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EARLY PERFORMANCE OF 'MUTSU' APPLE TREES ON DIFFERENT ROOTSTOCKS IN THE LOWER SILESIA REGION

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Abstract. Rootstock has a large impact, inter alia, on the growth of trees, yielding and fruit quality. Despite continuous breeding programmes, M.9 rootstock is still the best rootstock for apple trees. In the spring of 2007, at the Fruit Experimental Station at Samotwór near Wrocław, an experiment was set up, under which several less known rootstocks, grown mainly in Eastern Europe, were evaluated. The subject of the studies were 'Mutsu' trees planted with the spacing of 3.5 m between rows, and the within-row spacing of 0.8 m (PB-4, B.146), 1.2 m (B.491, P 16) and 1.7 m (B.7-35, B.396 and ARM 18). M.9 and M.26 were used as standard rootstocks. Until the fifth year after planting, the most vigorous were trees on the B.7-35 rootstock, while trees grafted on the PB-4 showed the weakest growth. The largest yield was obtained for apple trees grafted on the B.396. Trees growing on the PB-4 had the smallest fruits. Apples from trees grafted on other rootstocks were characterized by a similar mass.

Key words: *Malus* × *domestica*, vigour, blooming, yield, fruit mass

INTRODUCTION

Cultivar is a very important aspect of fruit production in modern apple orchards. The opinion of consumers looking for tasty and attractive fruit and an increase in the competition among fruit growers enriches the offer of cultivars. In the last decade, in the world, including Poland, a lot of attention was paid to cultivars with green-yellow peel, for example 'Mutsu' [Brown and Maloney 2003]. In Western Europe, the cultivars like 'Jonagold' or 'Golden Delicious' occupy a very strong position in the structure of dessert apples. In Poland the spread of cultivar depends inter alia on climate conditions. The most suitable cultivars for warm regions, such as Lower Silesia, include mainly 'Jonagold' and its numerous mutations, 'Golden Delicious', 'Gala' and less known – 'Mutsu'. This cultivar is characterised by precocious and high yields and has large, very tasty fruits [Kruczyńska 1998, Sosna 2007].

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Rootstock has a significant effect on the strength of tree growth, which is especially important in vigorous cultivars, such as 'Mutsu'. For many years the world's most popular dwarf rootstock for apple trees was M.9. It has not only dwarfing effect on trees, but also has a beneficial effect on the crop efficiency and quality of harvested fruit. However, some cultivars, e.g. 'Jonagold', often grow too intensively on it, and the colour development of fruits is not sufficient enough. Despite numerous experiments relating to cultivars and rootstocks, which are conducted around the world, no rootstock better than M.9 has been found yet. In Belgian studies a very promising results were obtained with the Polish P 16 rootstock, on which 'Jonagold' trees grow less intensively, yield equally well, and fruits, although smaller, were characterized by a good colour development [Vercammen et al. 2007]. In the recent years, several new rootstocks were developed in Eastern European countries, e.g. in Russia (B.146, B.491, B.396, B.7-35) and Belarus (PB-4), as well as in Armenia in the South Caucasus (ARM 18). Experiments evaluating the suitability of these rootstocks for various cultivars of apple trees are conducted not only in many European countries [Vercammen 2003, Maas and Wertheim 2004, Bielicki et al. 2006, Samus et al. 2006, Pietranek et al. 2007, Kviklys et al. 2012], but also in the USA [Autio et al. 2003, Marini et al. 2006].

The aim of this study is to evaluate several new rootstocks mainly of Eastern European origin for ‘Mutsu’ trees in climatic conditions of the Wrocław region.

MATERIAL AND METHODS

The experiment was conducted at the Fruit Experimental Station at Samotwór near Wrocław in 2007–2011. Plant material included maiden trees of ‘Mutsu’ cultivar on seven rootstocks, mainly of Eastern European origin. The trees were planted in the spring of 2007, in rows spaced 3.5 m. The within-row tree spacing varied according to the expected rootstock vigour: 0.8 m for PB-4 and B.146 (3571 trees per hectare), 1.2 m for B.491, P 16 and M.9 (2381 trees per hectare) and 1.7 m for B.7-35, B.396, ARM 18 and M.26 (1681 trees per hectare). Trees grafted on M.9 and M.26 rootstocks were used as a standard. The experiment was established in a randomised block design, in four replications, with five trees per plot.

All trees were trained in the form of spindle canopy. Until the third year after planting, the growing shoots have been mainly bent, and since the fourth year pruning has been performed in May after the blossoming. Herbicides were applied in the tree rows, with grassy strips between them. Plant protection was carried out in accordance with the current recommendations of the Orchard Protection Program. In 2007–2011, the following parameters were evaluated: blooming intensity, yield, fruit quality and vigour of trees. Trunk cross-sectional area (TCSA) was calculated on the basis of diameter or circumference since the fourth year after planting, measured 30 cm above the soil level. Besides of aforementioned parameters, number and length of one-year shoots, tree height, and crown width in two directions were recorded. Crown volume was calculated using a formula for cone volume. Crop efficiency coefficients were calculated by dividing the values of cumulative yields by those referring to the tree trunk cross-sectional area in autumn 2011. Every year the root suckers were counted twice and then were pruned. Blooming intensity was estimated visually according to 0–5 scale (0 – tree without flowers; 1 – several inflorescences on a tree, 2 – several dozen inflorescences on a tree; 3 – average tree blooming intensity; 4 – abundant flowering tree; 5 – exceptionally abundant flowering tree). Fruit size was estimated as mean mass of 20 fruits per each tree. In the period since 3 to 6 May 2011, the temperature for 3 consecutive nights dropped down to about minus 3 – minus 5°C destroying a lot of flowers. In order to determine the percentage of flowers and flower buds damaged by frost, 14 inflorescences, 7 from spurs and 7 from shoots over 20 cm long were collected from 5 trees in each replication immediately after frosts. In total it gave approx. 400 flowers for each tested rootstock.

The results of the experiment were analysed statistically, using the ANOVA method (analysis of variance), for the randomised blocks. Significant differences at $\alpha = 0.05$ were calculated using Duncan's multiple range t-test. Percentage data regarding flowers damaged by frost were analysed using transformed values according to Bliss function.

RESULTS AND DISCUSSION

By the fifth year after planting, the rootstocks covered by the study had a significant effect on the vegetative growth of 'Mutsu' trees (Tab. 1). The strongest growth was observed in the case of trees grafted on the B.7-35. They had thicker trunks as compared with those grafted on the M.26 rootstock and formed more dense crowns. A strong growth of 'Sawa' trees on this rootstock was confirmed also by Pietranek et al. [2007]. Trees grafted on B.396 and ARM 18 grew similarly as those grafted on the M.26 rootstock, but were characterized by a significantly stronger growth than the trees on the M.9 rootstock. In other studies conducted in Poland [Jadczuk-Tobjasz et al. 2009, Piestrzeniewicz et al. 2009], Belarus [Kukhto 2010], and in the Baltic states (Lithuania, Latvia and Estonia) [Haak 2006, Univer et al. 2010, Skrivele et al. 2011], trees on these rootstocks were characterized by a growth similar as on the M.9 and were classified as dwarf trees. Under the author's own studies, trees on the PB-4 showed a very weak growth, which has been confirmed in other reports [Samus et al. 2006, Jadczuk-Tobjasz and Zygmuntowska 2009, Piestrzeniewicz et al. 2009, Univer et al. 2010, Kowalczyk and Wrona 2011]. Trees grafted on B.146 and B.491 rootstocks had also thinner trunks and smaller crowns than trees on the M.9. Similar results were obtained by Autio et al. [2003], Maas and Wertheim [2004], and Marini et al. [2006]. In English studies [Webster and Hollands 1999], trees growing on B.146 were smaller even than those on M.27. However, in the studies conducted in Estonia [Haak 2006], growth of trees on B.146 was much stronger than in the case of trees on the M.9. Similarly as in the studies conducted by Webster and Hollands [1999], also in the author's own experiment no significant difference was found for the measured parameters of tree growth on the P 16 as compared with M.9. Different results were obtained in studies of other researchers, in which growth of trees on the Polish rootstock was significantly weaker [Gruca 1999, McAfee and Rom 2003, Sosna 2005, Porębski et al. 2009]. Differentiated impact of the studied rootstocks on growth of trees can be explained by different climatic and soil conditions, in which they were growing. Also reaction of a particular cultivar on spe-

Table 1. Biometric measurements of ‘Mutsu’ trees depending on the rootstock

Rootstock	Total number of shoots per tree 2007–2009	Total lenght of shoots (cm $tree^{-1}$) 2007–2009	Trunk cross-sectional area (cm^2) autumn 2011	Volume of crown (m^3) autumn 2011	Total number of root suckers per tree 2007–2011
M.26 – standard	65.5 c*	1977 cd	23.1 d	4.0 d	0.0 a
B.7-35	79.3 d	2606 e	31.9 e	4.2 d	17.8 c
B.396	88.7 d	2398 de	22.4 d	3.7 d	0.1 a
ARM 18	78.1 d	2152 de	21.0 d	3.7 d	10.5 b
M.9 – standard	56.3 bc	1599 bc	15.7 c	2.9 c	0.2 a
B.491	53.4 b	1201 ab	10.3 ab	2.0 ab	1.7 a
P 16	57.2 bc	1418 b	12.2 bc	2.4 bc	2.8 a
B.146	57.3 bc	1218 ab	9.6 ab	1.8 ab	0.7 a
PB-4	37.0 a	849 a	7.1 a	1.5 a	1.0 a

*Means indicate by the same letter within the columns do not significantly differ at $P \leq 0.05$ according to Duncan’s t-test cific rootstocks can be different. The highest number of root suckers was formed by the most vigorous trees on B.7-35. Trees on ARM 18 had a significantly lower number of such shoots. Other tested rootstocks were characterized by a similar, very small number of suckers, which was also confirmed by McAfee and Rom [2003], and Czynczyk et al. [2010]. According to Webster and Hollands [1999], apple trees growing on B.146 had more suckers than those on M.27.

In the second year after planting, trees on B.7-35 formed the lowest number of flowers, while trees on PB-4, B.146 and B.491 bloomed most intensively (Tab. 2). These differences were significant as compared with M.26 and M.9. A year later, the blooming intensity of trees was similar. Only trees on the B.491 had more flowers – at the level of the M.9 control rootstock. Differences in intensity of trees blooming between the studied rootstocks were not observed any more in the next two years. A similar situation in the third year after planting was recorded by Porębski et al. [2005]. The frosts, which occurred in early May 2011, i.e. during full blooming of 'Mutsu', damaged many flowers and flower buds. The lowest number of such damage was recorded in the case of the weakest growing trees grafted on B.146 and PB-4 rootstocks (respectively 49.8 and 57.6%). Freezing of flowers on trees grafted on other studied rootstocks were similar and exceeded 70–80%. This fact can be explained by a later blossoming of trees on super-dwarf rootstocks, which formed a lot of flower buds on shoots over 20 cm long. Most of them were not developed yet when the frost occurred. No information on this subject was found in the available literature.

Table 2. Blooming intensity and spring frost damage of 'Mutsu' flower buds depending on the rootstock

Rootstock	Mean number of flowers per tree 2008	Blooming intensity (scale 0–5)			% of frozen flower buds 2011
		2009	2010	2011	
M.26 – standard	14.2 bc*	3.4 a	1.4 a	3.7 a	82.7 cd
B.7-35	3.3 as	3.6 ab	0.9 a	3.7 a	85.0 cd
B.396	9.1 ab	3.7 ab	1.6 a	4.0 a	80.8 cd
ARM 18	8.3 ab	3.6 ab	1.1 a	3.8 a	87.1 d
M.9 – standard	15.4 bc	3.9 bc	0.7 a	3.9 a	75.2 cd
B.491	30.4 d	4.3 c	1.0 a	3.9 a	78.7 cd
P 16	21.1 cd	3.8 ab	1.0 a	3.7 a	71.8 bc
B.146	45.6 e	3.8 ab	1.5 a	3.8 a	49.8 a
PB-4	57.0 f	3.7 ab	1.6 a	3.8 a	57.6 ab

*see Table 1

Trees of 'Mutsu' started yielding already in the second year after planting (Tab. 3). The largest amount of fruits was harvested from the most abundantly blooming apple trees on PB-4, B.146, B.491 and P 16 – from 1.0 to 1.8 kg. These yields were higher than in the case of the standard M.9 – only 0.3 kg. The stronger growing rootstocks

Table 3. Mean yield, fruit mass and crop efficiency coefficient (CEC) of 'Mutsu' trees depending on the rootstock

Rootstock	Yield (kg tree^{-1})				Cumulative yield 2008–2011		Mean fruit mass (g) 2009–2011	CEC (kg · cm^{-2}) 2007–2011
	2008	2009	2010	2011	(kg tree^{-1})	(t ha^{-1})		
M.26 – standard	0.3 a*	13.6 b-d	3.7 ab	6.1 ab	23.7 ab	39.7 a	261 bc	1.03 ab
B.7-35	0.1 a	16.4 d	2.0 a	4.5 a	23.0 ab	38.5 a	254 bc	0.72 a
B.396	0.4 ab	20.3 e	6.4 b	9.8 c	36.9 c	61.9 cd	272 c	1.65 cd
ARM 18	0.2 a	15.1 cd	1.2 a	8.9 bc	25.4 b	42.7 ab	260 bc	1.21 a-c
M.9 – standard	0.3 a	11.0 b	0.9 a	6.9 a-c	19.1 ab	45.2 a-c	250 bc	1.22 bc
B.491	1.2 cd	9.8 ab	1.5 a	7.3 a-c	19.8 ab	47.1 a-c	239 ab	1.92 de
P 16	1.0 bc	11.9 bc	2.2 a	9.3 bc	24.4 ab	58.2 bc	251 bc	2.00 de
B.146	1.5 cd	10.2 ab	2.0 a	8.0 a-c	21.7 ab	77.1 d	249 bc	2.26 e
PB-4	1.8 d	7.0 a	2.8 a	5.0 a	16.6 a	59.3 bc	221 a	2.34 e

*see Table 1

estimated in the study yielded in this year at the similar level as the standard M.26. After abundant fruiting in 2009, 'Mutsu' trees entered into alternation, and a year later they bloomed and yielded very weakly. The differences in yields in those years, as compared with the standard rootstocks, were usually small and not statistically proven. In 2011 the blooming of trees was at a similar level as in 2009, but crops after the frosts that occurred in May were much lower. In the group of more vigorous rootstocks, trees on B.396 were characterized by the best fruiting, while in the group of dwarf rootstocks there were no statistical differences as compared with the standard M.9. Until the fifth year after planting, the highest amount of fruits was harvested from trees on the B.396. Trees on ARM 18 and B.7-35 yielded similarly to those on the M.26. Trees on PB-4 were characterized by the lowest crop efficiency, but as compared with the standard M.9 the difference was not significant. However, significantly lower yields from trees on PB-4 were obtained by other researchers [Bielicki et al. 2006, Jadczuk-Tobjasz and Zygmuntowska 2009, Univer et. al. 2010]. In the experiment conducted by Piestrzeniewicz et al. [2009] the 'Rubin' cultivar on ARM 18 fruited at a level similar to that on the M.9. On the other hand, Pietranek et al. [2007] harvested the lowest amount of apples from 'Sawa' trees grafted on the B.7-35. In author's own studies, after conversion of the yield into the unit area, trees growing on B.146 and B.396 appeared to have the highest crop efficiency (respectively 77.1 and 61.9 t ha^{-1}). Trees on other rootstocks fruited at a level similar to those on M.26 and M.9. A high crop efficiency of trees on B.146 and B.396 was also confirmed by Vercammen [2003], Kowalczyk and Wrona [2011] and Kviklys et al. [2012]. Like in the experiments of Gruca [1999] and Czynczyk et al. [2010], the crop efficiency of 'Mutsu' on P 16 was similar to that on M.9. On the other hand, much weaker fruiting of trees on this Polish rootstock was recorded by Sosna [2005] and Porębski et al. [2009].

The studied rootstocks had a little effect on the mean mass of 1 fruit (Tab. 3). As compared with the standard M.9 and M.26, only apples from trees growing on PB-4 were significantly smaller. It could be caused by a greater concentration of fruits in crowns of small trees, and thus a higher competition for nutrients. Other researchers [Jadczuk-Tobjasz and Zygmuntowska 2009, Kukhto 2010, Univer et al. 2010] also report that fruits on that rootstock are smaller. Many authors found that rootstocks did not affect the mass of harvested apples. Fruits with roughly the same size as fruits from trees grafted on M.9 and M.26 were observed for trees on the B.396 [Jadczuk-Tobjasz et al. 2009, Kviklys et al. 2012], as well as on PB-4, B.491, B.146, ARM 18 and P 16 [Bielicki et al. 2006, Piestrzeniewicz et al. 2009, Czynczyk et al. 2010, Kowalczyk and Wrona 2011]. In turn, the problem associated with the fact that fruits on B.146 and P 16 are smaller is indicated by Webster and Hollands [1999], Autio et al. [2003], Sosna [2005], Dierend and Bier-Kamotzke [2009].

The calculated crop efficiency coefficients were differentiated and generally higher for the group of dwarf rootstocks (Tab. 3). As compared to M.26, the highest coefficient was recorded for the B.396, whereas in respect of trees grafted on more dwarf rootstocks this coefficient was in each case significantly higher than for M.9. Reports on this subject in the available literature are not unambiguous. Similar results as in the author's own studies were obtained for the B.396 by Kowalczyk and Wrona [2011], for PB-4 – by Jadczuk-Tobjasz and Zygmuntowska [2009], and for P 16 – by Czynczyk et al. [2010]. For the rootstocks evaluated under the experiment other authors report crop efficiency coefficients at a lower or similar level as compared with M.9 or M.26 [Sosna 2005, Bielicki et al. 2006, Porębski et al. 2009, Kviklys et al. 2012]. Marini et al. [2006] obtained the lowest crop efficiency coefficients for the B.491.

CONCLUSIONS

1. Biometric measurements showed the strongest growth in the case of trees grafted on the B.7-35 rootstock, while trees grafted on the PB-4 showed the weakest growth.
2. The highest number of root suckers was observed for trees grafted on the B.7-35 and ARM 18. Trees on the other rootstocks produced very few root suckers.
3. Until the fifth year after planting, the largest yield per tree was observed for trees on B.396, while the largest yield per unit area – for trees on B.146.
4. Trees grafted on the PB-4 had the smallest fruits. Apples from trees growing on other rootstocks were characterized by similar mass.
5. Flowers and flower buds of trees grafted on B.146 and PB-4 appeared to be most resistant to spring frosts.
6. On the basis of the preliminary studies, which focused on the amount and quality of the harvested crop, the B.396 and B.146 can be considered as the most promising rootstocks for the 'Mutsu' cultivar.

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WSTĘPNA OCENA DRZEW JABŁONI ODMIANY ‘MUTSU’ NA RÓŻNYCH PODKŁADKACH W WARUNKACH DOLNEGO ŚLĄSKA

Streszczenie. Podkładka wywiera duży wpływ m.in. na wzrost drzew, plonowanie oraz jakość owoców. Pomimo nieustannych poszukiwań ciągle najlepszą podkładką dla jabłoni jest M.9. Wiosną 2007 r. w Stacji Badawczo-Dydaktycznej w Samotworze pod Wrocławiem założono doświadczenie, w którym ocenianych jest kilka mniej znanych podkładek wyhodowanych głównie w Europie Wschodniej. Przedmiotem badań były drzewa odmiany ‘Mutsu’ posadzone w rozstawie 3,5 m między rzędami, a w rzędzie co 0,8 m (PB-4, B.146), 1,2 m (B.491, P 16) i 1,7 m (B.7-35, B.396 i ARM 18). Za podkładki standardowe posłużyły M.9 i M.26. Do piątego roku po posadzeniu najsilniejszym wzrostem charakteryzowały się drzewa rosnące na podkładce B.7-35, natomiast najsłabiej rosły na PB-4. Najbardziej plenne były jabłonie na B.396. Najdrobniejsze owoce miały drzewa na PB-4. Jabłka z drzew okulizowanych na pozostałych podkładkach charakteryzowały się zbliżoną masą.

Słowa kluczowe: *Malus* × *domestica*, siła wzrostu, kwitnienie, plonowanie, masa owocu

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