SUITABILITY OF DIFFERENT DWARFING ROOTSTOCKS FOR 'RUBIN' APPLE TREES GROWN IN FERTILE SOIL

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A B S T R A C T

The effects of 19 rootstocks on growth, cropping and mean fruit mass of the 'Rubin' apple trees in fertile soil were investigated in the years 2001-2006. Six years after planting, the trunk cross-sectional area (TCSA) was the largest on P 62, M.9 EMLA and Arm 18, and the smallest on PJ 629 (No. 629), J-TE-G, PB-4, P 59 and No. 280. The highest cumulative yields per tree were obtained on the most vigorous rootstocks as well as on B 491, P 16, P 63 and P 65. Trees on the latter four rootstocks gave the highest yields per hectare. Trees on P 66 could also be very productive if they were planted at the right density, adequate to their tree size. Trees on P 59, No. 280, P 22, PB-4 and J-TE-G showed a high yield efficiency (expressed as a ratio of cumulative yield to the final TCSA); however, due to the small tree size their yield per area unit was lower. Mean fruit mass for the 5-year period was not significantly influenced by the rootstocks. The exception was PJ 629 which produced the smallest fruits.

Key words: apple, rootstock, tree vigour, yield, yield efficiency, fruit size

INTRODUCTION

Since the classical work of Drs. Wellington and Hatton at East Malling Research Station, England, breeders worldwide released many apple rootstocks. Evaluation of different clones in Europe and elsewhere has led to the conclusion that, at present, M.9 is nearly ideal for modern apple orchards. Its unique characteristics give it the high potential to induce dwarfing, precocity, productivity, regularity of bearing and superior fruit quality. These features made M.9 difficult to replace. The European apple orchards became dominated by this stock (Wertheim, 1998; Webster and Tobutt, 1994). The newly developed apple rootstocks should share the positive traits of M.9.

Intensive apple growing in some countries is threatened by winter damage; so winter hardy rootstocks are needed. Considerable advances in that respect have been achieved by breeding institutions in Northern and Eastern Europe, USA and Canada. Promising rootstocks were released by the Research Institute of Pomology and Floriculture in Skierniewice, Poland (Zagaja et al., 1988; Jakubowski and Zagaja, 2000).

The correct assessment of a secion/rootstock combination value should be carried out under particular soil conditions. Large amounts of various possible combinations of these factors impedes an evaluation. The model scion cultivars possess undesirable traits as excessive vigour, non-precocity or low yielding capacity and thus having special requirements for the rootstocks. Examples of such cultivars are ‘Northern Spy’, ‘Cox’s Orange Pippin’ or ‘Jonagold’ (Cummins and Aldwinckle, 1983; Webster and Tobutt, 1994; Jakubowski and Zagaja, 2000). The Czech cultivar ‘Rubin’ seems to possess similar attributes. Its fruit quality is remarkable, making it attractive on the market, though it must be noted that it is difficult in growing (Kruczyńska, 2008).

To achieve the best growing results with apples, it is recommended to plant trees be planted in fertile soils that contain sufficient amount of available nutrients and have a high water holding capacity. Fertile soils are particularly appropriate for dwarf trees. Such soil conditions exist at the Warsaw-Wilanów Experimental Station, where evaluation of a broad variety of dwarfing rootstocks has been carried out.

The aim of the study was to evaluate the suitability of some new promising apple rootstocks for the vigorous but low-yielding cultivar ‘Rubin’ grown on a fertile soil. The preliminary results of the experiment have already been published (Piestrzeniewicz et al., 2006; Piestrzeniewicz and Sadowski, 2007).

MATERIAL AND METHODS

The experiment was set up on a silty loam alluvial soil in the Experimental Orchard of the Warsaw University of Life Sciences at Warsaw-Wilanów, Poland, in the spring of 2001. Nineteen rootstocks of various genetic and geographical origins were compared, i.e. Arm 18 (Armenia), PB-4 (Belarus), J-TE-G and Unima (the Czech Republic), P 16, P 22, P 59, P 62, P 63, P 64, P 65, P 66, No. 280, No. 387 and PJ 629 (No. 629) of Poland, B 146 and B 491 (Russia) as well as M.9 EMLA and M.27 (the United Kingdom) that were considered as standards.

Maiden trees of ‘Rubin‘ were planted in rows spaced 3.25 m. The within-row tree spacing varied according to the expected rootstock vigour. It was 1 m for trees on rootstocks presumed to be very dwarfing (J-TE-G, M.27, P 22, P 59, P 63, P 64, P 65 and PB-4), 1.2 m for intermediate between very dwarfing and dwarfing (B 491, No. 280, No. 387, PJ 629, P 16 and Unima), and 1.5 m for standard dwarfing (Arm 18, B 146, P 62 P 66 and M.9 EMLA).

The experiment was arranged in a randomised block design with four replications and 5 trees per a plot, with the exception of PJ 629 that was represented by 3 trees per a plot. Trees were planted with the scion-rootstock bud union at 5 cm above the ground and trained as standard spindle with trunks ca 70 cm high. Routine orchard practices were carried out according to the recommendation for commercial apple orchards in Poland. In the first year after planting all flowers were removed by hand, at the beginning of bloom. In the following years, regular chemical and hand thinning was carried out, except for the year 2007 when a severe frost occurred on the night of May 1-2. As 'Rubin' is a an early blooming cultivar it was then in full bloom and the frost destroyed nearly all the blossoms. Only single fruits developed that year.

Every second year trunk diameter was measured, at the height of ca. 40 cm, and then the trunk cross-sectional area (TCSA) was calculated. Yield from each experimental plot was recorded every year, except for the year 2007. From the registered data, the yield per tree and per area unit was calculated. Then the yield efficiency (YE) was derived as a ratio of cumulative yield for three years to the TCSA.

All data were analysed by analysis of variance, with mean separation by the Newman-Keuls test at p = 0.05.

RESULTS

In the spring of 2007, which was six years after planting, the largest trunk cross-sectional area (TCSA) was recorded in trees on Arm 18, M.9 EMLA and P 62 stocks (Tab. 1). The crowns of the trees on these rootstocks had already begun to entangle two years earlier despite the highest in-row spacing applied (1.5 m). Trees on P 59, No. 280, M.27, P 22, No. 387, P 64, P 63, P 65, Unima, P 66, B 146, P 16 and B 491 reached a TCSA of 32% to 69% of those on M.9 EMLA. The lowest vigour, estimated on the same basis, was shown by trees on PJ 629, J-TE-G and PB-4 (16-29% compared to trees on M.9 EMLA). It is worth noting that at planting time the trees on PB-4 and P 22 were significantly larger than trees on M.9 EMLA – 115% and 117% of TCSA. However, after six years in the orchard their relative size was 29% and 37% of M.9 EMLA, respectively. Biennial increments of TCSA followed, in general, a similar trend as the final values of TCSA in the spring of 2007.

Initial yields, in the second and third year after planting (2002-2003), were the highest from trees on P 63, P 22, P 65, P 59 and P 16, reaching (in order) from 10.7 to 8.1 kg per tree (Tab. 2). In the following three years (2004-2006) the highest yields (from

Table 1. Indices of tree size and growth, depending on rootstock

Rootstock [1]	TCSA [cm^2]		Relative size[2] [%]		Biennial TCSA increments [cm^2]		
	spring 2001	spring 2007	2001	2007	2001-2002	2003-2004	2005-2006
PJ 629	1.20 a*	6.4 a	66	16	1.42 a	2.19 a	1.63 a
J-TE-G	1.18 a	9.6 ab	64	23	1.72 ab	3.34 ab	3.34 ab
PB-4	2.08 g	11.9 abc	115	29	2.99 bcd	3.41 ab	3.37 ab
P 59	1.45 c	12.9 abc	80	32	3.69 cde	4.07 abc	3.70 ab
No. 280	1.18 a	13.5 abc	65	33	2.30 abc	4.91 a-d	5.14 abc
M.27	1.24 ab	15.0 bcd	68	36	2.31 abc	5.05 a-e	6.36 a-d
P 22	2.12 g	15.1 bcd	117	37	4.31 def	4.59 a-d	4.07 ab
No. 387	1.24 ab	17.0 b-e	68	41	3.78 cde	6.24 b-e	5.75 a-d
P 64	1.39 bc	18.3 b-e	77	45	3.67 cde	6.34 b-e	6.85 bcd
P 63	1.71 de	19.1 cde	94	47	4.57 d-g	6.23 b-e	6.60 bcd
P 65	1.90 f	20.5 c-f	105	50	4.70 d-g	6.10 b-e	7.84 bcd
Unima	1.26 ab	23.3 def	70	57	3.44 cde	8.95 ef	9.68 cde
P 66	1.84 ef	23.8 def	102	58	4.99 e-h	8.92 ef	8.03 bcd
B 146	1.70 de	23.8 def	93	58	4.31 def	8.12 def	9.68 cde
P 16	1.63 d	24.5 ef	90	60	4.30 def	7.89 c-f	10.68 de
B 491	2.15 g	28.3 f	118	69	4.88 e-h	10.78 f	10.48 de
Arm 18	2.19 g	35.8 g	121	87	5.71 fgh	14.47 g	13.40 e
M.9 EMLA	1.81 ef	40.8 g	**100**	**100**	6.31 h	15.87 g	16.61 f
P 62	1.84 ef	41.5 g	102	101	6.06 gh	15.85 g	17.76 f

[1] The rootstocks have been arranged, from the top to the bottom of the table, in ascending order according to the values of TCSA 6 years after planting (in the spring of 2007)
[2] The relative tree size was calculated as a ratio of TCSA on a given rootstock to TCSA of trees on M.9 EMLA at the same time and expressed as percentages
*Mean separation (within columns) by Newman-Keuls test, at p = 0.05

60 to 51 kg per tree) were obtained from M.9 EMLA, P 66, B 491, Arm 18, P 16 and P 62. Tree cropping in 2006 was a little lower than in 2005 (Tab. 4). Cumulative yields for the whole five-year period of bearing (2002-2006) were the highest (within the range of about 65 down to 52.5 kg per tree) from trees on P 66, P 16, M.9 EMLA, B 491, Arm 18, P 63, P 65 and P 62. There were three relatively vigorous rootstocks among them: P 62, M.9 EMLA and Arm 18; the other ones showed an intermediate vigour – 47-69% of M.9 EMLA (Tab. 1). The lowest were the yields

Table 2. Yield per tree and yield efficiency, depending on rootstock

Rootstock [1]	Yield per tree [kg]					Yield efficiency [2] [kg cm^{-2}]
	2005	2006	2002-2003	2004-2006	2002-2006	
PJ 629	5.6 a*	2.7 a	3.1 ab	13.8 a	16.8 a	2.64 cde
J-TE-G	9.3 ab	8.0 b	3.2 ab	25.3 b	28.3 b	2.98 de
PB-4	9.5 abc	10.0 bc	6.2 cd	28.7 bc	34.9 bc	3.01 de
M.27	11.1 abc	11.1 bc	2.5 ab	32.6 bcd	35.1 bc	2.33 bcd
P 64	13.8 bcd	10.9 bc	2.8 ab	39.1 c-f	41.9 cd	2.30 bcd
P 59	13.1 bcd	10.1 bc	8.2 de	34.0 b-e	42.2 cd	3.27 e
No. 280	15.9 b-e	12.5 bcd	3.2 ab	40.0 c-f	42.2 cd	3.21 e
No. 387	15.9 b-e	10.8 bc	3.9 ab	40.7 c-f	44.5 cde	2.66 cde
B 146	15.6 b-e	12.2 bcd	3.2 ab	41.8 c-f	45.1 cde	1.90 abc
P 22	13.5 bcd	10.0 bc	9.5 ef	35.9 b-e	45.4 cde	3.04 de
Unima	16.9 cde	13.6 b-e	3.6 ab	45.5 dg	49.2 c-f	2.22 bcd
P 62	15.5 b-e	16.9 def	1.5 a	51.1 f-h	52.5 d-g	1.36 a
P 65	16.9 cde	14.2 c-f	9.3 ef	47.7 e-h	57.0 efg	2.86 de
P 63	15.8 b-e	14.2 c-f	10.7 f	46.8 e-h	57.6 efg	3.02 de
Arm 18	20.5 de	15.2 c-f	2.1 a	56.9 gh	59.0 fg	1.68 ab
B 491	20.0 de	18.4 ef	4.8 bc	57.3 gh	62.1 fg	2.21 bcd
M.9 EMLA	20.7 de	19.5 f	2.9 ab	60.0 h	62.8 g	1.54 ab
P 16	20.7 de	17.7 def	8.1 de	56.0 gh	64.1 g	2.69 cde
P 66	21.4 e	18.1 def	6.2 cd	58.7 gh	64.8 g	2.72 cde

[1] The rootstocks have been arranged, from the top to the bottom of the table, in ascending order according to the values of cumulative yield (2002-2006)
[2] Yield efficiency was calculated as a ratio of cumulative yield (2002-2006) per tree to the TCSA in tne spring of 2007
*Explanations, see Table 1
The outstanding rootstocks, both due to the cumulative yield and to the yield efficiency, are in boldface

of trees on PJ 629 (below 17 kg per tree). Trees on the remaining rootstocks bore in total from about 25 to 49 kg per tree.

Yield efficiency (YE) of trees on the rootstocks P 59, No. 280, P 22, P 63, PB-4, J-TE-G, P 65, P 66, P 16, No. 387 and PJ 629 ranged from 2.64 to 3.27 kg cm^{-2} (Tab. 2). The YE of trees grown on the remaining rootstocks varied from 1.36 to 2.33 kg cm^{-2} and the most vigorous trees

Table 3. Yield per area unit, depending on rootstock

Rootstock [1]	No. of trees per ha	Yield [t ha^{-1}]				
		2005	2006	2002-2003	2004-2006	cumulative 2002-2006
PJ 629	(2564) [2]	14.4 a*	6.8 a	7.9 ab	35.3 a	43.2 a
J-TE-G	3077	28.6 b	24.4 b	10.0 ab	77.0 b	87.0 b
B 146	2564	31.9 bcd	25.1 b	6.7 ab	85.8 bc	92.5 bc
PB-4	3077	29.2 bc	30.8 bcd	19.1 c	88.2 bc	107.3 bcd
P 62	2051	31.7 bcd	34.6 b-e	3.0 a	104.7 bc	107.7 bcd
M.27	3077	34.3 b-e	34.2 b-e	7.7 ab	100.2 bc	107.9 bcd
No. 280	(2564)	40.8 b-e	32.2 b-e	8.1 ab	102.6 bc	110.7 bcd
No. 387	(2564)	40.7 b-e	27.8 bc	10.1 ab	104.1 bc	114.2 bcd
Arm 18	2051	42.0 b-e	31.2 bcd	4.2 a	116.7 cd	120.9 b-e
Unima	2564	43.3 b-e	34.7 b-e	9.4 ab	116.6 cd	126.0 b-e
M.9 EMLA	2051	42.4 b-e	39.9 b-e	5.8 ab	123.0 cd	128.8 c-f
P 64	3077	42.5 b-e	33.6 b-e	8.7 ab	120.1 cd	128.8 c-f
P 59	3077	40.4 b-e	31.2 bcd	25.3 d	104.5 bc	129.8 c-f
P 66	(2051)	43.9 b-e	37.0 b-e	12.6 b	120.3 cd	132.9 c-f
P 22	3077	41.5 b-e	30.6 bcd	29.1 de	110.5 bcd	139.6 def
B 491	2564	51.3 de	47.2 e	12.2 b	146.9 d	159.1 efg
P 16	2564	57.4 e	45.5 de	20.7 c	143.6 d	164.3 fg
P 65	3077	51.9 e	43.6 cde	28.6 de	146.7 d	175.3 g
P 63	3077	48.7 e	43.8 cde	33.4 e	146.9 d	177.5 g

[1] The rootstocks have been arranged, from the top to the bottom of the table, in ascending order according to the values of cumulative yield per ha (2002-2006)
[2] Tree densities which were too low have been put in brackets
*Explanations, see Table 1

exhibited the lowest values, namely those on P 62, M.9 EMLA and Arm 18.

Calculated yields per hectare are presented in Table 3. The highest cumulative yields per hectare in the years 2002-2006 were from trees on P 63, P 65, P 16 and B 491. Those yields were from about 159 to 177.5 t ha^{-1} for the 5-year period. In contrast, trees on PJ 629 gave the lowest cumulative yield (43 t ha^{-1}). They were very small and, in spite of relatively dense planting (1 m within-row spacing), did not fill the assigned space. Similarly, the trees on P 66, and to some extent those on Nos. 280 and 387 also appeared smaller than their in--row spacing, even 6 years after planting.

Table 4. Mean fruit mass and yield per tree – in successive years; average values for all rootstocks

Year	Mean fruit mass [g]	Yield [kg tree^{-1}]
2002	not considered	0.6
2003	265 d*	4.4
2004	254 c	14.4
2005	199 a	15.3
2006	224 b	12.9

*Explanations, see Table 1

Table 5. Mean fruit mass, depending on rootstock; average for the years 2003-2006 and in 2005

Rootstock	Mean fruit mass [g]	
	average for 4 years (2003-2006)	2005
PJ 629	208 a*	168 a
P 22	215 ab	177 ab
P 59	218 ab	179 ab
PB-4	221 ab	183 ab
J-TE-G	225 ab	181 ab
B 146	228 ab	185 ab
P 65	233 b	195 ab
P 66	236 b	197 ab
P 63	237 b	219 b
M.27	238 b	198 ab
No. 387	240 b	185 ab
P 62	241 b	202 ab
B 491	243 b	206 ab
Arm 18	247 b	206 ab
P 64	247 b	203 ab
P 16	247 b	228 b
No. 280	248 b	204 ab
Unima	249 b	223 b
M.9 EMLA	251 b	243 b

*Explanations, see Table 1

Mean fruit mass depended mostly on the season (Tab. 4). On the average, of all rootstocks the lowest fruit mass was noted in 2005. This was the year when trees bore the highest yields. Depending on the rootstock, mean fruit mass for the years 2003-2006 varied between 208 g and 251 g (Tab. 5). Fruits from trees on very dwarfing rootstock PJ 629 were significantly smaller than those on the other rootstocks. The differences in fruit size were particularly pronounced during the heavy fruit load of 2005.

DISCUSSION

Rootstock evaluation using special test cultivars and in various cultural conditions and sites is essential for the selection of new candidates for commercial growing. It usually requires nearly 10 years of study. However, some parameters might be assessed as early as 3-4 years after planting, i.e. precocity. Other parameters might be assessed up to the 7th year after planting, as in the case of tree size on rootstocks that equal or are more dwarfing than M.26 (Cummins and Aldwinckle, 1983; Ferree and Carlson, 1987). Our 6--year results indicated that the majority of the rootstocks under study significantly reduced tree size, in comparison to the trees on M.9 EMLA. This is in line with the reports of Zagaja et al. (1989) and Jakubowski and Zagaja (2000). In addition, a common phenomenon observed was a progressive reduction of tree vigour on some very dwarfing rootstocks in the successive years (Wlosek-Stangret and Jadczuk, 2000).

Stimulation of precocious fruit bearing in commercial amounts is as important as the dwarfing effect of a rootstock. This ability, demonstrated by the Polish rootstocks, and also by PB-4 and B 491, was already mentioned in our earlier reports (Piestrzeniewicz et al., 2006; Piestrzeniewicz and Sadowski, 2007). It confirmed the previous data of Zagaja et al. (1989) and Jakubowski et al. (1995). This indicated the high value of 'Rubin' to differentiate rootstocks in respect to their effect on precocity and tree vigour control.

Cumulative yields per tree for the 5-year period were, in the case of some rootstocks, proportional to tree size, but this was not always true. This relationship was probably influenced by differences in fruit number in crown volume (Czynczyk et al., 2001; Webster and Tobutt, 1994, Wertheim, 1998). However, this parameter was not investigated in our experiment.

The genetically determined fruiting potential (productivity) provoked by a rootstock is generally expressed as yield efficiency (YE), called also cropping efficiency coefficient (CEC). This parameter appears to be adversely related to tree size. This relationship has been noted within a group of rootstocks with different vigour, ranging from dwarfing to vigorous. According to Zagaja et al. (1988; 1989), differences in productivity among trees on dwarfing and very dwarfing rootstocks are quite small. We have found that trees on M.9 EMLA and on other stocks of similar vigour had a significantly lower productivity. In the case of M.9 EMLA, a probable explanation of that phenomenon is its sub-clone origin as well as its vigour being about 50% higher than that of the original M.9 (Ferree and Carlson, 1987). So, it may be that M.9 EMLA is not a typical dwarfing rootstock. It may fit better in the category of stocks of intermediate vigour between dwarfing and semi-dwarfing. The same refers to the rootstocks P 62 and Arm 18.

Spacing for trees in the rows implicated important information for growers about potential yield per hectare of a cultivar on a particular rootstock. Trees on new rootstock clones are usually planted at wider spacing to avoid overfilling and the necessity for excessive pruning (Zagaja et al., 1989). Another option is to space the trees according to the expected tree vigour. The wrong decisions then often happen, however. In our trial, spacing of 1.5 m in the row for trees on the most vigorous rootstocks M.9 EMLA, Arm 18 and P 62 proved to be too small. On the other hand, 1-m spacing for trees on PJ 629 or 1.5 m for those on P 66 appeared definitely too large. That is why the yields per hectare obtained on these rootstocks were lowered to the level not equivalent to their true cropping potential.

Rootstocks may influence fruit size of a grafted scion (Zagaja et al., 1989). In our study, this effect was weakly pronounced since ‘Rubin’ is a large-fruited cultivar. Moreover, fertile soil and fruitlet thinning favoured a high mean fruit mass, even on very dwarfing rootstocks. An exception was PJ 629 that induced development of very small fruits. This confirmed an earlier tendency noted by Jakubowski (2004).

It may be stated that the rootstocks M.9 EMLA, P 62 and Arm 18 are too vigorous for vigorous cultivars grown in a fertile soil. Moreover, very dwarfing rootstocks, despite resulting in a high precocity and yield efficiency, do not ensure high yields per hectare for a long time. Finally, some rootstocks presenting a vigour intermediate between very dwarfing and standard dwarfing, namely P 63, P 65, P 16, B 491 as well as P 66 at dense planting, seem to be the most promising for 'Rubin' grown in fertile soil.

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PRZYDATNOŚĆ RÓŻNYCH PODKŁADEK KARŁOWYCH DLA JABŁONI ‘RUBIN’ NA ŻYZNEJ GLEBIE

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STRESZCZENIE

W latach 2001-2006 oceniano jabłonie odmiany ‘Rubin’ na 19 podkładkach pod względem siły wzrostu, owocowania i masy owocu. W szóstym roku po posadzeniu (2006) największe były drzewa na podkładkach P 62, M.9 EMLA i Arm 18, a najmniejsze na PJ 629 (Nr 629), J-TE-G, PB-4, P 59 i Nr 280. Największy plon łączny wydały drzewa na podkładkach P 62, M.9 EMLA, Arm 18, B 491, P 16, P 63 i P 65, a w przeliczeniu na jednostkę powierzchni te na B 491, P 16, P 63, P 65 i P 66 (na ostatniej pod warunkiem zastosowania mniejszej rozstawy odpowiedniej do ich wielkości). Drzewa na podkładkach P 59, Nr 280, P 22, PB-4 i J-TE-G miały wysoki współczynnik plenności, ale ze względu na małe rozmiary ich plon był niższy w przeliczeniu na hektar. Masa owocu nie zależała istotnie od podkładki, z wyjątkiem PJ 629, na której drzewa wydawały najmniejsze owoce.

Słowa kluczowe: jabłoń, podkładka, siła wzrostu, plon, wskaźnik plenności, masa owocu