUSSIONS

Worldwide consistent research on the interaction variety/rootstock has been done previously on different fruit tree species (Cichi et al., 2008; Mazilu et al., 2018; Cichi and Cichi, 2019; Santana et al., 2020; Shahkoomahally et al., 2020; Ntanos et al., 2021; Shahkoomahally et al., 2021). The proper choice of the rootstock and scion combination is probably the most important factor of the plum cultivation success.
Thus, the experiment results showed clear that rootstock had a significant effect on tree growth traits.
The assessment of the root's development pattern for roots between 0-3 mm in diameter which were oriented at the trunk distance of 1 m, on different soil depths
Roots with a diameter between 0-3 mm were developed on all soil depths for Miroval and Roşior văratic rootstocks, while they missed on the soil depths 50-60 cm, 80-90 cm, 90-100 cm for Oteşani 8 rootstock and on 90-100 cm soil depth for Pixy rootstock (Figure 1).

Figure 1. Aspects regarding the root system (0-3 cm) at the distance of 1 m of the trunk on different soil depths (original photo Ciobanu Andi)

On the soil 0-100 cm depth interval, the roots were more developed for Miroval rootstock (104 roots), followed by those of Pixy rootstock (72 roots), Roşior văratic (64 roots) and Oteşani 8 (48 roots).
As 0-3 cm roots assessed for all experimented rootstocks, approximatively 72% were spread over the soil depth range 10-40 cm at the trunk distance of 1 m (Table 1).

Table 1. Roots between 0-3 mm in diameter oriented at the trunk distance of 1m, on different soil depths

Rootstock Soil depth range	Oteşani 8	Pixy	Miroval	Roşior văratic	Average	Percent (%)
0-10	3	6	14	6	7,25	10,06
10-20	11	14	25	14	16,00	22,22
20-30	19	10	18	12	14,75	20,49
30-40	11	13	20	12	14,00	19,46
40-50	2	12	8	6	7,00	9,72
50-60	0	8	7	5	5,00	6,94
60-70	1	4	4	2	2,75	3,82
70-80	1	3	4	3	2,75	3,82
80-90	0	2	2	2	1,50	2,08
90-100	0	0	2	2	1,00	1,39
TOTAL	48	72	104	64	72,00	100

The assessment of the root's development pattern for roots between 0-3 mm in diameter which were oriented at the trunk distance of 2 m, on different soil depths
At the trunk distance of 2 m the highest number of the roots with 0-3 mm in diameter were observed for Roşior văratic rootstock (58 roots), while the lowest roots number were developed by Pixy rootstock (49 roots).
Oteşani 8, Pixy and Miroval rootstocks developed roots on the whole soil depth interval (1-100 cm) (Figure 2).

Figure 2. Aspects regarding the root system (0-3 cm) at the distance of 2 m of the trunk on different soil depths (original photo Ciobanu Andi)

Roşior văratic rootstock developed 0-3 mm roots only to 70 cm soil depth. As 0-3 cm roots assessed for all experimented rootstocks, approximatively 77% were spread over the soil depth range 0-50 cm at the trunk distance of 2 m (Table 2).

Table 2. Roots between 0-3 mm in diameter oriented at the trunk distance of 2 m, on different soil depths

Rootstock Soil depth range	Oteşani 8	Pixy	Miroval	Roşior văratic	Average	Percent (%)
0-10	2	8	2	8	5,00	9,48
10-20	11	11	7	16	11,25	21,33
20-30	11	11	5	14	10,25	19,43
30-40	11	2	13	7	8,25	15,64
40-50	6	5	9	4	6,00	11,37
50-60	4	3	5	4	4,00	7,58
60-70	2	2	4	2	2,50	4,74
70-80	1	2	3	0	1,50	2,85
80-90	1	2	4	1	2,00	3,79
90-100	1	3	2	2	2,00	3,79
TOTAL	50	49	54	58	52,75	100

The assessment of the root's development pattern for roots between 3-5 mm in diameter which were oriented at the trunk distance of 1m, on different soil depths

At the trunk distance of 1 m the roots number (3-5 mm in diameter) was limited for all rootstocks. Thus, for Oteşani 8 and Roşior văratic rootstocks only one root was developed for each soil depth interval (0-10cm, 10-20 cm, 30-40 cm), while for Pixy it was noticed for 10-20 cm, 40-50 cm, 50-60 cm soil depths (Figure 3).

Figure 3. Aspects regarding the root system (3-5 cm) at the distance of 1 m of the trunk on different soil depths (original photo Ciobanu Andi)

For Miroval rootstock one root of 3-5 mm was developed on the 10-20 cm soil depth and other one on the 20-30 cm soil depth interval. To the four rootstocks it was observed an average of 2.75 roots developed, most of them being observed on the 10-20 cm soil depth interval (36.37%) (Table 3).

Table 3. Roots between 3-5 mm in diameter oriented at the trunk distance of 1 m, on different soil depths

Rootstock Soil depth range	Oteşani 8	Pixy	Miroval	Roşior văratic	Average	Percent (%)
0-10	1	0	0	1	0,50	18,18
10-20	1	1	1	1	1,00	36,37
20-30	0	0	1	0	0,25	9,09
30-40	1	0	0	1	0,50	18,18
40-50	0	1	0	0	0,25	9,09
50-60	0	1	0	0	0,25	9,09
60-70	0	0	0	0	0	0
70-80	0	0	0	0	0	0
80-90	0	0	0	0	0	0
90-100	0	0	0	0	0	0
TOTAL	3	3	2	3	2,75	100

The assessment of the root's development pattern for roots between 3-5 mm in diameter which were oriented at the trunk distance of 2 m, on different soil depths

At the trunk distance of 2 m, the rootstocks Oteşani 8 and Pixy developed two roots each one, as fallows: Oteşani 8 had one root for every soil depth interval of 40-50 cm and 80-90 cm, while Pixy had one root for every soil depth interval of 40-50 cm and 60-70 cm (Figure 4).

Figure 4. Aspects regarding the root system (3-5 cm) at the distance of 2 m of the trunk on different soil depths (original photo Ciobanu Andi)

At a distance of 2 m from the trunk the most roots were observed to Miroval rootstock, two roots were developed at soil depth of 30-40 cm (2 roots) and soil depth of 40 -50 cm (1 root).

For the rootstock Roşior văratic no roots were observed for the whole soil depth interval (0-100 cm).

For all rootstocks it was observed an average of 1,75 roots of 3-5 mm, most of them being developed at 40-50 cm soil depth (Table 4).

Table 4. Roots between 3-5 mm in diameter oriented at the trunk distance of 2 m, on different soil depths

Rootstock Soil depth range	Oteşani 8	Pixy	Miroval	Roşior văratic	Average	Percent (%)
0-10	0	0	0	0	0	0
10-20	0	0	0	0	0	0
20-30	0	0	0	0	0	0
30-40	0	0	2	0	0,50	28,57
40-50	1	1	1	0	0,75	42,85
50-60	0	0	0	0	0	0
60-70	0	1	0	0	0,25	14,29
70-80	0	0	0	0	0	0
80-90	1	0	0	0	0,25	14,29
90-100	0	0	0	0	0	0
TOTAL	2	2	3	0	1,75	100

The assessment of the root's development pattern for roots up to 5 mm in diameter which were oriented at the trunk distance of 1 m, on different soil depths

At a distance of 1 m from the trunk, all rootstocks included in the experiment developed at least one root up to 5 mm in diameter. A significant number of roots (9 roots) was developed by Miroval rootstock on soil depth of 0-30 cm (Figure 5).

Figure 5. Aspects regarding the root system up to 5 mm at the distance of 1 m of the trunk on different soil depths (original photo Ciobanu Andi)

For Pixy rootstock two roots were developed on soil depth of 10-20 cm and three roots on soil depth pf 40-50 cm.

For all rootstocks an average of 5 roots were developed on the soil depth interval of 10-20 cm. None of the rootstocks developed roots on depths up to 70 cm (Table 5).

Table 5. Roots up to 5 mm in diameter oriented at the trunk distance of 1 m, on different soil depths

Rootstock Soil depth range	Oteşani 8	Pixy	Miroval	Roşior văratic	Average	Percent (%)
0-10	0	0	3	0	0,75	15,00
10-20	1	2	3	2	2,00	40,00
20-30	1	0	3	0	1,00	20,00
30-40	1	0	0	0	0,25	5,00
40-50	0	3	0	0	0,75	15,00
50-60	0	0	0	0	0	0
60-70	1	0	0	0	0,25	5,00
70-80	0	0	0	0	0	0
80-90	0	0	0	0	0	0
90-100	0	0	0	0	0	0
TOTAL	4	5	9	2	5,00	100

The assessment of the root's development pattern for roots up to 5 mm in diameter which were oriented at the trunk distance of 2 m, on different soil depths

At a distance of 1 m from the trunk, only Oteşani 8 rootstock developed 3 roots, one on the soil depth of 20-30 cm and two roots on the soil depth of 30-40 cm (Figure 6 and Table 6).

Figure 6. Aspects regarding the root system up to 5 mm at the distance of 2 m of the trunk on different soil depths (original photo Ciobanu Andi)

Table 6. Roots up to 5 mm in diameter oriented at the trunk distance of 2 m, on different soil depths

Rootstock Soil depth range	Oteşani 8	Pixy	Miroval	Roşior văratic	Average	Percent (%)
0-10	0	0	3	0	0,75	15,00
10-20	1	2	3	2	2,00	40,00
20-30	1	0	3	0	1,00	20,00
30-40	1	0	0	0	0,25	5,00
40-50	0	3	0	0	0,75	15,00
50-60	0	0	0	0	0	0
60-70	1	0	0	0	0,25	5,00
70-80	0	0	0	0	0	0
80-90	0	0	0	0	0	0
90-100	0	0	0	0	0	0
TOTAL	4	5	9	2	5,00	100

The biometric parameters assessed during 2018-2020 varied significantly among the experimented biosystems rootstock/variety. Thus, the highest value of canopy diameter and canopy volume were recorded by the biosystem rootstock/variety Vâlcean/Miroval (399 cm), while Vâlcean/Oteşani 8 was less developed (297 cm), respectively 47 m^3 and 21 m^3. Also, the highest plum trees were those that used Pixy and Miroval rootstocks (457 cm) (Table 7).

Among all plum rootstocks included in the experiment Miroval had the most performant root system and together with Vâlcean plum variety emphasized the highest biometric parameters for the assessed period.

Table 7. The biometric parameters of rootstocks/ Vâlcean variety biosystem for period 2018-2020

No	Variety/ rootstock	Biometric parameters			
		Canopy diameter (cm)	Tree height (cm)	Canopy volume (m^3)	Degree of space used (%)
1.	VÂLCEAN/ OTEŞANI 8	297b	383b	21b	43,2b
2.	VÂLCEAN/ PIXY	364a	456a	40a	65,0a
3.	VÂLCEAN/ MIROVAL	399a*	457a	47a	78,1a
4.	VÂLCEAN/ ROŞIOR VĂRATIC	334b	391a	28b	54,7b
Average		349	422	34	59,7

**Mean values followed by a different letter show a statistically significant difference by Duncan's multiple range test ($p<0.05$).*

CONCLUSIONS

The present study was carried out to assess the architecture of root system of Vâlcean plum variety and four rootstocks (Oteşani 8, Pixy, Miroval, Roşior văratic) in the agro-environmental conditions of Dolj county, Romania. The root system and biometric parameters (canopy size, tree height, canopy volume) were strongly influenced by genetic background of rootstock and environmental conditions. Both rootstock and plum variety have been found to influence roots and tree growth. Thus, the highest roots number were developed for 0-3 mm thickness category and it was observed to Miroval rootstock (104 roots) at 1m distance from the trunk, while at 2 m trunk distance the best root system development was noticed in Roşior văratic rootstock (58 roots). The best value of canopy diameter (399 cm) and canopy volume (21m^3) were recorded by the biosystem rootstock/variety Vâlcean/Miroval. Also, the highest plum trees were those that used Pixy and Miroval rootstocks due to their best root system development.

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