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Evaluation of plum rootstock-scion combinations in a young orchard

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Abstract
The aim of our study was to compare the growth vigour of three plum cultivars grafted onto four different rootstocks. The vegetative characteristics of rootstock-scion combinations can determine, along with other factors, planting density. Informed decisions regarding tree spacing are needed in commercial orchards to increase profitability, and the use of rootstocks which induce a weaker vigour in cultivars can allow for intensive orchard management. We measured trunk cross-sectional area (TCSA), total volume of shoot growth and canopy volume. The trees were planted in a low nutrient content, sandy soil. Based on the first two years of results 'St Julien A' proved to dwarfing, while 'Marianna 2624' exceled in its adaptability and drought resistance compared to myrobalan rootstocks in these conditions.

1 Introduction

The steady decrease and stagnation of plum production in Hungary has been ongoing for decades. Low yields per hectare and extensive production technologies are frequent [1] [2]. A potential avenue for improvement could be the usage of new rootstocks and cultivars and the spread of intensive orchard management techniques. These combined could lead to earlier fruiting, higher yields per hectare, increased ratio of export quality fruits and improved labor efficiency [3].

The production share of traditional Hungarian plum cultivars has been decreasing for decades. Their biggest drawback is susceptibility to plum pox virus (PPV). As is the case of 'Besztercei' plum and its selections, which cannot be produced economically despite their excellent fruit characteristics [3]. Susceptible varieties suffer from decreased fruit weight and quality coupled with early fruit fall [4]. Newer cultivars brought in from abroad have greater virus tolerance and potentially better production qualities. Varieties from the research institute at Čačak ('Cacanska lepotica') and from the US ('Stanley') make up the largest share of production, while newly bred German cultivars are increasing in popularity [1]. Three German, plum pox virus tolerant cultivars were chosen for the experiment, 'Topend Plus', 'Juna' and 'Haroma'.

Rootstock usage can be just as important as selecting a suitable variety in fruit production. Rootstocks can influence vigour, precocity, fruit quality, resistance against pests and diseases. The primary use of them is to reduce tree sizes and allow for denser planting [5]. Rootstocks which induce medium growth can be suitable for intensive plum orchards with proper maintenance and care. In Hungary, the majority of harvested plums are used in processing and are grown on large, open center trees. This meant little desire to use rootstocks other than traditional myrobalan seedlings,

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which provide strong growth [6]. For decades selections of *Prunus cerasifera* seedlings were propagated almost exclusively [7]. Recently other rootstock varieties are being used by nurseries, like *Prunus insititia* ('St. Julien GF655/2') and *Prunus domestica* ('WaVit', Wangenheim') selections but myrobalan remains the favourite [8] [9]. We chose the myrobalan selection 'C. 162' as a control in our experiment, which we compared to 'Myrobalan 29 C', 'Marianna 2624' (*Prunus cerasifera x Prunus munsoniana*) and 'St. Julien A' (*Prunus insititia)*.

The seedling selection 'C. 162' provides strong growth with potentially higher productivity than medium strength or dwarfing rootstocks, while being less productive compared to other strong rootstocks in unirrigated conditions [10]. 'Myrobalan 29 C' provides strong and uniform growth with good adaptability to different soil and moisture conditions, while also having some tolerance to soil pests and diseases [11] [12]. Its productivity is close to myrobalan seedlings [13]. 'St. Julien A' has weaker growth compared to myrobalan seedlings but the productivity of cultivars grafted onto it can also be lower or higher [14] [15]. It is susceptible to drought and frost [9]. 'Marianna 2624' provides a strong growth comparable to myrobalan seedlings with a similar productivity as well [13]. It has a great adaptability to different soil and moisture conditions, with exceptional drought tolerance and recovery, while also providing some resistance to different soil pests and diseases [12] [16].

2 Material and Method

The trees were planted in the fall of 2023 with a spacing of 5x2,18 meters. The sandy soil of the experimental plot has low nutrient content and organic matter. We put 2 kg of granular cow manure fertilizer in each of the planting holes. The trees were watered using drip irrigation and the area under them kept clean from weeds. Each combination was made up of 12 trees at the start of the experiment except one, they are shown in Table 1. The trees were pruned to a slender spindle system.

Table 1. Planted rootstock-scion combinations

	'Topend Plus'	**'Juna'**	**'Haroma'**
Myrobalan seedling ('C. 162')	X	X	X
'St. Julien A'	X	X	X
'Marianna 2624'	X	X	X
'Myrobalan 29 C'	X (13 trees)	-	-

In the first two years we compared the vegetative growth and vigour of the ten combinations planted. We measured the trunk diameter of all the trees 40 cm high from ground level in the fall of 2023 after planting, in 2024 after one year and in 2025 after the second vegetation period. The trunk cross-sectional area (TCSA) was calculated from the diameter (d) using the formula (1).

$$\left(\frac{d}{2}\right)^2 \times \pi \tag{1}$$

Total volume of shoot growth was measured in late summer in both 2024 and 2025. In 2024 all one-year-old shoots of each tree were measured and were added together by trees. In 2025 we chose a branch on each tree on which we measured every shoot grown in that year. We added these together and calculated a total shoot growth for each tree based on the branch's size compared to the whole canopy.

For the canopy volume we measured three dimensions on each tree both in the fall of 2024 and 2025. The first two dimensions were the length and width of the canopy. The former being the spread of the lower branches parallel to the rows. The latter the spread of the trees perpendicular to the rows. The last one was the height of the trees measured from the starting point of the lowest branch on the trunk to the top of the highest shoot. The canopy volume was calculated from the three measurements using the equation (2).

$$\frac{\frac{Length}{2} \times \frac{Width}{2} \times \pi \times Height}{3} \tag{2}$$

Using these parameters we could compare the combinations. The measured data was typed into Excel and analyzed statistically using SPSS. The first and last tree of each row was excluded from the analysis. We assessed the homogeneity of variance using Levene's test and tested for normality using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. A One-Way ANOVA was used, and we differentiated the means of the combinations using Duncan's post-hoc test.

3 Results

3.1 Trunk cross-sectional area (TCSA)

There were significant differences in the average TCSA-s of the ten combinations after planting (Figure 1). Rootstock combinations of 'Topend Plus' were close to uniform in width except for 'Topend Plus'/'Myrobalan 29 C', which was slightly thinner. In the case of the cultivar 'Juna' trees on myrobalan seedlings and on 'Marianna 2624' were equal in size, while those on 'St. Julien A' were significantly larger. The opposite was true for 'Haroma', were trees grafted onto 'St. Julien A' were the thinnest, while the rootstock 'Marianna 2624' yielded the largest TCSA, with myrobalan seedlings between the other two.

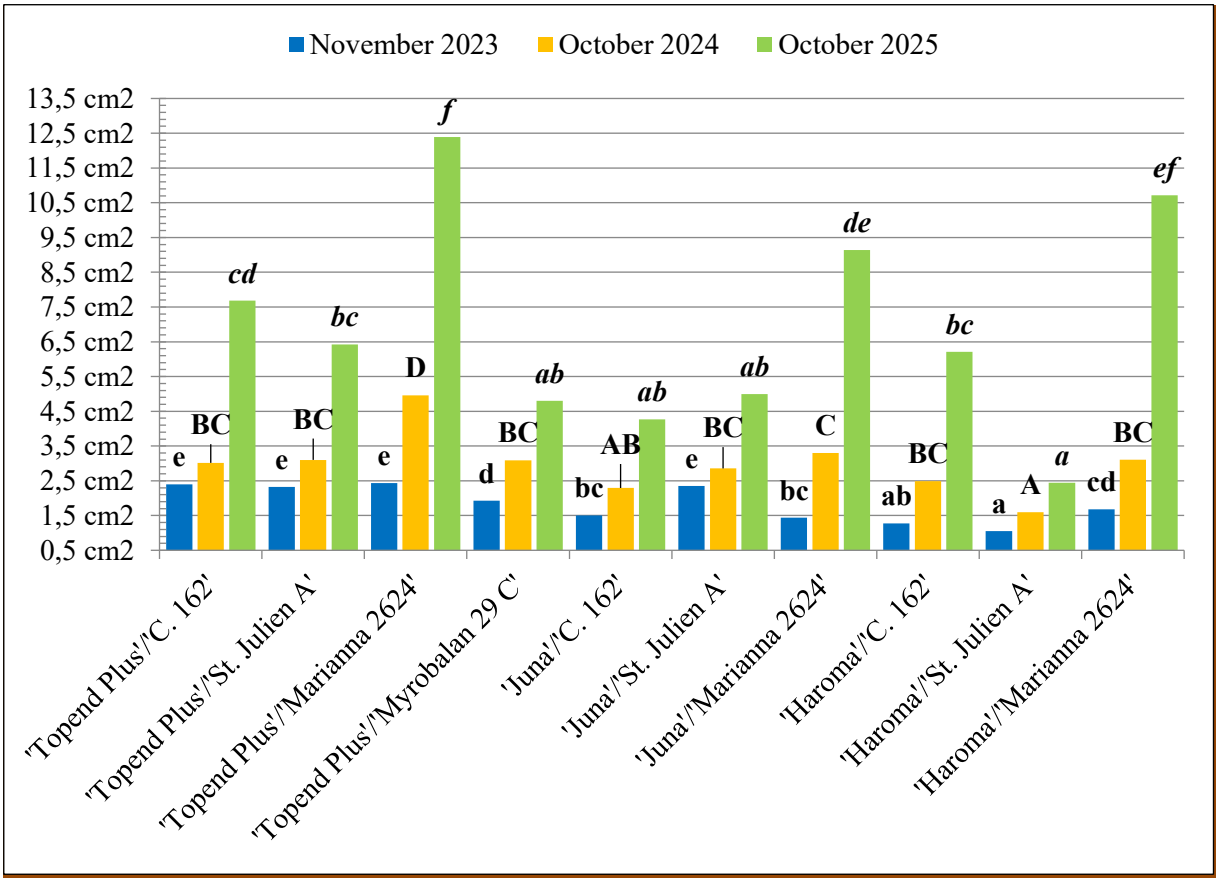

Figure 1. The trunk cross-sectional area (cm^2) of the combinations after planting (2023), after one year (2024) and after the second vegetation period (2025)

After the first vegetation significant differences remained between the combinations and a trend emerged in the case of all the cultivars (Figure 1). Trees on 'Marianna 2624' rootstock had statistically the largest TCSA-s for all the varieties in the experiment. There were no significant differences between the three other combinations of 'Topend Plus'. For the cultivar 'Juna', its combination with 'St. Julien A' was only the second largest after the first year (with 'Marianna 2624' rootstock providing the largest TCSA). Trees on myrobalan seedlings were the thinnest for this variety. In the case of the cultivar 'Haroma' the same differences and order remained between its three rootstock combinations, namely 'Marianna 2624' providing the largest TCSA, 'St. Julien A' the thinnest, while myrobalan seedling was between these two.

Significant differences remained between the TCSA-s of the combinations after the second year as well (Figure 1). The trend of the ‘Marianna 2624’ rootstock yielding the thickest TCSA in the case of all cultivars remained. The difference between the thinnest and widest combinations in the case of a variety became even larger, with trees on ‘Marianna 2624’ being close to twice as large as those on other rootstocks. The combinations of the cultivar ‘Topend Plus’ had significant differences between them by the end of the second vegetation. Trees on ‘Myrobalan 29 C’ where the thinnest, followed by those grafted onto ‘St. Julien A’, which were slightly smaller than those on myrobalan seedlings. In the case of ‘Juna’ ‘Marianna 2624’ was the widest, as said previously, and the difference between the cultivar’s combination with myrobalan seedlings and ‘St. Julien A’ were no longer statistically significant. The cultivar ‘Haroma’ had the same order between its combinations as the previous years, namely ‘St. Julien A’ yielding the thinnest trunks, followed by trees on myrobalan seedlings.

3.2 Volume of shoot growth

The total volume of shoot growth of the first vegetation resulted in significant differences between the combinations (Figure 2). The cultivar ‘Topend Plus’ grafted onto different rootstocks produced varying volumes of shoot growth. ‘St. Julien A’ provided the smallest growth, followed by myrobalan seedlings. ‘Myrobalan 29 C’ was slightly stronger, while trees on ‘Marianna 2624’ were the most vigorous. In the case of ‘Juna’, its combination with ‘Marianna 2624’ rootstock was also the strongest, while the variety produced the smallest growth grafted onto ‘St. Julien A’. Myrobalan seedling provided a vigour between the other two rootstocks. The cultivar ‘Haroma’ also had the weakest vigour on the rootstock ‘St. Julien A’, but there was no significant difference between the trees on ‘Marianna 2624’ and on myrobalan seedlings in this case.

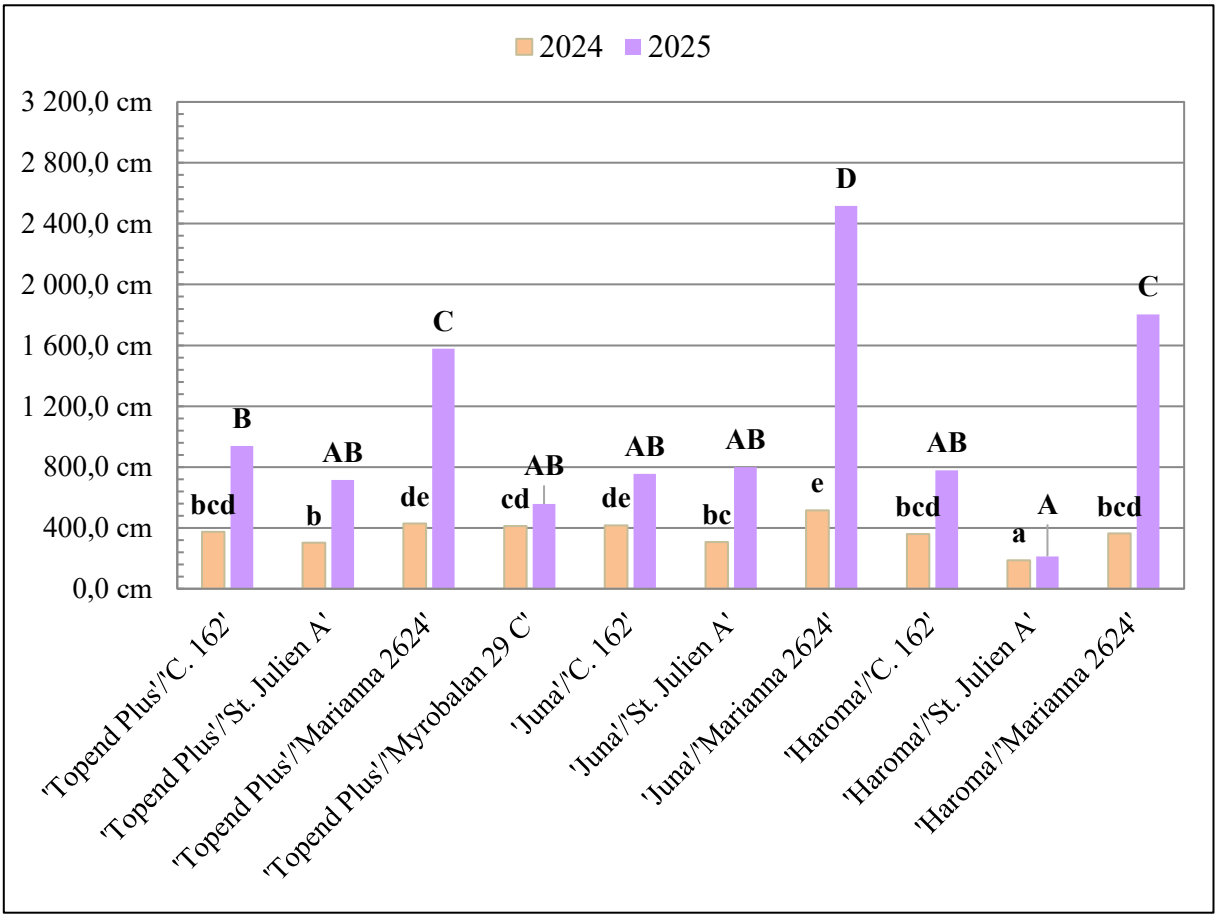

Figure 2. The total volume of shoot growth of the combinations in 2024 and 2025

The volume of shoot growth of the second vegetation also showed significant differences, but five of the ten combinations had statistically equal growth (Figure 2). It was also the case by the second year, just as it was for TCSA, that trees on ‘Marianna 2624’ rootstock were the most vigorous in growth for all three varieties. The other three combinations of the cultivar ‘Topend Plus’ had close to half as much shoot growth than the trees on ‘Marianna 2624’. ‘Myrobalan 29 C’ was the weakest, followed by ‘St. Julien A’ and then trees on myrobalan seedlings, which was a different order than the one in the first year. The combination of ‘Juna’/’Marianna 2624’ had the largest volume of shoot growth of all the ten combinations. Three times as much as this cultivar’s trees grafted onto myrobalan seedlings and ‘St. Julien A’, which were statistically equal in volume. In the case of the variety ‘Haroma’, trees on ‘St. Julien A’ had the smallest volume of growth, just as in the year before. But unlike the previous vegetation trees on myrobalan seedlings were less vigorous than those on ‘Marianna 2624’ rootstocks. The biggest difference between a cultivar’s combinations with rootstocks was also in the case of this variety. The total volume of shoot growth of ‘Haroma’/’Marianna 2624’ was almost eight times as much as the growth of ‘Haroma’/’St. Julien A’.

3.3 Canopy volume

Differences between canopy volumes were significant after the first vegetation (Figure 3).

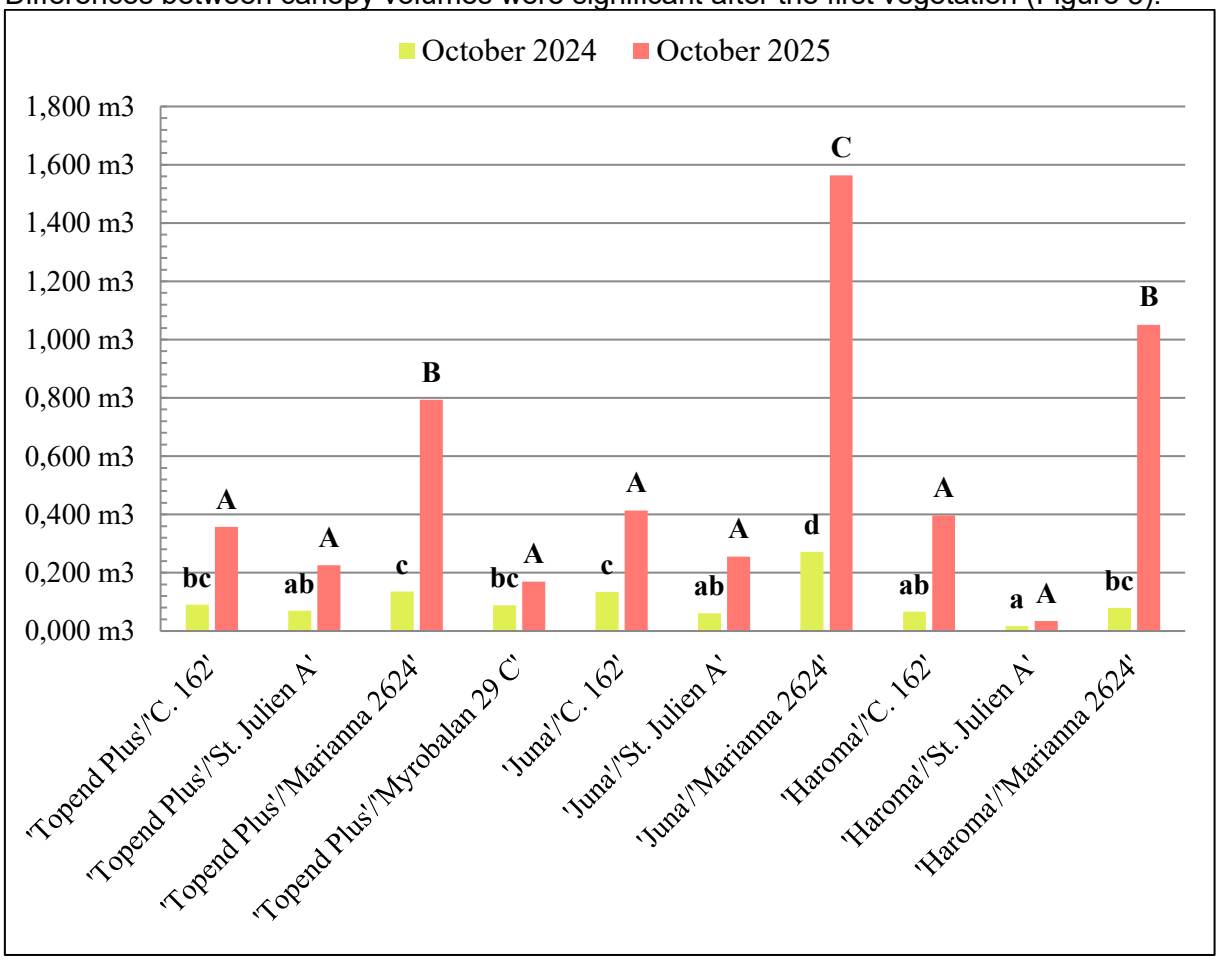

Figure 3. The canopy volumes of the combinations after the first (2024) and second year (2025)

The biggest differences between combinations were experienced in the volumes of the trees’ canopies. Trees of the largest combination were sixteen times larger than the smallest combination’s ones. Trees grafted onto ‘Marianna 2624’ rootstock already had the largest canopies only after one year in the case of every variety. For ‘Topend Plus’, its other combinations were significantly smaller, with trees on ‘St. Julien A’ having the lowest canopy volume. ‘Myobalan 29 C’ and myrobalan seedlings yielded equal canopy sizes. For the cultivar ‘Juna’ the other two combinations had twice

and four times as little canopy volumes as the variety's trees on 'Marianna 2624'. Just as was the case of 'Topend Plus', 'St. Julien A' produced the smallest canopy, while myrobalan seedlings a statistically larger one. The 'Haroma' variety's canopy volumes had the same order as the previous two cultivars, with 'St. Julien A' being the weakest one and myrobalan seedlings being stronger.

Significant differences remained between the canopies even after the second vegetation, but unlike TCSA and total volume of shoot growth there were only three statistically significant groupings of the combinations' means (Figure 3). There were differences in the actual volumes of the individual canopies, but these differences were not statistically significant due to a severe violation of variance homogeneity. Only the three combinations with the rootstock 'Marianna 2624' were significantly larger. All combinations of 'St. Julien A' and myrobalan seedlings with all three varieties had the same statistically equal canopy volumes, which was also equal to the volume of 'Topend Plus'/'Myrobalan 29 C'. The combination of 'Topend Plus' and of 'Haroma' cultivars with the rootstock 'Marianna 2624' produced equal canopy volumes, while trees of the variety 'Juna' grafted onto 'Marianna 2624' yielded the largest trees in terms of their canopy's volumes. The differences between different combinations became even larger after the second year. The combination of 'Juna'/'Marianna 2624' was almost 46 times as large as the combination of 'Haroma'/'St. Julien A'.

4 Discussion

Combining all measured parameters, we ranked the ten combinations by their growth vigour (Table 2).

Table 2. The ten combinations ranked by their growth vigour

Very strong	Strong	Medium	Weak
'Topend Plus'/'Marianna 2624'	'Topend Plus'/'C. 162'	'Topend Plus'/'St. Julien A'	'Topend Plus'/'Myrobalan 29 C'
'Juna'/'Marianna 2624'	'Haroma'/'C. 162'	'Juna'/'C. 162'	'Haroma'/'St. Julien A'
'Haroma'/'Marianna 2624'		'Juna'/'St. Julien A'	

Trees on 'Myrobalan 29 C' were considerably weaker than those on myrobalan seedlings in the case of 'Topend Plus'. Only this cultivar was grafted onto 'Myrobalan 29 C', meaning that paired with other varieties the rootstock could induce a different vigour. We base this on the fact that in our experiment the same type of rootstock produced statistically different growth vigour depending on the cultivar grafted onto it. A good example for this is the rootstock 'St. Julien A' which induced the weakest growth in the rootstock combinations of the cultivar 'Haroma' and 'Topend Plus' as well, while being on par with myrobalan seedlings in the case of the variety 'Juna'. For each of the three cultivars, trees on 'Marianna 2624' produced the strongest growth, exceeding myrobalan seedlings considerably. By the end of the second year, in all three measurements trees on this rootstock were the largest. A contributing factor to these results can be the different rootstock's ability to adapt to different soil conditions. The sandy soil of the experiment meant that despite irrigation some trees started wilting during the hot, dry summer periods. In the case of trees grafted onto 'St. Julien A' early leaf fall and dieback was experienced in the first vegetation. Some of these trees dried out during the next summer. Trees on 'Marianna 2624' produced little symptoms and faired far better in these conditions. These observations could explain some of the differences between the vegetative growth of the observed rootstock-scion cultivars.

5 Conclusions

Based on the first two years of data we can only draw preliminary conclusions. Differences between the combinations can easily change year by year, as we have experienced it in our experiment as well. Therefore, it is important to continue gathering and analyzing data to get a more accurate picture of the combinations' vigour. So far, we can generally say that trees grafted onto 'Myrobalan 29 C' and 'St. Julien A' had a reduced vegetative growth compared to trees on myrobalan seedlings. The rootstock 'Marianna 2624' provided the strongest growth, significantly exceeding

trees on myrobalan seedlings. These results are most likely influenced by the rootstocks' ability to adapt to the experimental plot's soil conditions. 'Marianna 2624' had great drought tolerance, while 'St. Julien A' was sensitive to dry periods despite irrigation.

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