Results of ten-year rootstock testing with apple cultivar Rubin on fertile soil

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Abstract

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The experiment was carried out on a fertile alluvial soil at Warsaw-Wilanów, Central Poland, in years 2001–2010. Nineteen very dwarfing and dwarfing rootstocks were tested for vigorous apple cultivar Rubin. Ten-year-old trees were the largest on M 9 EMLA and P 62, smaller on Arm 18, and then on B 491, Unima and B 146. Even smaller were the trees on M 27, P 63 and P 64, and the smallest those on PJ 629. The highest cumulative yield (2002–2010) per tree was on P 66, Arm 18, M 9 EMLA, B 491 and P 16, lower on P 64, P 22, P 59, M 27, PB-4 and J-TE-G, and the lowest on PJ 629. Trees on P 59, PJ 629, PB-4, No. 280, J-TE-G, P 63, P 66, P 22, No. 387 and P 64 showed higher yield efficiency than those on M 9 EMLA or P 62. The mean fruit mass from trees on P 63, M 27, No. 387, Arm 18, P 62, P 64, No. 280, B 491, P 16, Unima and M 9 EMLA was larger than from trees on PJ 629. Trees on P 63, B 491, P 16, P 66, and P 65 produced higher cumulative yield per ha than trees on PB-4, J-TE-G or PJ 629.

Keywords: *Malus* × *domestica* Borkh.; vigour; yield; yield-efficiency; fruit-size

Rootstock breeding aimed at obtaining apple rootstocks with improved characteristics has been conducted in many countries. Attempts undertaken for replacements of M 9, as well as of M 26, M 7, or MM 106, resulted in numerous new clones (Cummins, Aldwinckle 1983; Webster, Tobutt 1994). At the Institute of Horticulture (former Institute of Pomology and Floriculture) in Skierniewice, Poland, a large number of rootstocks named as the P-series (Jakubowski, Zagaja 2000) was obtained. Many of them as well as some selections introduced from abroad, were included in the rootstock trials conducted at the Department of Pomology of the Warsaw Agricultural University (now University of Life Sciences – WULS-SGGW) (Jadczuk, Wlosek-Stangret 1999; Sadowski et al. 1999; Słowiński, Sadowski 1999; Wrona, Sadowski 1999).

Cultivars used for rootstock testing should show a rather vigorous growth and late and/or low yielding capacity. Such features characterize the Czech cultivar Rubin, which is also known for high quality fruit (Kruczyńska 2008).

The aim of this study was to compare suitability of some Polish and foreign dwarfing rootstocks for the cultivar Rubin on a fertile soil. Preliminary results of this trial were published by Piestrzeniewicz et al. (2006; 2009) and Piestrzeniewicz and Sadowski (2007). Summary of the ten-year results is a subject of this treatise.

MATERIAL AND METHODS

The trial was set up in the experimental orchard of the Warsaw Agricultural University at Warsaw-Wilanów on a silty loam alluvial soil. Apple rootstocks of various genetic origins were compared with M 9 EMLA and M 27, commonly used as standard stocks in that kind of study. The other seventeen rootstocks tested were Arm 18 from Armenia, PB-4 from Belarus, J-TE-G and Unima from the Czech Republic, a series including 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) from Poland, and B 146 and B 491 from Russia.

Maiden trees of the cv. Rubin apple were planted at 3.25 m between rows, in spring 2001. The within-row tree spacing was assigned according to the expected rootstock vigour; in case of new Polish rootstocks it was based on the preliminary studies of Jakubowski (1994) and Jakubowski et al. (1995). Trees on rootstocks supposed to be very dwarfing (M 27, PB-4, J-TE-G, P 22, P 59, P 63, P 64 and P 65) were spaced at 1 m, those expected to be intermediate between very dwarfing and dwarfing (Unima, P 16, No. 280, No. 387, PJ 629 and B 491) – at 1.2 m, and those considered as standard dwarfing (M 9 EMLA, Arm 18, P 62, P 66 and B 146) – at 1.5 m.

The experiment was arranged in a randomised block design with four replications and 5 trees (3 trees on PJ 629) per plot. Trees were trained as standard spindle, with trunks ca. 70 cm high. Regular orchard practices were applied according to the standard recommendations for commercial apple growing in Poland. In the first year after planting all flowers were removed manually. In the following years, chemical and hand thinning of fruitlets was carried out, according to the apparent fruit set on particular trees. In 2007, due to severe spring frost damage of flowers, no crop was obtained. Measurements of trunk diameter were carried out at the height of 40 cm above the ground, followed by conversion of the measurement data to the trunk cross-sectional area (TCSA). Yield from each experimental plot was assessed every year, and subsequently yield per tree and per unit area were computed. Every year, samples of 30 fruits were randomly taken from each plot to estimate the mean fruit mass. The yield efficiency (YE) was calculated as a ratio of cumulative yield for the years 2002–2010 to the TCSA in spring 2011.

All data were elaborated using the analysis of variance, with mean separation by the Newman-Keuls test at the level of significance $\alpha = 0.05$.

RESULTS AND DISCUCSSION

The largest trunk cross-sectional area, at the end of the experiment (in early spring 2011), was noted in the trees on M 9 EMLA and P 62 rootstocks (Table 1). Trees on Arm 18 had significantly smaller TCSA, followed in descending order by B 491, Unima, B 146, P 16, P 66 and P 65, then successively by No. 387, M 27, P 63, P 64, No. 280, P 22, J-TE-G, P 59 and PB-4; the smallest was the TCSA of trees on PJ 629. Relative size of trees on P 62 or M 9 EMLA was about nine times larger than that of trees on PJ 629.

Cropping of trees till 2006 was described in the papers mentioned before. In 2008 most of the trees gave a yield lower than 20 kg per tree with no significant differences due to rootstock (Table 2). A notable exception was P 66, as trees on this rootstock gave the highest yields, being over double of the grand mean for the whole experiment in that year (16.5 kg/tree). In the next year (2009) yields were even higher. Trees on nine rootstocks, including Arm 18, B 146, M 9 EMLA, P 66, P 16, P 62, B 491, Unima and P 63, gave a significantly higher yield than those on PB-4 or on PJ 629. In the last year (2010), cropping of all trees was lower than two years before. Nevertheless, the highest yields were obtained again from trees on P 66. Trees on the remaining rootstocks gave significantly lower yields. Cumulative yield for eight years of bearing (2002–2010, 2007 excluded due to spring frost damage) was the highest from trees on P 66, Arm 18, M 9 EMLA, B 491 and P 16. Significantly lower yields were produced by trees on P 64, P 22, P 59, M 27, PB-4 and J-TE-G. The lowest were the yields of trees on PJ 629.

Yield efficiency (YE) of trees on rootstock P 59, PJ 629, PB-4, No. 280, J-TE-G, P 63, P 66, P 22, No. 387 or P 64 was significantly higher (about 2–3 times) than on M 9 EMLA or P 62 (Table 1). The other rootstocks did not induce YE significantly different from those of the latter two and then some former ones.

Cumulative yield per hectare did not differ significantly between trees on P 63, B 491, P 16, P 66, P 65, P 64, P 22, No. 280, Arm 18, M 9 EMLA and Unima (Table 2). It ranged within 255–334 t/ha. Significantly lower crops were produced only by trees on PJ 629 (< 100 t/ha). Trees on PJ 629 should be planted at definitely narrower in-row spacing; however, probably even then they could not attain full productivity per area unit. Tree vigour was overestimated also in case of several other rootstocks – PB-4, P 59, J-TE-G, P 22, No. 280, No. 387, P 66 and B 146. Trees on those rootstocks should be planted at higher density and then their potential of productivity could be fully manifested. On the other hand, trees on M 9 EMLA, Arm 18, and

Table 1. Indexes of tree size and productivity, depending on rootstock

Rootstock[1]	TCSA – spring 2011 (cm^2)	Relative tree size[2] spring 2011 (%)	Yield efficiency[3] (kg/cm^2)
PJ 629	10.0[a]	11	3.86[de]
PB-4	17.7[ab]	20	3.84[de]
P 59	19.2[abc]	21	4.17[e]
J-TE-G	20.2[abc]	22	3.34[cde]
P 22	28.1[bcd]	31	3.25[cde]
No. 280	28.6[bcd]	32	3.75[de]
P 64	31.6[b–e]	35	2.85[b–e]
P 63	33.5[b–e]	37	3.28[cde]
M 27	33.9[b–e]	38	2.18[abc]
No. 387	35.4[b–f]	39	2.90[b–e]
P 65	38.9[c–g]	43	2.67[a–d]
P 66	46.3[d–g]	51	3.26[cde]
P 16	48.9[efg]	54	2.62[a–d]
B 146	52.8[fg]	59	2.18[abc]
Unima	53.0[fg]	59	2.02[abc]
B 491	56.3[g]	62	2.23[abc]
Arm 18	74.1[h]	82	1.74[ab]
P 62	88.7[i]	98	1.34[a]
M 9 EMLA	90.1[i]	100	1.40[a]

[1]arranged from the top to the bottom of the table, in ascending order according to the values of TCSA 10 years after planting (in spring 2011); TCSA – trunk cross-sectional area; [2]calculated as a ratio of TCSA on a given rootstock to TCSA of trees on M 9 EMLA at the same time (%); [3]calculated as a ratio of cumulative yield/ tree (2002–2010) to the TCSA in spring 2011; [a–i]mean separation (within columns) by the Newman-Keuls test, at $\alpha = 0.05$

P 62, where evident overcrowding of canopies was noted, should be rather planted at lower density.

Significant differences in mean fruit mass, noted in the years 2008–2010, were erratic (Table 3). In 2008 fruits from trees on PJ 629 and PB-4 were smaller than on most of the remaining rootstocks. In 2009, trees on PJ 629, P 59 and PB-4 produced significantly smaller fruits than trees on B 491, Unima and M 9 EMLA. In 2010, trees on 18 rootstocks did not differ significantly in their fruit mass. The average mean fruit mass for the whole period of bearing (2002 to 2010) was significantly lower only for the trees on PJ 629 than on P 63, M 27, No. 387, Arm 18, P 62, P 64, No. 280, B 491, P 16, Unima or on M 9 EMLA.

Innovations of apple industry require implementation of new dwarfing rootstocks. It should be, however, preceded by a careful testing of important scion cultivars on the most promising rootstock under various orchard conditions before the introduction.

The presented research visualized unusual range of apple tree vigour within a group of dwarfing and very dwarfing rootstocks. It was possible thanks to a genetic potential of apple that had been successfully utilised by numerous apple rootstock breeders (Cummins, Aldwinckle 1983; Zagaja et al. 1988; Webster, Tobutt 1994; Jakubowski, Zagaja 2000). Nevertheless, the current trend in Poland as well as in the whole Europe, is toward growing dwarf apple trees exclusively on the M 9 rootstock, in its different clones (Wertheim 1998). In our study, growth of cv. Rubin on the standard M 9 EMLA as well as on P 62, or on Arm 18, was extremely vigorous; trees on those rootstocks developed very large canopies, with excessive bare wood, and needed very troublesome and laborious training. Trees on other rootstocks were significantly smaller, i.e. dwarf or very dwarf; their growth was moderate and productivity satisfactory. Trees on PJ 629 were extremely small, considerably

Table 2. Yield per tree and per unit area, depending on rootstock and year

Rootstock[1]	Yield per tree (kg)				Number trees per ha	Cumulative yield (2002–2010) (t/ha)
	2008	2009	2010	cumulative (2002–2010)		
PJ 629	8.3^{a}	7.3^{a}	5.4^{a}	37.9^{a}	2564 +	97.1^{a}
PB-4	11.2^{ab}	13.6^{ab}	7.8^{ab}	67.5^{b}	3077 +	207.8^{b}
P 59	10.4^{ab}	17.4^{bc}	8.4^{ab}	79.1^{bcd}	3077 +	243.4^{bcd}
J-TE-G	10.2^{ab}	19.5^{bcd}	8.2^{ab}	66.2^{b}	3077 +	203.8^{b}
P 22	12.6^{abc}	19.9^{bcd}	9.8^{ab}	87.7^{b-e}	3077 +	269.8^{b-e}
No. 280	21.0^{bcd}	24.8^{b-f}	14.4^{b}	103.3^{c-f}	2564 +	264.7^{b-e}
P 64	13.8^{abc}	21.4^{b-e}	12.2^{ab}	89.3^{b-e}	3077	274.7^{b-e}
P 63	14.8^{a-d}	26.8^{c-g}	9.4^{ab}	108.6^{def}	3077	334.2^{e}
M 27	11.3^{ab}	21.3^{b-e}	6.2^{ab}	73.9^{bc}	3077	227.5^{bc}
No. 387	16.5^{a-d}	24.7^{b-f}	10.8^{ab}	96.4^{c-f}	2564 +	247.2^{bcd}
P 65	12.1^{ab}	20.5^{bcd}	8.9^{ab}	98.6^{c-f}	3077	303.3^{cde}
P 66	32.5^{e}	32.9^{efg}	19.6^{c}	149.9^{g}	2051 +	307.4^{cde}
P 16	18.3^{a-d}	32.8^{efg}	9.2^{ab}	124.3^{fg}	2564	318.7^{de}
B 146	20.4^{bcd}	36.2^{fg}	11.5^{ab}	113.2^{ef}	2051 +	232.2^{bcd}
Unima	15.7^{a-d}	27.3^{c-g}	7.1^{ab}	99.3^{c-f}	2564	254.5^{b-e}
B 491	24.7^{d}	30.2^{d-g}	7.5^{ab}	124.4^{fg}	2564	319.0^{de}
Arm 18	23.2^{cd}	36.5^{g}	6.5^{ab}	125.2^{fg}	2051 –	256.9^{b-e}
P 62	18.6^{a-d}	32.1^{efg}	6.7^{ab}	109.9^{def}	2051 –	225.4^{bc}
M 9 EMLA	18.4^{a-d}	34.7^{fg}	9.1^{ab}	125.0^{fg}	2051 –	256.4^{b-e}

"+" the vigour of trees on these rootstocks was overestimated, so they should be planted at a higher density (at a narrower in-row spacing); "–" underestimated vigour, hence trees on these rootstocks should be planted at a lower density (at a wider in-row spacing); explanation: see Table 1

smaller than those on the standard very dwarfing M 27. So, PJ 629 is apparently useless for commercial orchards. Special attention should be paid to the new rootstocks bred at the Institute of Pomology and Floriculture at Skierniewice – P 63, P 65 and particularly P 66. These rootstocks as well as the earlier bred P 16 induced high yields per tree as well as high yield efficiency; at a proper planting density, trees of the vigorous cv. Rubin should produce maximum yields per area unit.

Size of the cv. Rubin trees, expressed as TCSA, was interrelated with their yields. It was demonstrated that it clearly refers to trees on very dwarf rootstocks or those between very dwarf and dwarf. However, trees on typically dwarf rootstocks (M 9 EMLA and P 62) did not produce higher yields than those on some stocks of significantly lower vigour. Barritt et al. (1997) illustrated a similar relationship with three cultivars on dwarfing and semi-dwarfing rootstocks. They attributed this phenomenon to the increasing proportion of shaded canopy volume within the large trees.

Reduction of scion vigour by the rootstock or interstock resulted generally in higher tree productivity, expressed usually as a ratio of yield to TCSA of a tree (Parry, Rogers 1972; Zagaja et al. 1988; Barritt et al. 1997; Czynczyk et al. 2010). Our results confirmed this tendency, but some exceptions were also observed. Barritt et al. (1997) and Jakubowski (1999) noted similar inconsistency, so the dwarfing capacity of a rootstock may not be always associated with high tree productivity.

The highest practical value has cumulative yield calculated per orchard unit area. It reaches a maximum value in case of correct choice of both rootstock and tree spacing at particular environmental

Table 3. Mean fruit mass, depending on rootstock and year

Rootstock[1]	Mean fruit mass (g)			
	2008	2009	2010	2002–2010
PJ 629	208[a]	166[a]	226[ab]	196[a]
PB-4	214[ab]	168[a]	197[a]	200[ab]
P 59	244[abc]	164[a]	226[ab]	203[abc]
J-TE-G	263[c]	184[abc]	234[ab]	209[a-e]
P 22	244[abc]	178[ab]	229[ab]	205[a–d]
No. 280	263[c]	199[abc]	239[ab]	229[efg]
P 64	283[c]	190[abc]	227[ab]	228[d–g]
P 63	270[c]	191[abc]	221[ab]	220[b–g]
M 27	277[c]	181[ab]	243[ab]	220[b–g]
No. 387	272[c]	200[abc]	248[b]	223[c–g]
P 65	257[c]	188[abc]	200[a]	214[a–f]
P 66	250[bc]	176[ab]	239[ab]	217[a–g]
P 16	275[c]	201[abc]	233[ab]	234[fg]
B 146	284[c]	187[abc]	230[ab]	215[a–f]
Unima	272[c]	212[bc]	236[ab]	236[fg]
B 491	257[c]	211[bc]	238[ab]	231[efg]
Arm 18	264[c]	189[abc]	214[ab]	222[c–g]
P 62	274[c]	192[abc]	221[ab]	223[c–g]
M 9 EMLA	292[c]	220[c]	238[ab]	240[g]

For eplanation see Table 1

(soil and climatic) conditions. However, it seems rather difficult to predict optimal tree spacing in an experimental approach, as at the time of planting usually limited information on some rootstock traits is available (Zagaja et al. 1989). In this study, according to expectation, trees on some rootstocks were planted at a right density, whereas few others could be planted more densely.

Variability in vegetative growth of trees implicated to some extent a fruit mass. It was previously documented that trees on some very dwarfing rootstocks produced smaller fruit than those on dwarfing or semi-dwarfing ones. Such an example is the rootstock PB-4 (Tomala et al. 2008) as well as PJ 629 in some seasons (Jakubowski 2000). M 9 rootstock, however, had a long lasting reputation as a promoter of large-sized apple fruit (Wertheim 1998). It was found that the majority of rootstocks favoured cv. Rubin fruit mass in a similar extent as M 9 EMLA. Only in some seasons, trees on PJ 629 or PB-4 produced smaller fruit than on the remaining rootstocks. However, the fruit mass reduction would not present a problem in case of a large-fruited cultivar, like cv. Rubin, as the fruit from trees on M 9 EMLA and on some other rootstocks are frequently over-sized.

CONCLUSIONS

– Rootstocks considerably and significantly differentiate cv. Rubin apple tree vigour, yield and yield efficiency, but only slightly the fruit mass.
– Nearly all studied rootstocks significantly reduce cv. Rubin tree vigour and increase productivity in comparison to M 9 EMLA.
– Rootstocks P 16, P 63, P 65, P 66, No. 280 and P 22 seem to be the most suitable for cv. Rubin apple on a fertile soil. In contrast, the least suitable appear the most vigorous rootstocks M 9 EMLA, P 62, and Arm 18.

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