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'Rootpac R' for Apricots? Yes!

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Abstract: The rootstock 'Rootpac R' is not used for apricots. The aim of this study was to evaluate the characteristics of 'Rootpac R' in comparison to the widely used 'Myrobalan 29C' rootstock. The evaluation of the rootstocks was conducted in combination with 16 scion cultivars to assess their effects on vegetative traits and mortality. The total height of the trees on 'Rootpac R' initially surpassed the 'Myrobalan 29C' trees. By the end of the fourth year, both rootstocks showed comparable heights with 'Rootpac R' standing at 317 cm and 'Myrobalan 29C' standing at 307 cm. Both rootstocks exhibited comparable TCSA values of 5 cm^2 initially; 'Rootpac R' surpassed 35% compared to 'Myrobalan 29C'. Canopy space occupancy assessments revealed that 'Rootpac R' initially demonstrated superior space utilization, occupying 8% of the designated volume compared to 4% for 'Myrobalan 29C'. By the fourth year, 'Rootpac R' exhibited a higher occupancy rate of 65% compared to 50% for 'Myrobalan 29C'. For apricot cultivars, such as 'Bergeron', 'C. óriás', 'Gönci magyarkajszi', 'Lady Cot', 'Tardif de Valance', and 'Tom Cot', 'Rootpac R' exhibited survival rates beyond the fourth season, highlighting its effectiveness for these varieties. Based on these results, 'Rootpac R' rootstock could be useful in apricot growing.

Keywords: compatibility; grafted tree; *Prunus armeniaca*; rootstock; sustainability

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1. Introduction

Apricots are a highly significant stone fruit globally with a major economic impact. They are primarily grown in regions with Mediterranean climates, with the majority of the world's production coming from Turkey, Uzbekistan, Iran, Italy, and Algeria, respectively [1].

The worldwide cultivation of apricots spans 560 thousand hectares with an annual harvest of approximately 4 million tons [FAOSTAT]. Apricots are frequently cultivated on seedling wild apricot or myrobalan rootstocks, as noted by Ercisli [2] and Miodragović et al. [3].

Apricots are a significant commercial crop in Hungary with over 5000 hectares dedicated to their cultivation. On average, the country produces 22,000 tons of apricots per year, although this number can fluctuate due to late spring frosts. The industry is expanding with an additional 100 to 200 hectares of commercial orchards being planted each year. Approximately 10% of the Hungarian apricot industry is made up of intensive orchards, which have a planting density greater than 667 trees per hectare. The orchard area is predominantly irrigated with 60% of the total area utilizing this method. The open vase and spherical tree training systems are the most commonly used, accounting for 45% and 40%, respectively, while the intensive vase and tall spindle systems are used to a lesser extent, at 10% and 5%. However, there appears to be an imbalance in the usage of rootstocks with 73% of apricot trees being grafted on myrobalan selected seedlings and an additional 10% grafted on apricot seedlings [4].

In recent decades, there have been changes in orchard management systems, cultivar, and rootstock traits [5]. Orchard systems worldwide are transitioning from medium-low planting densities (600–750 trees/ha) to high-density (1000–1250 trees/ha) plantings. Vertical axis canopy systems, which have one or more vertical axes, are increasingly utilized in modern commercial apricot orchards [6–10]. These systems enable the planting of 1100–1600 apricot trees per hectare, as reported by Stanica et al. [11].

Rootstocks possess numerous characteristics that facilitate apricot cultivation in environments unsuitable for apricot cultivars. Roots play a crucial role in water and nutrient uptake as well as adaptation to diverse ecological conditions, such as frost, drought, soil pH, salt, waterlogging, soil-borne pests, and diseases. They significantly influence various aspects of apricot cultivation, including growth vigor, resilience to biotic and abiotic soil factors, flowering patterns, and both the quantity and quality of fruit. Experts have emphasized the pivotal role of rootstocks in determining the success of apricot cultivation [12–15]. In some instances, rootstocks require a robust and stable trunk for optimal development. Conversely, grafted trees benefit from the synergistic interaction between the rootstock and scion. Apricot selected seedlings are commonly utilized as rootstocks for apricot cultivation, compatible with all apricot cultivars [16]. Given the limited adaptive capacity of scions and rootstocks from differing climatic conditions, the comprehensive evaluation of the climatic adaptability of various rootstocks, particularly for apricots, is essential [17].

In order to optimize the performance of rootstock–scion combinations, it is crucial to accurately determine the interdependence of their vegetative and generative traits [18].

Myrobalan (*Prunus cerasifera myrobalana* Ehrh.) is a widely spread species native to Europe and Asia. It is commonly used as a rootstock and for ornamental purposes. The sub-species of Myrobalan is highly diverse and can survive high water levels and waterlogging, but it may not thrive in dry or stony soils. Apricot cultivars grafted onto Myrobalan rootstock may be susceptible to late spring frost damage and *Verticillium*. In their evaluation of a large-scale rootstock experiment, Southwick and Weis [19] found that certain Myrobalan rootstocks may cause greater mortality in apricot orchards compared to other species. Despite its shortcomings, the rootstock 'Myrobalan 29C' has become increasingly popular in recent decades due to its early bearing period and good adaptation, especially on soils with high lime content. Its usage has also been expanding in Hungary in recent years. This rootstock was selected by Gregory Brothers nursery in Brentwood, CA, USA. The rootstock commonly used for peaches and almonds in both the USA and Italy is 'Myrobalan 29C'. It has strong vigor and can be propagated through soft-wood cuttings and micropropagation. 'Myrobalan 29C' is adaptable to various soil conditions and has a moderate rate of sucker production. The apricot cultivars have demonstrated excellent compatibility with it, as evidenced by several studies [20–22]. It is important to consider the adaptability of the rootstock to soil conditions when selecting a location for apricot orchards. This requires the development of new apricot rootstocks that exhibit resistance or tolerance against nematodes, diseases, pests, and edaphic conditions, while also demonstrating exceptional rooting and performance in the nursery.

Interspecific hybrids, such as those between plums, peaches, or other stone fruit species, can provide significant advantages in rootstock breeding programs [20,23]. The 'Monclar' cultivar (*Prunus persica* L.), known for its strong and vigorous growth, is particularly suitable for early bearing of grafted apricot and peach cultivars. The interspecific hybrid 'Rootpac R', which shares many characteristics with 'Monclar', is also well-adapted to suboptimal soil and climatic conditions and exhibits strong vigor [24]. The plant was created through a cross between *Prunus cerasifera myrobalana* L. and *Prunus dulcis* Mill. Its main purpose is for replanting, as stated by Agromillora [25].

Based on the research conducted by Darikova et al. [26], Milosevic et al. [27], and Yilmaz et al. [28], it is important to note that the results of experiments on apricot rootstocks cannot be generalized. Usually, the aim is to identify the most suitable rootstock–scion combinations for production in a specific growing area, as highlighted by Oprita and Gavat [29].

The objective of this study is to determine the stability of apricot production by selecting rootstocks, throughout vegetative characteristics, that are better adapted to a changing climate. Through comparative experiments, we aim to gain a comprehensive understanding of the selected rootstock ('Rootpac R'), focusing on the impact on vegetative development, viability, and usefulness in new plantations. It is worth noting that the rootstock 'Rootpac R' is currently not used for apricots and is the subject of our first large-scale comparative experiment [24]. 'Rootpac R' has achieved the best results among all the tested rootstocks, making it an excellent choice for this study and comparation with the standard rootstock 'Myrobalan 29C'.

2. Materials and Methods

2.1. Growing Conditions

The experimental orchard was planted at the Cegléd Research Station of Hungarian University for Agriculture and Life Sciences. The orchard is located at 47°10′35.0″ N, 19°50′28.6″ E, and is situated at an altitude of 96 m above sea level. The trial was established on chernozem soil with a high lime content and a humus content of 3.27%. The region is known to have a climate that is characterized as temperate, continental, and semi-arid [24].

The trees were planted in spring of 2018 with a spacing of three meters between each tree in a row and five meters between each row, resulting in a density of 665 trees per hectare. A layer of living mulch was added between the rows subsequent to the planting process. During the vegetative period, drip irrigation was applied 4 to 5 times with an average of 40 mm of water per irrigation. Pruning was typically performed annually in August, following the harvest. Canopies were formed into an intensive vase. The rootstock–scion combinations were replicated at least six times. The blocks were allocated in a totally random arrangement.

2.2. Plant Material

The investigated plant material included two rootstocks, non-commercially used rootstock 'Rootpac R' (RR) and rootstock 'Myrobalan 29C' (My) as a control. The breeder has not provided any information about 'Rootpac R' regarding the vegetative traits and the mortality rates of the trees [24]. It is important to mention that, despite the robust vigor of 'Myrobalan 29C', the root system alone is unable to anchor the entire tree securely to the soil, necessitating additional support for the grafted tree [20,21]. In order to assess compatibility and minimize the impact of cultivar, this trial included 16 different scion cultivars that originated from six different countries (Table 1). These cultivars represent the backbone of the local apricot production.

Table 1. Grafted scions and their state of origin.

Scion Cultivar	State of Origin
Ceglédi óriás	Hungary
Ceglédi szilárd	Hungary
Gönci Magyar kajszi	Hungary
Pannónia	Hungary
FlavorCot	USA
Goldrich	USA
LillyCot	USA

Table 1. *Cont.*

Scion Cultivar	State of Origin
Spring Blush	USA
TomCot	USA
Bergeron	France
Bergarouge	France
LadyCot	France
PinkCot	France
Tardif de Valence	Italy
Harogem	Canada
Roxana	Afghanistan

2.3. Vegetative Parameters and Calculations

The vegetative parameters were measured for four consecutive years (2018–2021) after planting to assess the performance of the two rootstocks in combination with the selected cultivars. Data were collected during fall of the four growing seasons following planting. Measurements were taken of shoot length (SL), tree height (TH), and trunk circumference (at 35 cm above the graft union). Trunk cross-sectional area (TCSA) and canopy space occupancy (CO) were calculated using the equations described by Mendelné et al. [24].

Trunk cross-sectional area was determined by measuring the circumference, serving as an indicator of the vigor induced by the rootstock:

$$\text{TCSA} = [\text{trunk perimeter}/2\pi]^2 \times \pi.$$

Canopy volume (CV) was calculated as follows:

$$\text{CV} = [\text{Tree height} - \text{trunk height}] \times \text{cross-directional canopy diameter} \times \text{row-directional canopy diameter}/3.$$

Canopy space occupancy (CO) of each along within the row. The effective width and height of canopies in apricot orchards are also 3 m; hence, canopy space occupation was calculated from the ratio of the canopy volume and the total available space (3 m × 3 m × 3 m = 27 m^3):

$$\text{CO} = (\text{CV}/27) \times 100.$$

The survival rate (SR) of the trees by plot was calculated as a percentage, based on the number of trees originally planted and the number of living trees at the end of each growing season.

2.4. Statistical Analysis

Data were statistically evaluated using standard deviation and ANOVA methods and represent the mean values of at least three measurements of the sixteen scion cultivars. The vegetative properties were tested by one-way analysis of variance (ANOVA). To examine the significance of the overall test, the univariate main effects were analyzed using Bonferroni's correction. The skewness and kurtosis of the residuals were assessed to confirm their normality. The homogeneity of variances was tested by Levene's test. Post hoc and contrast methods were conducted to compare factor levels. Given that the Levene's test yielded a significant result ($p < 0.05$) and the between-subject effect demonstrated significant differences, it is possible to differentiate the vegetative properties by utilizing the Tukey's post hoc test. The statistical procedures were carried out using the IBM SPSS v.27 software (IBM Corp., Armonk, NY, USA).

3. Results and Discussion

The statistical analysis indicates that the rootstocks had a significant impact on the SL, TH, TCSA, CO, and SR of the 16 scion cultivars (Wilk's $\lambda = 0.47$; $p < 0.001$). Figure 1 displays the SL, TH, TCSA, and CO of the rootstocks during the investigated period.

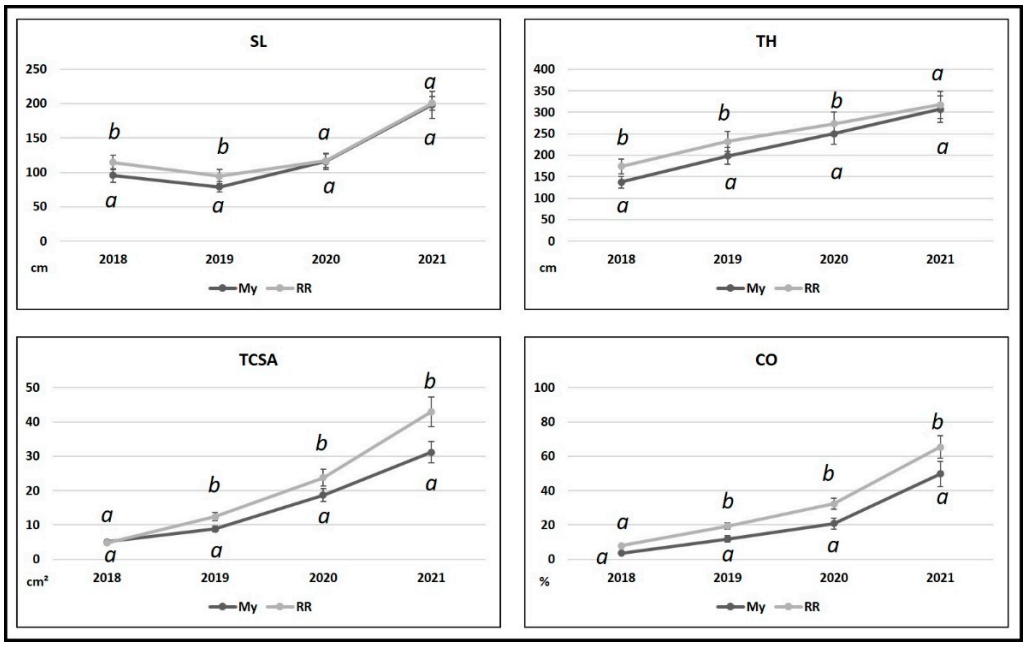

Figure 1. Shoot length (SL), tree height (TH), trunk cross-sectional area (TCSA), and canopy space occupancy (CO), as assessed between 2018 and 2021, of 16 apricot cultivars grafted to two rootstocks grown at the Cegléd Research Station, Hungary. (My—'Myrobalan 29C', RR—'Rootpac R'). Different letters indicate significantly different subsets (Tukey's post hoc test, $p < 0.05$).

In the year of planting, there was a noticeable difference in SL between the two rootstocks. The trees grafted on 'Myrobalan 29C' had an average SL of 95 cm, while those on 'Rootpac R' had a mean SL of 114 cm, indicating a significant initial advantage for the latter. Although there was a slight weakening in growth observed in the following year, the relative proportions between the two rootstocks remained consistent. This trend continued into the third and fourth growing seasons, during which the differences in SL between the trees on 'Myrobalan 29C' and 'Rootpac R' began to decrease. Notably, in these seasons, the two rootstocks exhibited statistically identical average SLs across all 16 cultivars, indicating a convergence in growth performance. The SL serves as a crucial indicator of a tree's growth potential and vigor, offering valuable insights into its developmental trajectory. Similar findings have been observed previously with almond cultivars and with apricot cultivars among South Greek conditions [30].

During the first year, the TH on 'Rootpac R' was significantly greater than that of 'Myrobalan 29C'. Specifically, the trees on 'Myrobalan 29C' had an average TH of 137 cm, while the trees on 'Rootpac R' reached an average height of 174 cm. This difference in height persisted throughout the following seasons. In the second season, the trees on 'Myrobalan 29C' grew to a TH of 198 cm, while the trees on 'Rootpac R' grew taller, reaching 232 cm. This trend continued into the third season with THs increasing to 250 cm for 'Myrobalan 29C' and 273 cm for 'Rootpac R', highlighting the consistent advantage of the latter. However, over time, the trees gradually grew to similar TH. By the end of the fourth year, 'Myrobalan 29C' had reached a TH of 307 cm, while 'Rootpac R' slightly outpaced it at 317 cm. The difference in TH between the trees on the two investigated rootstocks decreased over time, indicating a convergence towards equilibrium in growth patterns. Measurements of TH provide a comprehensive view of vertical growth and

overall tree strength. Yahmed et al. (2016) also demonstrated this heightened vigor of the trees grafted on 'Rootpac R' [31].

The calculated values for TCSA show slight variations from the previously described results. At the end of the first season, both 'Myrobalan 29C' and 'Rootpac R' induced a mean TCSA of 5 cm^2, indicating comparable surface area development. However, as the experiment progressed, distinct trends emerged. Over the following years, the trees on 'Myrobalan 29C' exhibited a gradual and consistent expansion of surface area with values reaching 9, 19, and eventually 31 cm^2, showcasing a steady thickening process. In contrast, the trees on 'Rootpac R' displayed a more robust thickening pattern, surpassing the trees on 'Myrobalan 29C' in surface area expansion. With values of 12, 24, and notably 43 cm^2 over the same period, 'Rootpac R' demonstrated a substantial increase in TCSA, outpacing its counterpart. The analysis shows that 'Rootpac R' induced greater thickening, surpassing 35%, compared to the trees on 'Myrobalan 29C' during the years of the experiment. This difference highlights the inherent differences in growth dynamics between the two rootstocks with 'Rootpac R' showing a propensity for more vigorous thickening over time. These findings offer valuable insights into the comparative growth performances of 'Myrobalan 29C' and 'Rootpac R'. These findings underscore the remarkable ability of 'Rootpac R' for thickening [32]. However, almond cultivars grafted on 'Rootpac R' produce weak vigor among semiarid Mediterranean climate conditions [32], and Cline and Bakker (2022) reported that there were no significant differences between peach varieties grafted on 'Rootpac' series ('Rootpac R', 'Rootpac 20', 'Rootpac 40', 'Rootpac 70') in their TCSA among South Canadian climate conditions [33]; apricot cultivars showed higher vigor on this specific rootstock in this experiment.

The CO value is an important metric that reflects the efficiency of space utilization within the plantation. At the end of the plantation year, the trees on 'Myrobalan 29C' occupied only 4% of the planned volume, while those on 'Rootpac R' occupied 8%. This indicates a disparity in space utilization efficiency between the trees on the two rootstocks. However, over time, both rootstocks influenced a significant increase in COs of the grafted scions, indicating an expansion in their spatial utilization. In the following years, 'Myrobalan 29C' and 'Rootpac R' continued to increase COs. By the second year, the canopies of the trees on 'Myrobalan 29C' occupied 12% of the planned volume, while those on 'Rootpac R' increased their occupancy to 19%. This trend continued into the third year with CO rates increasing to 21% for 'Myrobalan 29C' and 32% for 'Rootpac R', indicating the latter's faster use of available space. Notably, in the fourth year of measurement, the trees on 'Myrobalan 29C' achieved a significant CO of 50%, demonstrating a considerable expansion in space utilization. However, 'Rootpac R' surpassed its counterpart by reaching a CO of 65%, demonstrating its superior efficiency in utilizing the available space. Both 'Myrobalan 29C' and 'Rootpac R' exhibited considerable increases in CO values over time. Additionally, the excellent space efficiency achieved by 'Rootpac R' demonstrates its potential as a rootstock for cultivation, providing improved spatial utilization and potentially higher yields. These findings underscore the dynamic nature of space utilization within orchards and suggest that 'Rootpac R' may serve as a more favorable rootstock for optimizing spatial use and potentially enhancing yields [34].

For a lesser-known rootstock, perhaps the most important trait in the plantation is mortality. The SR values, expressing the susceptibility of the two rootstocks, as an average of the 16 cultivars studied over the years are shown in Figure 2.

At the conclusion of the initial growing season, all trees grafted on both 'Myrobalan 29C' and 'Rootpac R' demonstrated good SR values, underscoring the successful establishment of the orchard. However, as the experiment progressed into the second season, a significant contrast in SR emerged between the two rootstocks. While the SR of 'Rootpac R' experienced a marginal decrease to 94%, 'Myrobalan 29C' suffered a more pronounced decline to 85%, highlighting a notable discrepancy in resilience. As the study advanced through subsequent years, both 'Myrobalan 29C' and 'Rootpac R' encountered marginal increments in mortality rates ranging between 1 and 2%. These incremental losses signaled

ongoing environmental pressures or intrinsic factors impacting tree health within the orchard ecosystem. Despite these challenges, the initial variance in SR persisted between the two rootstocks.

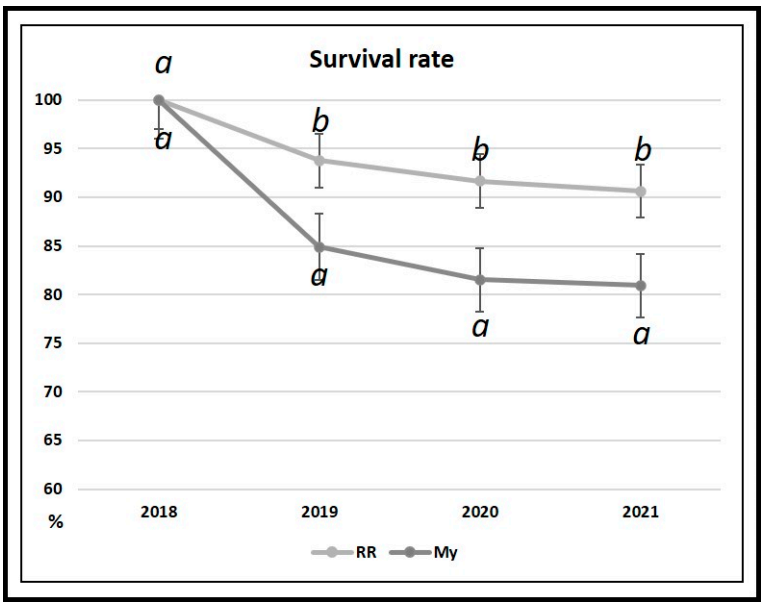

Figure 2. Survival rate (SR) values in percentage, assessed between 2018 and 2021, as the means of the 16 apricot cultivars grafted to the two rootstocks grown at the Cegléd Research Station, Hungary. (My—'Myrobalan 29C', RR—'Rootpac R'). Different letters indicate significantly different subsets (Tukey's post hoc test, $p < 0.05$).

The varieties grafted on Myrobalan 29C' produced more tree mortality in our trial than was reported in Lower Silesian (Poland) [35,36] but less than was reported by Southwick and Weis as well as Bassi [19,37]. Among Bulgarian conditions, no mortality was reported during the trial period [38]. Among the climate conditions of South Ontario (Canada), there was no mortality rate on 'Rootpac R' during the five years of evaluation [34]. SR, crucial for gauging adaptability and resilience to environmental stresses, provides key feedback on orchard health [39].

Not all scion varieties showed observable differences in SR between 'Myrobalan 29C' and 'Rootpac R'. Figure 3 visualizes and analyzes the variability in SR across the different cultivars, revealing specific trends and patterns for each cultivar.

There were no significant differences in SR between the two tested rootstocks, 'Myrobalan 29C' and 'Rootpac R', for the cultivars 'Ceglédi szilárd' (C. szilárd) and 'Pannónia'. Both cultivars exhibited comparable SRs with 'C. szilárd' registering a 92% SR and 'Pannónia' demonstrating an 83% across both rootstocks.

For the cultivars 'Harogem', 'Pink Cot', and 'Roxana', the data revealed a notable advantage in SR values when grafted on the 'Myrobalan 29C' rootstock. Moreover, it is noteworthy that all trees of the 'Harogem' and 'Pink Cot' cultivars endured to the end of the fourth year when grafted on the 'Myrobalan 29C' rootstock, indicating exceptional performance and longevity. This consistent survival underscores the reliability and suitability of the 'Myrobalan 29C' rootstock for supporting the growth and development of these cultivars over an extended period.

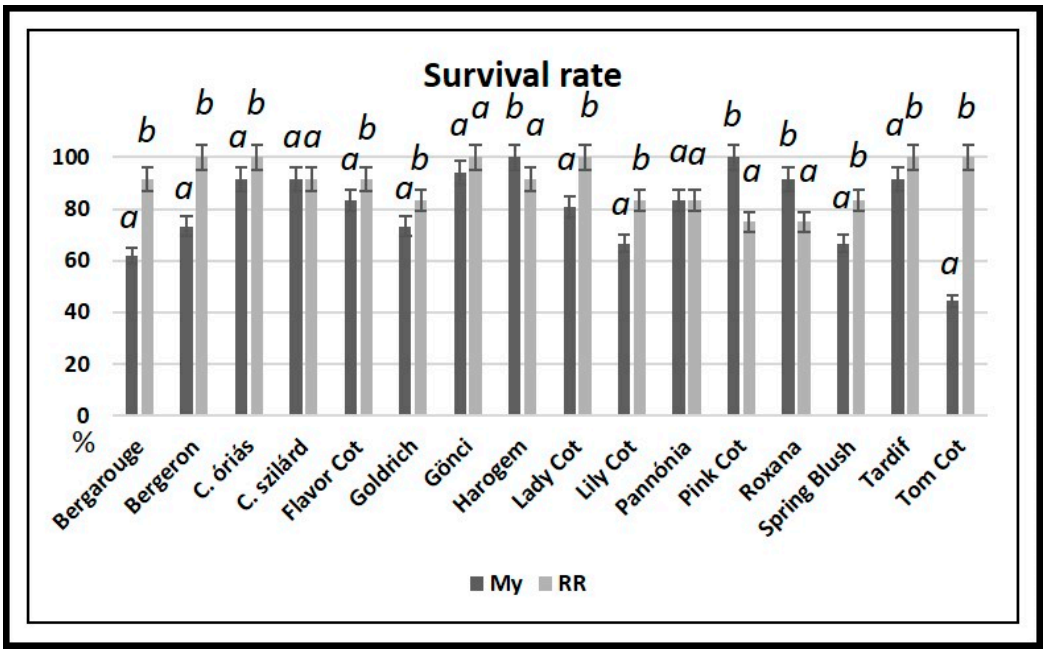

Figure 3. Survival rate (SR) values in percentage, as assessed in 2021, of the 16 apricot cultivars grafted to the two rootstocks grown at the Cegléd Research Station, Hungary. (dark columns: My—'Myrobalan 29C', light columns: RR—'Rootpac R'). Different letters indicate significantly different subsets (Tukey's post hoc test, $p < 0.05$).

For the remaining eleven scion cultivars, the 'Rootpac R' rootstock showed superior SR compared to 'Myrobalan 29C'. For six cultivars, namely 'Bergeron', 'Ceglédi óriás (C. óriás)', 'Gönci magyarkajszi' (Gönci), 'Lady Cot', 'Tardif de Valance', and 'Tom Cot', remarkably high SRs were observed with all trees showing 100% survival after the fourth growing season. This exceptional performance on the 'Rootpac R' rootstock underscores its effectiveness in providing optimal support for these specific cultivars. The case of 'Tom Cot' presents a particularly interesting scenario in this context. Despite the overall higher survival rates observed on the 'Rootpac R' rootstock, 'Tom Cot' showed a unique pattern. While 100% of the trees on the 'Rootpac R' rootstock survived, a significantly lower percentage, 44%, of 'Tom Cot' trees on the 'Myrobalan 29C' rootstock remained alive after the fourth growing season. This high survival rate of trees grafted on 'Rootpac R' indicates its usefulness for these specific cultivars [40]. Comparative trials are vital for thoroughly evaluating the ongoing advancements in apricot rootstocks, necessitating accurate and repeated measurements to identify subtle distinctions [41].

Based on the assessed parameters, 'Rootpac R' offers certain advantages, including superior canopy space occupation and higher TCSA growth. These traits suggest the potential for robust growth and development, potentially leading to higher yields over time [42].

4. Conclusions

When choosing a rootstock for fruit tree cultivation, one must prioritize the mortality. This is crucial because a rootstock with a high SR forms a solid foundation for the orchard, reducing the need for replanting and associated costs and labor. It is preferable to select a rootstock that consistently demonstrates high SR values across different cultivars. Further experiments are required to thoroughly assess the compatibility of 'Rootpac R' with various apricot cultivars. Maximizing yields in the shortest time necessitates considering multiple parameters beyond SR. While this trait is important, factors like growth vigor, disease resistance, environmental adaptability, and compatibility with scion cultivars significantly influence overall yield potential.

The evaluation included the assessment of 16 scion cultivars grafted onto these rootstocks. The SL is a vital indicator of a tree's growth potential and vigor. Initially, the trees on 'Rootpac R' demonstrated a significant advantage over those on 'Myrobalan 29C' in shoot length, although this difference diminished over time, indicating a convergence in growth performance between the two rootstocks. The TH measurements provide insights into vertical growth and tree strength. The trees on 'Rootpac R' initially surpassed those on 'Myrobalan 29C' in height, but the difference decreased over time, suggesting a balance in growth between the two rootstocks. 'Rootpac R' exhibited greater thickening compared to 'Myrobalan 29C' over the study period, indicating differences in growth dynamics between the two rootstocks. The CO evaluates spatial resource allocation and canopy development within an orchard. 'Rootpac R' demonstrated superior space utilization compared to 'Myrobalan 29C', suggesting its potential for optimizing spatial use and potentially enhancing yields. The SR is crucial for assessing adaptability and resilience to environmental stresses. While both 'Myrobalan 29C' and 'Rootpac R' initially exhibited high SR values, 'Rootpac R' showed superior SRs for specific cultivars, highlighting its effectiveness for those varieties. Further experiments are necessary to thoroughly assess the compatibility of 'Rootpac R' with various apricot cultivars.

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