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Study of apple rootstock Supporter 4 Pi 80 in intensive orchard

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Abstract

The genetic makeup of each scion–rootstock combination, along with their physiological and biochemical interactions with the environment, is unique. This necessitates a continuous process of research and the collection of extensive information about their behavior. To address this, the influence of the less well-known rootstock Supporter 4 Pi 80 and the widely used M9 T-337 on the growth and reproductive characteristics of the Granny Smith apple cultivar was studied. The trees were planted in the autumn of 2017 at a density of 2,380 plants per hectare. They were branched in the nursery (7+), and no pruning was applied after planting. During the period 2019–2022, the rootstocks Supporter 4 Pi 80 and M9 T-337 showed significant differences in terms of tree height, but not in the volume of the crowns they induced in the tested cultivar. Both rootstocks did not differ significantly in terms of yield per unit area and crop efficiency coefficients with this cultivar. The Granny Smith cultivar produced greater fruit weight when budded on M9 T-337 compared to Supporter 4 Pi 80.

***Keywords*:** rootstocks, cultivars, growth, yield, productivity.

INTRODUCTION

According to their vigour, rootstocks are classified as dwarfing, moderate or vigorous-growing, which is the main reason why the cultivar grafted onto them produces trees of different sizes. In addition to vigour, rootstocks also influence important indicators such as the onset of vegetation, productivity, period of entry into bearing and the life span of the trees (Blažek & Pištěková, 2012; Kumar et al., 2021; Jänes & Pae, 2003). The influence of rootstocks affects not only vigour but also the shape of the scion's crown. Planting density and the crown shapes used in orchard cultivation significantly affect both the quantity and quality of yield. In dense planting, appropriate crown formation creates a balance between the vegetative and generative potential, directly contributing to earlier entry into bearing and increased yield quantity (Čmelik et al., 2006; Miletić et al., 2011a; 2011b; Fallahi et al., 2018).

Over the past 60 years, the demand for apple rootstocks has been primarily driven by the need to reduce tree size and shorten the period of juvenile sterility, leading to dramatic changes in cultivation systems. Rapid entry into bearing, high planting density, and the achievement of high yields of good quality over an extended period stem from the increasing commercialization of apple production (Robinson et al., 2011).

More than two decades ago, Kviklys (2002) highlighted that the vast diversity of cultivars with varying fruiting habits and growth vigour makes it imperative to study their interaction with both established and newly developed rootstocks. The growth characteristics of the trees, the timing of fruiting, overall productivity, and fruit quality depend on the selection of an appropriate rootstock (Webster, 1993).

Considerable efforts have been made in Germany to select new clonal rootstocks. Particular hopes are placed on the Pillnitz series, which includes four weakly growing rootstocks. Those weaker or close in vigour to M9 (Fisher, 2001; Autio et al., 2008) are: Pillnitzer

Supporter 1 (M9 × *Malus baccata* 9L) Borkh; Pillnitzer Supporter 2 (M9 × *Malus micromalus*); Pillnitzer Supporter 3 (M9 × *Malus micromalus*); and Pillnitzer Supporter 4 Pi80 (M9 × M4). The rootstock Supporter 4 Pi 80, developed in Pillnitz, is a semi-dwarfing rootstock. It was initially introduced into commercial nurseries in France. The following rootstocks also belong to this series: Pi-AU 36-2, Pi-AU 51-4, Pi-AU 51-11, and Pi-AU 56-83 (Fisher, 2001; Stehr, 2005; Marini et al., 2009; Auvil et al., 2011). Of course, the most important characteristic of certain rootstocks is the productivity they induce in the cultivars and their ability to maintain it over a long period of time (Mantinger, 1996; Kviklys, 2002; Kosina, 2004; Vercamen, 2004). Therefore, studies on different rootstocks are mainly aimed at estimating the growth and reproductive performance of the cultivars budded onto them (Budagovski, 1962; Parry & Boustred, 1976; Engel, 1977; Van Oosten, 1986; Masseron & Roche, 1993; Barritt et al., 1997; Callesen, 1997; Wertheim, 1997, 1998; Webster & Hollands, 1999; Lipecki & Jadczuk, 1999; Quamme et al., 1999; Czynczyk & Piskon, 1999; Słowiński & Sadowski, 2000; Słowiński, 2004; Bielicki & Pąśko, 2018; Rufato et al., 2021).

In recent years, one of the most important parameters for evaluating different apple rootstocks has been the Crop Efficiency Coefficient (CEC) (Uselis, 2006). It represents the cumulative yield per tree over a given period (kg) per unit area (cm^2) of trunk cross-sectional area measured at the end of that period. According to this indicator, the weakest-growing combinations have an advantage over the more vigorous ones (Autio & Anderson, 1998). This approach is considered reliable only in long-term trials. Most studies report a larger trunk cross-sectional area when vigorous rootstocks are used (Andreev, 1984; Pepelyankov, 1989; Pepelyankov & Tabakov, 1997; Tsuchiya, 1979; Kosina, 1988; James, 1997). Due to the rapid increase in stem area during the initial years of the study, vigorous rootstocks exhibit a low productivity coefficient. However, as they age, they produce higher yields over a longer period, while the potential of weak-growing rootstocks becomes exhausted (Barden & Marini, 1997). The complex configuration of interactions in this type of experiment allows only trends to be outlined, without enabling comprehensive conclusions or the establishment of general rules.

The aim of the study was to expand the knowledge about the behaviour of the rootstock Supporter 4 Pi 80 in intensive apple orchard grown in environmental conditions of Central South Bulgaria compared with well-known M9 T-337 rootstock.

MATERIALS AND METHODS

The orchard was established in Plovdiv city region in the autumn of 2017 at the density of 2,380 trees per hectare (3.5 × 1.2 m). The apple cultivar ‘Granny Smith’ was budded on the relatively new for our country Supportrer 4 Pi 80 and well known M9 T-337 rootstocks. The trees were branched in the nursery (7+) and no pruning was applied after planting. The experiment was set up in a randomized block design with four replications and four plants per plot in each variant. The trees were drip irrigated and sod-mulch system was applied between the rows. The soil in the rows was maintained with herbicides. Trees were formed as tall spindle. During the period 2019 – 2022 the following parameters were evaluated at the end of each vegetation: trunk diameter (at 15 cm above the graft union), tree height, crown volume, mean yield per tree and cumulative yield per tree for the period, crop productivity coefficient (for each year) and crop efficiency - total yield per cm^2 of trunk-cross section area (TCSA) for 2022 and total yield per m^3 of the crown volume for 2022. The data was statistically processed using a variance analysis and Tukey’s test at 5% level of significance.

RESULTS AND DISCUSSION

One of the important parameters that provide information about the vigour induced by rootstocks is the trunk cross-sectional area. Vigorous rootstocks form thicker scions with a larger trunk cross-sectional area. The dynamics of trunk growth in the Granny Smith cultivar during the study period are presented in Figure 1. The data show that throughout the study period, trees grafted onto both rootstocks exhibit no significant difference in trunk cross-sectional area. In terms of crown volume growth (Figure 2), trees with the Supporter 4 Pi 80 rootstock consistently develop larger crowns. A greater intensity of growth is noticeable in the middle of the period; however, the difference in this indicator remains statistically insignificant even at the end of the study.

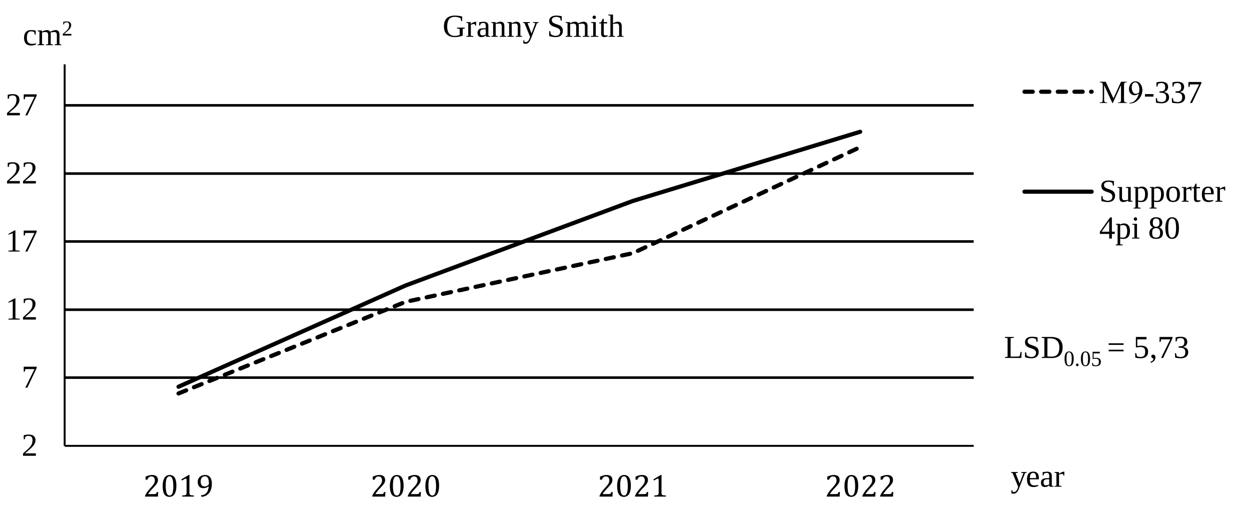

Figure 1. Trunk cross-sectional area (cm^2)

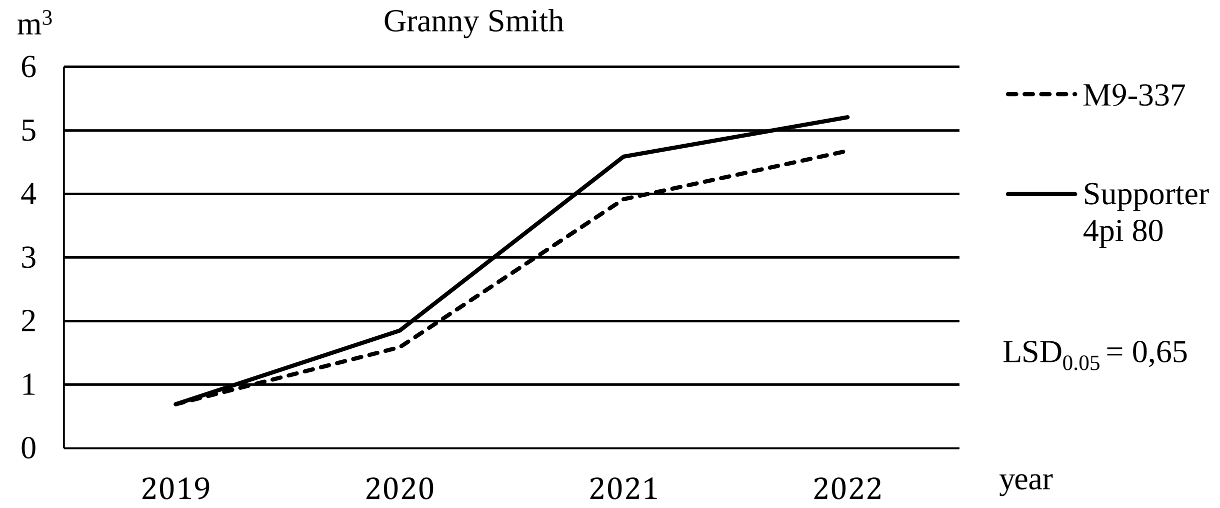

Figure 2. Crown volume (m^3)

During the study period, the rootstock Supporter 4 Pi 80 induced greater tree height in the tested cultivar compared to M9-T337, with the differences being significant (Table 1).

Table 1. Tree height of cultivar Granny Smith budded on two rootstocks, cm

Rootstock	Year			
	2019	2020	2021	2022
M9-T337	188.00	237.00	313.75	323.50
Supporter 4pi 80	188.05	253.00	339.25	396.00
$LSD_{0.05}$	6.80	6.50	16.75	8.06

It has long been known that growth and productivity of apple are very closely related and can hardly be considered separately from each other (Roberts & Blany, 1967). The most important characteristic of the different rootstocks according to Mantinger (1996), Kviklys (2002), Kosina (2004), Vercamen (2004) is the productivity that they induce on the cultivars and their ability to maintain it for a long period of time. It has been proven that in weak-growing apple trees, half of the products of photosynthesis are spent on fruit nutrition, while in the vigorous ones the ratio is 25% to 75% in favor of vegetative growth (Mitov et al., 1981). According to Barden & Marini (1997), as trees age, vigorous rootstocks increase their yield over time, while the potential of weaker-growing ones becomes exhausted. In this regard, long-term trails which include a large number of rootstocks grown in different environmental conditions provide valuable information (Autio et al. 2017a; Autio et al. 2017b; Kviklys et al. 2022).

The yield per tree, as well as per unit area, is considered a reliable parameter for estimating the productive potential of different scion-rootstock combinations (Tables 2 and 3). Since the yields in individual years were not consistent, a relatively accurate assessment of productivity is provided by the average yield and cumulative yield over the study period. In the current trial, a slightly higher cumulative yield was obtained from trees with the M9-T337 rootstock, although the difference was not statistically significant. The results from this study confirm the findings of Gjamovski & Kiprijanovski (2011), who reported nearly equal yields under the influence of both rootstocks.

Fruit weight is one of the important parameters characterizing fruit quality. Larger fruits of cultivar Granny Smith were obtained from trees budded on M9-T337 rootstock (Table 4). The results from the study are in agreement with those published by Gjamovski et al. (2013), who reported a positive influence of the M9-T337 rootstock on fruit weight and size compared to Supporter 4pi 80.

Table 2. Yield per tree (kg)

Rootstock	Year				Cumulative for the period 2019-2022
	2019	2020	2021	2022	
M9-T337	12.62	12.40	25.22	23.55	73.79
Supporter 4pi 80	11.24	11.40	26.04	20.77	69.45
$LSD_{0.05}$	2.75	2.16	6.11	2.53	4.35

Table 3. Yield (kg/ha)

Rootstock	Year				Average for the period 2019-2022
	2019	2020	2021	2022	
M9-T337	30,003.35	29,510.01	60,030.05	56,040.63	43,900.51
Supporter 4pi 80	26,760.29	27,130.44	61,960.59	49,430.63	41,320.49
$LSD_{0.05}$	655.28	513.00	1454.80	602.13	504.54

Table 4. Fruit weight, (g)

Rootstock	Year			
	2019	**2020**	**2021**	**2022**
M9-T337	197	194	190	186
Supporter 4pi 80	186	186	182	174
$LSD_{0.05}$	7.23	8.75	9.81	9.13

Table 5. Productivity and efficiency coefficients (kg per cm^2 of trunk cross-section area)

Rootstock	Year				Cumulative yield per tree/ cm^2 of TCSA for 2022
	2019	**2020**	**2021**	**2022**	
M9-T337	2.16	0.99	1.56	0.98	3.08
Supporter 4pi 80	1.78	0.83	1.30	0.83	2.77
$LSD_{0.05}$	0.74	0.16	0.71	0.17	0.45

Table 6. Productivity and efficiency coefficients (kg per m^3 of crown volume)

Rootstock	Year				Cumulative yield per tree/ m^3 of crown volume for 2022
	2019	**2020**	**2021**	**2022**	
M9-T337	18.29	7.80	6.43	5.03	15.77
Supporter 4pi 80	16.29	6.16	5.67	3.99	13.33
$LSD_{0.05}$	7.67	2.23	1.86	1.23	3.48

In recent decades, the most important indicator for characterizing the productivity of rootstocks has been the Crop Efficiency Coefficient (CEC) (Autio, 1998; Uselis, 2006). It expresses the cumulative yield for the study period in kilograms per unit area of trunk cross-sectional area (cm^2) or per crown volume (m^3) at the end of the period. Most often, combinations with larger crowns show higher yield per tree but lower productivity coefficients compared to those with smaller crowns. The calculated productivity coefficients vary from year to year, but based on the coefficients for cumulative yield over the period—relative to TCSA and crown volume in the final year—there were no significant differences between the rootstocks (Tables 5 and 6). Similar results were reported by Gjamovski & Kiprijanovski (2011).

CONCLUSIONS

During the study period, the rootstocks Supporter 4 Pi 80 and M9-T337 showed significant differences in terms of tree height, but not in crown volume induced in the Granny Smith cultivar. Both rootstocks did not differ significantly in yield per unit area or crop efficiency coefficients with this cultivar. The Granny Smith cultivar produced greater fruit weight when budded onto M9-T337 compared to Supporter 4 Pi 80.

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