RESULTS OF GROWING THREE APPLE CULTIVARS GRAFTED ON A NUMBER OF POLISH AND ENGLISH ROOTSTOCKS AND THEIR SUBCLONES

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A B S T R A C T

The effect of the subclones of M.9 (M.9 T 337, Pajam 1, RN 29) and the subclones of P 22 (P 22/K, P 22/A, P 22/J), and some of the new Polish rootstocks (P 59, P 60, P 61 and P 62) on the growth and yield of 'Jonagold', 'Ligol' and 'Gala' apple trees was studied in a field experiment over a period of 10 years. The growth vigour of these cultivars on the M.9 subclones was similar to that observed on the standard rootstock M.9 EMLA and among the subclones of P 22, and was similar to those for the standard P 22. Trees of 'Jonagold' grafted on the new Polish rootstock P 62 were significantly less vigorous than those on M.9 EMLA. Trees grafted on P 61 were significantly smaller than the standard trees on P 22. The smallest trees of the tested cultivars were obtained on P 59. In the group of semi-dwarfing rootstocks, the smallest trees were on P 60 and the largest on P 14. The cumulative yields of tested cultivars on the subclones of M.9 were similar to that on standard rootstocks of M.9 EMLA. The cumulative yields of tested cultivars on subclones of P 22 were similar to standard P 22. In the semi-dwarfing group, the highest yields for 'Jonagold' and 'Gala' trees were on P 60 and for 'Ligol' trees on P 14. The values of the yield efficiency index for the subclones of M.9 and new rootstock P 62 were similar to those for M.9 EMLA. Among the subclones of P 22 and new rootstock P 61, the values of this index were similar to those for the standard P 22 rootstocks. The highest yield efficiency index among the semi-dwarfing rootstocks was obtained for P 60. The tested subclones of M.9 and P 22 and new rootstocks P 61 and P 62 produced no significant effect on the size, weight and colouring of apples, with the exception of 'Jonagold' and 'Gala' trees growing on P 59. In 2004, the apples on this rootstock were significantly smaller.

Key words: apple cultivar, rootstock, subclone, growth, yield efficiency, fruit quality

INTRODUCTION

Most fruit growers in Poland are looking for the ideal apple tree that does not grow too vigorously, requires little labour input, and produces a good crop of high quality apples every year. Such trees can be obtained by using dwarfing rootstocks for their production (Czynczyk, 1995; 2000; Mika et al., 2000; Czynczyk and Jakubowski, 2004). There is, however, no universal rootstock for all kinds of soil, climatic conditions, or the various apple cultivars. On light soils (the predominant type of soil in Poland), these requirements are satisfied by trees grafted on semi-dwarfing rootstocks such as M.26, P 14 and P 60 (Czynczyk, 1995; Skrzyński and Poniedziałek, 1999; Czynczyk and Piskor, 2000; Bielicki et al., 2002). However, trees grafted on these rootstocks often grow too strongly (vigorously) in more fertile soils. The rootstock M.9, the most commonly used rootstock in the countries of Western Europe, is also recommended for cultivation in Poland (Czynczyk et al., 2001). However, to grow trees on this rootstock in Poland can sometimes be risky (Czynczyk, 1995; Webster, 1999; Wertheim, 1998). For example, the root system of the trees growing on M.9 could be damaged by low temperatures during winters without snow. Trees on P 22, on the other hand, are more winter hardy, but they require a more fertile soil, irrigation and heavy thinning of fruitlets to produce good quality fruits. So far, the usefulness of the subclones of the M.9 and P 22 rootstocks in growing the more economically important apple cultivars in Poland ('Jonagold', 'Ligol' and 'Gala') has not been tested over a long period of time. Can apple trees grafted on the subclones of M.9 and P 22, and grown in light soils, continue to bear fruits of good quality as the trees age? The aim of the study presented here was to determine the orchard performance of 'Jonagold', 'Ligol' and 'Gala' apple cultivars grafted on different rootstocks, mainly on subclones of the two rootstocks: M.9 and P 22. In this trial, we determined their adaptability to the variable conditions of Poland's climate, paying particular attention to tree health and growth vigour, crop size and fruit quality on ageing trees.

MATERIAL AND METHODS

The orchard used for this experiment was set up in the autumn of 1994 at the Experimental Orchard of the Research Institute of Pomology and Floriculture in Dąbrowice, central Poland. One-year-old maidens grafted on the subclones of M.9 and P 22 rootstocks, and also on the dwarfing rootstocks: P 14, P 59 and P 60 as well as P 61 and P 62 which were recently bred at the Institute of Pomology and Floriculture (Jakubowski, 1999; Jakubowski and Zagaja, 1999). All of the rootstocks were classified into three groups. The first group consisted of strongly dwarfed trees on P 59, P 61 and P 22 (as standard) and its three subclones: P 22/K (mother plants propagated

in vitro, a rootstock intermediate in character), P 22/A (an adult subclone with poor rooting ability, without spines in stoolbeds), and P 22/J (a juvenile subclone with very good rooting ability, a few spines and a significantly higher number of layers in stoolbeds). The second group consisted of various subclones of M.9; M.9 T 337, Pajam 1, RN 29 and new rootstock P 62, whilst the third group included the semi-dwarfing rootstocks: P 14, P 60 and M.26 (Tab. 1). The control function was fulfilled by trees grafted on the P 22, M.9 EMLA and M.26 rootstocks commonly used in the production of apple trees in Poland. The orchard was located on a sandy loam podsolic soil overlaying loam. The experimental trees were planted according to a randomized block design with 3 sub-blocks for each cultivar, in 4 replications and 3 trees per a plot. Strongly dwarfed trees were planted at a distance of 4.0 x 1.5 m, dwarf trees at 4.0 x 1.75 m, and semi dwarfed at 4.0 x 2.0 m (Tab. 1). The trees were trained in the slender spindle bush system. Fertilization, soil cultivation and orchard protection procedures were applied according to the recommendations for commercial orchards. The following observations and measurements were recorded: the health status of trees, trunk circumference, yield, and fruit size and quality. In 2003 and 2004, fruit quality was assessed using an electronic sorting machine manufactured by Greef-Holland. The results were statistically analyzed using the variance analysis method. To assess the significance of the differences between means, Duncan's t-test was used at the 5% level of significance. The significance of the differences was assessed separately for the rootstock sub-blocks, which represented the specific groups of rootstocks (Tab. 1).

RESULTS AND DISCUSSION

Tree health

During the ten-year-long period of tree growth, there was no loss of trees due to frost damage to the cultivar or the root system. The highest number of trees of the cultivars 'Ligol' and 'Gala' were lost as a result of them falling over during periods of strong winds while carrying a heavy crop. Out of the 17 trees of 'Ligol' planted, the following numbers were lost: on P 22/J and P 22/K – 3 trees, on M.9 RN 29 – 3 trees, on M.9 EMLA – 2 trees, on P 59 – 2 trees and on P 60 – 2 trees and M 26 – 1 and Pajam 1 – 1. A high number of lost trees of the cultivar 'Gala' was noticed on P 22 – 3 trees, M.9 RN29 – 3 trees, P 59 – 2 trees, and Pajam 1 – 2 trees (Tab. 2 and 3). The relatively large numbers of lost tress of the cultivars 'Ligol' and 'Gala' show that strongly dwarfing rootstocks, such as P 22 and its subclones, P 59, and some subclones of M.9, had poorly developed root systems. The poor rooting ability of trees growing on very dwarfing rootstocks corresponds with the observations made by Webster (1999) and Wertheim (1998). Six out of the 17 lost trees of the cultivar 'Ligol' and

Table 1. Trunk cross-sectional area, yield, yield efficiency and quality of 'Jonagold' fruit from trees grown on the subclones of M.9 and P 22, and new dwarfing rootstocks

Rootstocks	Number of trees lost out of 12 plants	TCA in 2004 [cm^2]	Total yield in kg/tree			Yield efficiency [kg cm^{-2} TCA]	Weight of 100 fruits [kg]		% of fruits with diameter > 7 cm		% of fruits with blush over > 50% of skin	
			1996-2001	1992-2004	1996-2004		2003	2004	2003	2004	2003	2004
P 22**	**0**	**59.13c***	**99.7bc**	**50.0b**	**149.7b**	**2.62a**	**17.4a**	**25.3b**	**91.0a**	**99.1b**	**50.0a**	**87.2b**
P 22/K	1	52.17c	100.4bc	49.1b	149.5b	3.13a	16.1a	27.3b	79.6a	100.0b	62.9ab	88.2b
P 22/A	2	60.40c	105.7c	52.0b	157.7b	2.64a	17.1a	27.3b	85.8a	100.0b	62.2ab	86.9b
P 22/J	0	54.94c	102.4c	54.2b	156.6b	2.92a	18.4a	26.9b	93.3a	100.0b	63.6ab	91.2b
P 59	1	16.44a	44.7a	26.5a	71.2a	4.76b	17.1a	15.3a	82.5a	54.5a	77.7b	24.7a
P 61	1	37.86b	84.2b	51.9b	136.1b	3.73a	17.2a	27.6b	87.4a	99.8b	38.0a	86.2b
M.9 EMLA**	**0**	**72.76b**	**120.9b**	**60.4a**	**181.3ab**	**2.54ab**	**20.9b**	**28.7ab**	**98.0a**	**96.2ab**	**59.3a**	**61.3a**
M.9 T 337	1	76.31b	126.3b	62.0a	188.3b	2.49ab	20.2ab	26.9ab	96.5a	99.1b	51.0a	82.2a
Pajam 1	0	73.17b	118.8b	60.1a	178.9ab	2.50ab	19.7ab	30.36b	97.0a	100.0b	57.1a	68.0a
RN 29	1	73.94b	104.9ab	52.8a	157.7ab	2.17a	20.1ab	26.1a	95.8a	99.3b	64.6a	84.4a
P 62	0	55.36a	96.6a	55.0a	151.6a	2.83b	18.1a	25.7a	94.4a	91.1a	63.1a	78.9a
M.26**	**1**	**96.05b**	**120.2a**	**58.4a**	**178.6a**	**1.92a**	**22.1a**	**24.7a**	**98.5a**	**97.0a**	**76.0a**	**39.2a**
P 14	0	118.28c	125.5a	65.9a	191.4ab	1.67a	22.2a	24.9a	99.3a	98.4a	75.0a	29.2a
P 60	0	77.81a	128.3a	80.3a	208.6b	2.70b	19.5a	24.9a	94.6a	99.8a	63.2a	56.4a

*Averages followed by the same letter do not differ significantly at p = 0.95 (Duncan's multiple range test)
** standard rootstocks
K – stoolbeds established from in vitro propagated mother plants
A – adult subclone
J – juvenile subclone

Table 2. Trunk cross-sectional area, yield, yield efficiency and quality of 'Ligol' fruit from trees grown on the subclones of M.9 and P 22, and new dwarfing rootstocks

Rootstocks	Number of trees lost out of 12 plants	TCA in 2004 [cm^2]	Total yield in kg/tree			Yield efficiency [kg cm^{-2} TCA]	Weight of 100 fruits [kg]		% of fruits with diameter >7cm		% of fruits with blush over >50% of skin	
			1996-2001	19922004	1996-2004		2003	2004	2003	2004	2003	2004
P 22**	**0**	**40.28c***	**97.1b**	**44.5bc**	**141.6bc**	**3.62a**	**17.8a**	**22.5a**	**91.2ab**	**96.2a**	**88.4a**	**91.7a**
P 22/K	3	44.72c	105.0b	48.3c	153.3c	3.55a	22.9b	30.4b	99.35b	97.5a	88.5a	80.2a
P 22/A	0	39.97c	105.4b	50.9c	156.3c	3.92a	16.1a	21.7a	78.0ab	92.9a	83.1a	87.1a
P 22/J	3	30.84b	91.9b	35.5b	127.4b	4.18a	15.1a	23.1ab	73.0ab	91.6a	76.8a	95.9a
P 59	2	11.43a	56.5a	17.2a	73.7a	6.60b	13.6a	26.0ab	65.0a	93.5a	79.5a	94.5a
M.9 EMLA**	**2**	**56.14a**	**128.6a**	**68.2ab**	**196.8a**	**3.54a**	**20.9a**	**30.5a**	**96.9a**	**91.9a**	**74.0a**	**73.8a**
M.9 T 337	0	52.67a	132.7a	67.6ab	200.3a	3.87a	21.5a	26.9a	99.3a	97.2ab	83.3a	76.6a
Pajam 1	1	54.87a	125.3a	54.6a	179.9a	3.34a	21.7a	26.9a	99.6a	100.0b	87.5a	100.0a
RN 29	3	55.86a	110.8a	75.7b	186.5a	3.40a	19.1a	27.2a	94.6a	100.0b	79.0a	92.2a
M.26**	**1**	**73.91b**	**136.3a**	**64.7a**	**201.0a**	**2.75a**	**23.0a**	**27.4a**	**99.4a**	**91.5a**	**82.1a**	**77.7a**
P 14	0	84.00c	141.6a	61.9a	203.5a	2.45a	19.7a	31.5a	98.2a	93.5a	84.8a	90.5a
P 60	2	58.26a	127.3a	64.4a	191.7a	3.33b	21.3a	24.2a	99.3a	88.9a	89.9a	89.0a

*, ** For explanation, see Table 1

Table 3. Trunk cross-sectional area, yield, yield efficiency and quality of 'Gala' fruit from trees grown on the subclones of M.9 and P 22, and new dwarfing rootstocks

Rootstocks	Number of rees lost out of 12 plants	TCA in 2004 [cm^2]	Total yield in kg/tree			Yield effi-ciency [kg cm^{-2} TCA]	Weight of 100 fruits [kg]		% of fruits with diameter >7cm		% of fruits with blush over >50% of skin	
			1996-2001	1992-2004	1996-2004		2003	2004	2003	2004	2003	2004
P 22**	**3**	**35.41c***	**55.4b**	**68.8b**	**124.4bc**	**3.63a**	**14.0a**	**14.5ab**	**49.8a**	**58.6ab**	**82.0ab**	**62.0a**
P 22/K	0	34.89bc	61.2b	75.8b	137.0c	3.85a	13.6a	14.1ab	45.4a	55.7ab	87.2b	63.9ab
P 22/A	2	27.65b	48.3b	54.4b	102.7b	3.85a	12.5a	16.8b	29.5a	72.5b	90.5b	81.5b
P 22/J	0	37.46c	57.9b	60.1b	118.0bc	3.22a	12.9a	14.9ab	32.3a	58.8ab	73.6a	70.3ab
P 59	2	14.64a	34.2a	24.1a	62.3a	4.53a	12.3a	13.0a	20.8a	29.1a	93.0b	79.3ab
M.9 EMLA**	**1**	**42.77ab**	**72.9a**	**90.0a**	**162.9a**	**3.96a**	**14.8a**	**15.4a**	**60.7a**	**64.3a**	**82.7a**	**71.1a**
Pajam 1	2	40.83a	66.8a	84.2a	151.0a	3.73a	12.9a	16.4a	37.5a	72.0a	74.6a	69.5a
RN 29	3	50.16b	74.2a	89.2a	163.4a	3.26a	14.1a	16.7a	49.5a	82.3a	78.2a	80.0a
M.26**	**1**	**54.43a**	**76.5a**	**99.0a**	**175.5a**	**3.28a**	**12.4a**	**16.8a**	**26.4a**	**83.6a**	**67.3a**	**56.9a**
P 14	1	61.37a	106.4c	99.1a	205.5b	3.46ab	11.2a	17.2a	7.0b	81.4a	73.1a	80.7a
P 60	1	53.21a	93.3b	113.5a	206.8b	3.93b	12.8a	15.9a	31.2a	73.0a	66.1a	61.6a

*, ** For explanation, see Table 1

three trees of the cultivar 'Gala' had an on-stem infection with Nectria canker. The bark and wood of 'Ligol' trees is more sensitive to this disease than are those of 'Jonagold' trees. The higher yield efficiency index of the cultivars 'Ligol' and 'Gala' was also a factor contributing to the trees falling over because of a heavy fruit crop. Only eight 'Jonagold' trees were lost and they were lost by accident.

Tree vigour

After ten years, the weakest growth was shown by those trees of the three cultivars that were growing on P 59. Significantly smaller trees of the cultivar 'Jonagold' in comparison with the trees growing on the traditionally propagated rootstock P 22 were also obtained on P 61. Trees growing on the subclones of P 22 were similar in size to the trees growing on the standard rootstock P 22 (Tab. 1-3). After ten years, the relationship between the size of ten-year-old trees on the subclones of P 22 was almost the same as that previously noted by Czynczyk et al. (2004). Within the group of typically dwarfing rootstocks, 'Jonagold', 'Ligol' and 'Gala' trees on the subclones of M.9, were similar in size. The most vigorously growing trees of 'Jonagold' were obtained on the M.9 T 337 subclone, whereas the significantly smaller trees of 'Jonagold' were obtained on the newly bred P 62 rootstock. Small differences found in the group of the M.9 subclones are in line with the reports by Jadczuk and Włosek-Stangret (1999), Kurlus and Ugolik (1999), Engel (1999) and Sadowski et al. (2004). Within the group of the semi-dwarf trees, all the tested cultivars grew more vigorously on P 14 in comparison with the trees on M.26 – the standard rootstock. The 'Jonagold' and 'Ligol' trees on P 60 were significantly smaller than the trees growing on M.26. The obtained results relating to the vigour of dwarf and semi-dwarf trees correspond with the results presented by Bielicki et al. (2002), Czynczyk et al. (2004), Czynczyk and Bartosiewicz (2003), and Jadczuk (2000).

Yields

All the trees of the three apple cultivars began bearing fruit in the second year after planting. Yield per tree in the following years corresponded to the size of the tree. After ten years, within the group of the least vigorously growing trees, the total yields for the three cultivars on the subclones of P 22 were similar in size to the total yields obtained from the control trees on P 22 (Tab. 1-3). The lowest total yields of all the cultivars were obtained from the smallest trees on P 59. A lower yield for 'Jonagold' was also obtained from the trees growing on the new P 61 rootstock. In the group of the typical dwarf trees, the total yields for all the tested cultivars were similar in size to the total yields obtained from the standard trees growing on M.9 EMLA. The obtained results relating to the total yields of the three

cultivars growing on the dwarfing rootstocks followed a trend similar to those presented earlier by Jakubowski (1999), Bielicki et al. (2002) and Czynczyk et al. (2004). Within the group of semi-dwarf trees, the total yields for 'Jonagold' and 'Gala' trees on P 60 were significantly higher in size compared with the cumulative yields obtained from the trees on M.26. The cumulative yields for 'Ligol' trees on P 60 and P 14 were similar in comparison with the yield obtained from the trees on M.26. Yield data related to the rootstocks in this experiment correspond with those presented previously by Bielicki et al. (2002) and Czynczyk et al. (2004). The total yield efficiencies (in kg per cm^2 of trunk cross--sectional area) within the group of the trees growing on the subclones of P 22 were similar to the yield efficiencies obtained from the standard trees on P 22 (Tab. 1-3). Trees of all the tested cultivars on P 59 and 'Jonagold' on P 61 also had a higher yield efficiency index than the standard trees on P 22. Within the group of dwarf trees on M.9 EMLA and its subclones, and trees on the new P 62 rootstock, all had very similar numerical values of the yield efficiency index. In the group of semi-dwarf trees of all cultivars, the highest yield efficiency index was obtained for the trees on the P 60 rootstock. The results concerning the yield efficiency index for the different rootstocks are in agreement with the data presented earlier by Czynczyk and Bartosiewicz (2003), and Czynczyk et al. (2004). The size and weight of the fruits of all cultivars were similar for all the rootstocks with the exception of P 59 (Tab. 1-3). In 2004, 'Jonagold' trees on the P 59 rootstock produced significantly smaller fruits which also had the least red blush. Fruitlets on 'Jonagold' trees growing on P 59 have to be thinned more heavily. Winter and summer pruning treatments of all the tested cultivars on P 59 have to be precisely done.

CONCLUSIONS

1. Trees growing on the subclones of P 22 and on the new rootstock P 61 were similar in size to the trees growing on the standard rootstock P 22. Significantly smaller trees of all cultivars in comparison to P 22, were obtained on P 59.
2. The trees grafted on the subclones of M.9 rootstocks have a growth vigour similar to the standard trees grown on M.9 EMLA. Trees of the cultivar 'Jonagold' on the new rootstocks P 62, were significantly smaller than the trees on M.9 EMLA.
3. Within the group of semi-dwarf trees, all tested cultivars grew less vigorously on P 60 and more vigorously on P 14 in comparison with the trees on M.26.
4. The cumulative yields of tested cultivars on the subclones of M.9 were similar to those on the standard rootstock M.9 EMLA. The cumulative yields of tested cultivars on subclones of P 22 were similar to the standard P 22. In the semi-dwarfing group, the

highest yields for 'Jonagold' and 'Gala' trees were produced on P 60 and for 'Ligol' trees on P 14. The values of the yield efficiency index for the subclones of M.9 and the new rootstock P 62 were similar to those for M.9 EMLA. Among the subclones of P 22 and the new rootstock P 61, the values of this index were similar to those for the standard P 22 rootstock. The highest yield efficiency index among the semi-dwarfing rootstocks was obtained for P 60.

5. The tested subclones of M.9 and P 22, and new rootstocks P 61 and P 62 produced no significant effect on the size, weight or colouring of apples, with the exception of 'Jonagold' and 'Gala' trees growing on P 59.

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WYNIKI UPRAWY TRZECH ODMIAN JABŁONI SZCZEPIONYCH NA KILKU POLSKICH I ANGIELSKICH PODKŁADKACH ORAZ ICH PODKLONACH

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S T R E S Z C Z E N I E

Przez 10 lat badano wpływ podklonów podkładki M.9 EMLA (M.9 T 337, M.9 Pajam 1 i M.9 RN 29) i podklonów P 22 (P 22/K, P 22/A i P 22/J) oraz kilku nowych podkładek polskich (P 59, P 60, P 61 i P 62) na wzrost i owocowanie trzech odmian jabłoni: 'Jonagold', 'Ligol' i 'Gala'. Wielkość drzew trzech odmian na podklonach podkładki jabłoni M.9 EMLA i P 22 była zbliżona do wielkości drzew rosnących na standardowych podkładkach M.9 EMLA i P 22. Drzewa odmiany 'Jonagold' rosnące na nowej podkładce P 62 były istotnie mniejsze niż drzewa na M.9 EMLA, a rosnące na P 61 były istotnie mniejsze niż rosnące na P 22. Najmniejsze drzewa

badanych odmian otrzymano na P 59. W grupie drzew rosnących na podkładkach półkarłowych najmniejsze drzewa otrzymano na P 60, a największe na P 14. Sumy plonów otrzymane z drzew trzech odmian rosnących na podklonach M.9 EMLA i P 22 były wielkością zbliżone do plonów zebranych z drzew rosnących na podkładkach standardowych M.9 EMLA i P 22. W grupie podkładek półkarłowych najobfitsze plony odmian 'Jonagold' i 'Gala' zebrano z drzew rosnących na P 60, a odmiany 'Ligol' z drzew rosnących na P 14. Wskaźnik plenności otrzymany z drzew rosnących na podklonach M.9 i P 22 był zbliżony do jego wartości otrzymanych z drzew rosnących na standardowych podkładkach M.9 EMLA i P 22. W grupie podkładek półkarłowych najwyższy wskaźnik plenności uzyskały drzewa trzech odmian na P 60. W latach 2003 i 2004 jakość owoców trzech odmian obejmująca: masę, średnicę i wielkość rumieńca powyżej 50% powierzchni na badanych podklonach i nowych podkładkach P 61 i P 62 była zbliżona do wartości otrzymanych z drzew rosnących na podkładkach standardowych M.9 EMLA i P 22. Jedynie w 2004 roku z drzew odmiany 'Jonagold' i 'Gala' rosnących na P 59 otrzymano mniejsze owoce.

Słowa kluczowe: odmiany jabłek, podkładka, podklon, wzrost, wskaźnik plenności, jakość owoców