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# GROWTH AND CROPPING OF SEVERAL SCAB--RESISTANT APPLE CULTIVARS ON SIX ROOTSTOCKS

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**Abstract**. The experiment was conducted at Fruit Experimental Station Samotwór near Wroclaw in the years 1998–2003, The aim of the experiment was to estimate the influence of six rootstocks on the growth, cropping and fruit quality of some new scab-resistant apple cultivars. Two of the cultivars were Polish –Waleria and Sawa, and four of them were Czech – 'Rosana', 'Rubinola', 'Rajka' and 'Topaz'. In the spring of 1998 maiden trees on rootstocks M.9, P2, P60, P16, P22 and M.27 were planted at the spacing 3.5×1.2 m (2380 trees/ha). The results of six-year-long studies confirmed that 'Rubinola' and 'Rajka' were characterised by the strongest vigour (the lowest crop efficiency indices – CEI), while 'Rosana' grew very weakly (the highest CEI). Fruit quality in terms of presentation and taste was the best in the case of 'Rubinola'. 'Sawa', 'Rubinola' and 'Topaz' had the biggest potential for commercial production. The rootstocks M.9 and P60 proved to be the most useful for the studied apple cultivars.

**Key words:** apple tree, scab-resistant cultivars, rootstock, growth, yield, fruit quality

## INTRODUCTION

Apple scab (*Venturia inaequalis*) is the most dangerous disease in apple orchards. In favourable conditions the attack of scab may be very strong and completely destroy a yearly yield or significantly decrease the commercial value of fruit [Carisse and Dewdney 2002]. Effective protection of trees against this disease involves a dozen or so fungicide applications in one vegetative season, which is expensive and affects the environment. According to Goszczyński [1998], expenditures on scab control make up, depending on the season, 50–70% of the costs incurred in fighting diseases and pests in apple trees cultivation.

One of the most effective and at the same time environmentally friendly ways of fighting the fungus *Venturia inaequalis* is breeding scab-resistant cultivars. It decreases production costs, reduces pollution and solves the problem of harmful chemicals cumu-

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lated in fruit [Żurawicz 1998]. Apple cultivars genetically resistant to scab are bred in many countries all over the world. The vast majority of these cultivars are characterised by monogenic $V_f$ resistance with its source in *Malus floribunda* [Crosby et al. 1992, Fischer et al. 1998, Janick and Giongo 2002]. Unfortunately, in many cases the fruit do not meet the requirements concerning quality, taste and storage properties. That is why only some of the cultivars have been introduced to commercial orchards, e.g. 'Freedom', 'Liberty', 'Florina' [Ugolik et al. 1993, Schupp and Koller 1998]. In recent years there has been a growing popularity of winter cultivars of Czech origin, such as 'Topaz', 'Rubinola' and 'Rajka'. As regards the taste and the storage properties of fruit, these cultivars can compete even with 'Jonagold' [Osterreicher 1996, Łysiak and Kurlus 1998]. They have already been acknowledged not only in the Czech Republic, but also in Germany, Switzerland and the Netherlands [Kellerhals et al. 1998, Kemp and van Dieren 1999].

The use of cultivars genetically resistant to scab significantly reduces the number of fungicide applications. However, some fungicide sprays are still necessary, because there might occur other diseases, e.g. *Gloedes pomigena*, normally not met in the orchards protected against scab [Grabowski et al. 2002].

The aim of the present study was the evaluation of several new scab-resistant apple cultivars of Polish and Czech origin, budded on six rootstocks, in the weather and soil conditions of south-western Poland.

## MATERIAL AND METHODS

The experiment was established in the spring of 1998 at Fruit Experimental Station Samotwór near Wroclaw. There were 4 Czech ('Rosana', 'Rubinola', 'Rajka' and 'Topaz') and 2 Polish ('Waleria' – U184 and 'Sawa') cultivars tested. One-year-old trees produced at the Station were planted on 6 rootstocks: M.9, P2, P60, P16, P22 and M.27 at the spacing of 3.5×1.2 m (2380 trees/ha). The experiment was carried out by a randomised split-plot design, the total number of cultivar and rootstock treatments being 36, in 4 replications, with 5 trees per plot (there were 20 trees in each combination). The following data were recorded: the growth of trees (trunk cross-sectional area, crown volume), the degree of infection with powdery mildew (*Podosphaera leucotricha*), yield and fruit quality. The circumference of the trunk of each tree was measured at the height of 30 cm above the level of soil. The height of trees and the width of crowns were measured with a pole in two directions (east-west and north-south). on the basis of the obtained results and using the formula for cone volume, the crown volume was calculated. Every month, during orchard inspections shoots infected with powdery mildew were first counted and then cut off. The obtained results were statistically elaborated by the analysis of variance and gathered in tables and diagrams. The differences between means were estimated by the t-Student test at the 5% level of significance.

In the years 2000–2003, the Czech winter cultivars and other cultivars popular in Lower Silesian region ('Jonagold', 'Golden Delicious' 'Szampion' and 'Elstar') were evaluated in terms of taste. Each year, at the beginning of December a group of 40–50 students compared the taste and the presentation of apples using a scale from 1 to 5,

where 1 meant tasteless and unattractive fruit and 5 meant very tasty and very attractive ones. The diagrams show the means from 4 years.

All the trees in the experiment were trained as a spindle with the shoots bent down by means of concrete weights until the 3rd year after planting and pruned only after blossoming. The trees were not irrigated, except for the year 2003 when the whole orchard was irrigated twice because of a drought. Agrotechnical practices followed the commercial guidelines. Chemical pest and disease control was carried out in accordance with the current recommendations of the Orchard Protection Programme, but no chemicals were used to protect the trees against apple scab. During the first two years after planting no fungicides were used, while in the next years fungicides against other diseases were applied only twice.

## RESULTS AND DISCUSSION

Till the 6th year after planting the studied cultivars and rootstocks significantly influenced the vegetative growth of trees, the yield and the fruit quality. 'Rubinola' and 'Rajka' proved to be the most vigorous cultivars, having taken into consideration trunk cross-sectional area and crown volume. The weakest growth was noted for 'Rosana' (tab. 1 and 2). The obtained results confirmed Sosna's [2001] earlier conclusions, concerning more vigorous growth of 'Sawa' in comparison with 'Waleria', but the differences were not statistically significant. According to Pitera and Gałecki [1998], the trunk cross-sectional area of 'Waleria' did not differ significantly from that of 'Sawa'. However, Szklarz and Pacholak [2000] regarded 'Sawa' on rootstock M.9 as the most vigorous. The rootstocks weakened the growth of trees, which agrees with earlier reports. Regardless of the cultivar, the super-dwarfing rootstocks P22 and M.27 significantly affected the growth of trees. These rootstocks proved to be the most suitable for very strongly growing cultivars, whereas in the case of 'Rosana' and 'Waleria' the

Table 1. Trunk cross-sectional area ($cm^2$) of several scab resistant apple cultivars depending on rootstock- autumn 2003

Tabela 1. Pole przekroju poprzecznego pnia ($cm^2$) kilku parchoodpornych odmian jabłoni w zależności od podkładki – jesień 2003

| Cultivar/Rootstock<br>Odmiana/Podkładka | M.9 | P2 | P60 | P16 | P22 | M.27 | Mean for cultivar<br>Średnia dla odmiany |
|---|---|---|---|---|---|---|---|
| Waleria | 13.8 | 13.6 | 19.6 | 19.1 | 7.0 | 5.7 | 13.1 |
| Sawa | 17.1 | 22.6 | 20.5 | 10.8 | 9.9 | 7.5 | 14.7 |
| Rosana | 8.6 | 11.6 | 15.8 | 9.4 | 6.3 | 3.6 | 9.2 |
| Rubinola | 24.2 | 24.7 | 29.3 | 16.2 | 12.0 | 10.4 | 19.5 |
| Rajka | 19.0 | 34.6 | 21.9 | 15.8 | 8.4 | 7.7 | 17.9 |
| Topaz | 17.6 | 15.8 | 21.6 | 14.7 | 10.2 | 8.0 | 14.7 |
| Mean for rootstock<br>Średnia dla podkładki | 16.7 | 20.5 | 21.4 | 14.3 | 9.0 | 7.1 | |
| $LSD_{0.05}$ for – $NIR_{0,05}$ dla<br>cultivar – odmiany<br>rootstock – podkładki<br>interaction – interakcji | 3.3<br>2.1<br>5.2<br>5.8 | | | | | | |

Table 2. Volume of crown ($m^3$) of several scab resistant apple cultivars depending on rootstock – autumn 2002

Tabela 2. Objętość korony ($m^3$) kilku parchoodpornych odmian jabłoni w zależności od podkładki – jesień 2002

| Cultivar/Rootstock<br>Odmiana/Podkładka | M.9 | P2 | P60 | P16 | P22 | M.27 | Mean for cultivar<br>Średnia dla odmiany |
|---|---|---|---|---|---|---|---|
| Waleria | 2.23 | 2.39 | 2.88 | 2.14 | 1.08 | 0.63 | 1.89 |
| Sawa | 2.57 | 2.65 | 2.79 | 1.86 | 1.47 | 1.02 | 2.06 |
| Rosana | 1.64 | 1.89 | 2.38 | 1.33 | 0.80 | 0.42 | 1.41 |
| Rubinola | 4.05 | 3.20 | 4.14 | 3.23 | 2.11 | 2.16 | 3.15 |
| Rajka | 2.70 | 3.72 | 3.28 | 2.23 | 1.40 | 0.96 | 2.38 |
| Topaz | 2.54 | 2.21 | 2.63 | 2.29 | 1.33 | 1.15 | 2.03 |
| Mean for rootstock<br>Średnia dla podkładki | 2.62 | 2.67 | 3.02 | 2.18 | 1.36 | 1.06 | |
| $LSD_{0.05}$ for – $NIR_{0,05}$ dla | | | | | | | |
| cultivar – odmiany | 0.33 | | | | | | |
| rootstock – podkładki | 0.26 | | | | | | |
| interaction – interakcji | 0.65 | | | | | | |
| | 0.68 | | | | | | |

weakening influence was too strong. Especially small trees were observed in the case of 'Rosana' on rootstock M.27. The weak growth of the cultivars on rootstocks P22 and M.27 is confirmed by other authors [Barritt et al. 1995, Schupp and Koller 1998, Wlosek-Stangret and Jadczuk 2000, Ostrowska and Zdzieszyńska-Mazurczak 2001]. The strongest vegetative growth of trees was caused by rootstocks P60 and P2, which was also proved by Hampson et al. [1997] and Skrzyński and Poniedziałek [2000].

Table 3. Cumulative yield 1999-2003 [kg $tree^{-1}$] with several scab resistant apple cultivars depending on rootstock

Tabela 3. Suma plonu z lat 1999-2003 [kg $drzewo^{-1}$] dla kilku parchoodpornych odmian jabłoni w zależności od podkładki

| Cultivar/Rootstock<br>Odmiana/Podkładka | M.9 | P2 | P60 | P16 | P22 | M.27 | Mean for cultivar<br>Średnia dla odmiany |
|---|---|---|---|---|---|---|---|
| Waleria | 46.4 | 38.3 | 41.4 | 28.5 | 22.9 | 14.4 | 32.0 |
| Sawa | 45.8 | 48.4 | 41.3 | 32.8 | 31.5 | 20.0 | 36.6 |
| Rosana | 42.9 | 43.1 | 56.7 | 32.7 | 20.5 | 13.1 | 34.8 |
| Rubinola | 39.4 | 30.4 | 34.9 | 26.5 | 26.8 | 20.4 | 29.7 |
| Rajka | 33.4 | 32.5 | 34.4 | 31.8 | 21.0 | 15.4 | 28.1 |
| Topaz | 47.8 | 40.7 | 46.9 | 45.9 | 26.3 | 20.7 | 38.1 |
| Mean for rootstock<br>Średnia dla podkładki | 42.6 | 38.9 | 42.6 | 33.0 | 24.8 | 17.3 | |
| $LSD_{0.05}$ for – $NIR_{0,05}$ dla | | | | | | | |
| cultivar – odmiany | 4.2 | | | | | | |
| rootstock – podkładki | 3.4 | | | | | | |
| interaction – interakcji | 8.3 | | | | | | |
| | 8.6 | | | | | | |

Crop yields were the highest in the case of 'Topaz' and 'Sawa', whereas the lowest yield was noted for 'Rajka' and 'Rubinola' (tab. 3). In comparison with the experiments with different apple cultivars on rootstock M9 conducted in the Czech Republic [Blazek and Hlusickova 2002], the productivity of 'Rubinola' was similar, i.e. moderate, but

'Rajka' yielded much worse. Kellerhals et al. [2001] report the comparable productivity of ,Rosana' and ,Rubinola', but again 'Rajka' is described as very productive. Lower cumulative crops from 'Rajka' trees recorded in this study could be caused by biennial cropping, observed since the 3rd year after planting. The cultivars 'Sawa' and 'Waleria' on rootstock M.9 both gave high yields, whereas in other experiments 'Sawa' on rootstock M.9 [Pitera and Gałecki 1998], and 'Sawa' on rootstock M.27 [Sosna 2001] proved to be less productive than 'Waleria'. Regardless of the cultivar, significantly the highest yields were obtained from the trees on rootstock M.9 and P60, and the lowest from very small trees on rootstock P22 and M.27. Similar results with rootstock P22 are reported by other authors, e.g. Skrzyński and Poniedziałek [2000] and Ostrowska and Zdzieszyńska-Mazurczak [2001]. By contrast, according to Hampson et al. [1997], trees on rootstock P2 and P22 were characterised by comparable productivity. In this study the highest crop efficiency indices were recorded for 'Rosana', and the lowest for 'Rubinola' (tab. 4), which is also reported by Kellerhals et al. [2001]. The highest CEI values relating to rootstocks M.9 and P22 are confirmed by Barritt et al. [1995], Skrzyński and Poniedziałek [2000], Wlosek-Stangret and Jadczuk [2000] and Ostrowska and Zdzieszyńska-Mazurczak [2001].

Table 4. Crop efficiency index (CEC) (kg $cm^{-2}$) 1999–2003 with several scab resistant apple cultivars depending on rootstock

Tabela 4. Współczynnik plenności (kg $cm^{-2}$) za lata 1999–2003 dla kilku parchoodpornych odmian jabłoni w zależności od podkładki

| Cultivar/Rootstock<br>Odmiana/Podkładka | M.9 | P2 | P60 | P16 | P22 | M.27 | Mean for cultivar<br>Średnia dla odmiany |
|---|---|---|---|---|---|---|---|
| Waleria | 3.36 | 2.82 | 2.11 | 1.49 | 3.27 | 2.53 | 2.60 |
| Sawa | 2.68 | 2.14 | 2.01 | 3.04 | 3.18 | 2.67 | 2.62 |
| Rosana | 4.99 | 3.72 | 3.59 | 3.48 | 3.25 | 3.64 | 3.78 |
| Rubinola | 1.63 | 1.23 | 1.19 | 1.64 | 2.23 | 1.96 | 1.65 |
| Rajka | 1.76 | 0.94 | 1.57 | 2.01 | 2.50 | 2.00 | 1.80 |
| Topaz | 2.72 | 2.58 | 2.17 | 3.12 | 2.58 | 2.59 | 2.63 |
| Mean for rootstock<br>Średnia dla podkładki | 2.86 | 2.24 | 2.11 | 2.46 | 2.84 | 2.57 | |
| $LSD_{0.05}$ for – $NIR_{0.05}$ dla | | | | | | | |
| cultivar – odmiany | 0.33 | | | | | | |
| rootstock – podkładki | 0.23 | | | | | | |
| interaction – interakcji | 0.56 | | | | | | |
| | 0.61 | | | | | | |

From among the evaluated cultivars the biggest fruited were picked from 'Sawa' and 'Rubinola' (tab. 5, fig. 1).The mean fruit weight from 5 years exceeded 170 g and 160 g respectively. Significantly the smallest fruit were obtained from the trees of the summer cultivar 'Waleria'. For all the tested cultivars the mean fruit weight for the years 2000-2003 was affected by the drought of 2003. The best blushed apples were those frm 'Rajka', 'Rubinola' and 'Sawa' (fig. 1). The high fruit quality of the cultivar 'Sawa' (mean fruit weight, size and blush) is also mentioned by other authors [Pitera and Gałecki 1998, Szklarz and Pacholak 2000, Sosna 2001]. The rootstocks used in the experiment had a great influence on the crop quality. The trees on rootstocks M.9 and P60 had significantly the biggest apples, whereas the smallest fruit were picked from

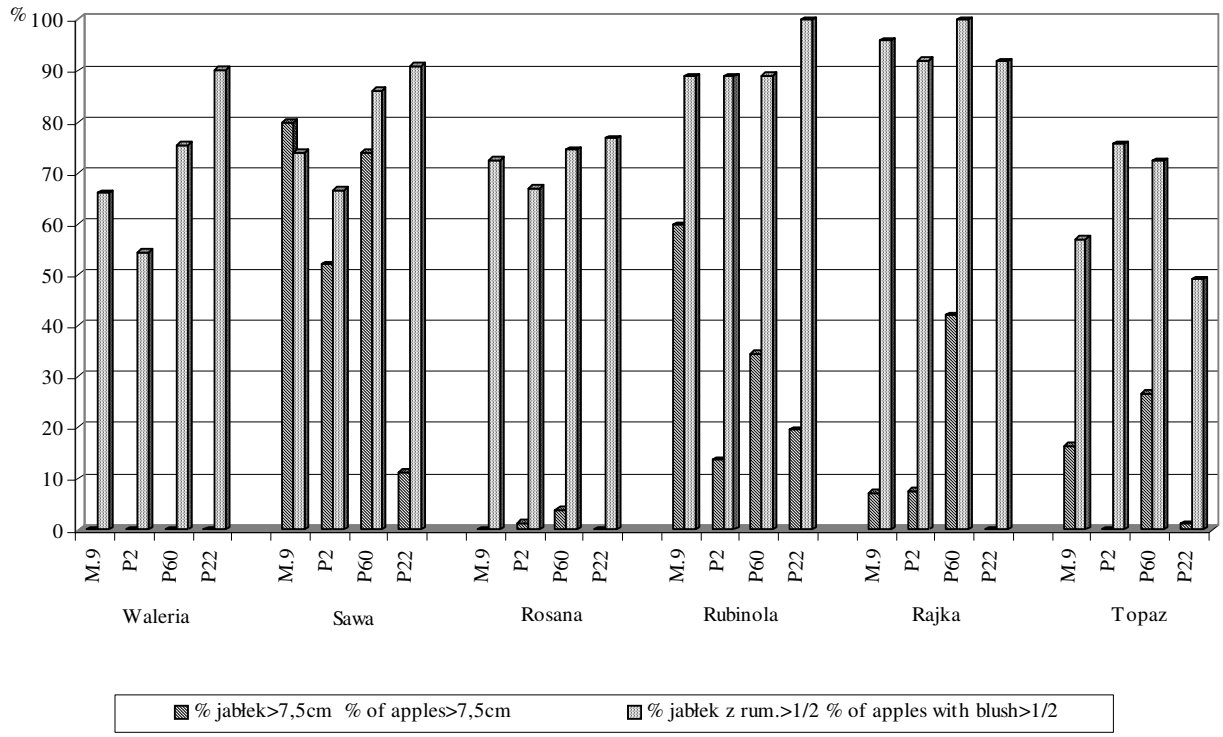


Fig. 1. Percentage of fruit with diameter >7.5 cm and with blush >1/2 of surface depending on cultivar and rootstock in 2003
Rys. 1. Procentowy udział owoców o średnicy >7,5 cm i wybarwieniu >1/2 powierzchni w zależności od odmiany i podkładki w 2003 r.

Table 5. Mean fruit weight (g) 1999–2003 with several scab resistant apple cultivars depending on rootstock

Tabela 5. Średnia masa 1 owocu (g) z lat 2000–2003 dla kilku parchoodpornych odmian jabłoni w zależności od podkładki

| Cultivar/Rootstock<br>Odmiana/Podkładka | M.9 | P2 | P60 | P16 | P22 | M.27 | Mean for cultivar<br>Średnia dla odmiany |
|---|---|---|---|---|---|---|---|
| Waleria | 113 | 106 | 102 | 114 | 93 | 94 | 104 |
| Sawa | 186 | 179 | 187 | 162 | 173 | 172 | 177 |
| Rosana | 157 | 152 | 160 | 145 | 131 | 130 | 146 |
| Rubinola | 181 | 162 | 175 | 172 | 150 | 164 | 167 |
| Rajka | 163 | 152 | 154 | 155 | 149 | 125 | 150 |
| Topaz | 152 | 142 | 157 | 140 | 135 | 134 | 143 |
| Mean for rootstock<br>Średnia dla podkładki | 159 | 149 | 156 | 148 | 139 | 137 | |
| $LSD_{0.05}$ for – $NIR_{0.05}$ dla | | | | | | | |
| cultivar – odmiany | 8 | | | | | | |
| rootstock – podkładki | 6 | | | | | | |
| interaction – interakcji | 14 | | | | | | |
| | 15 | | | | | | |

those very small trees on rootstocks M.27 and P22. Similar results occur in literature [Barritt et al. 1995, Skrzyński and Poniedziałek 2000]. By contrast, Ostrowska and Zdzieszyńska-Mazurczak [2001] recorded the biggest mean fruit weight for the cultivars on rootstock P22. The results of this study show that for most of the cultivars the best coloured fruit were obtained from the trees on rootstock P22, except for 'Rajka' and 'Topaz', where fruit blush was caused by rootstocks P60 and P2 respectively.

Table 6. Shoots with apple mildew symptoms (number $tree^{-1}$) – sum 2000–2003

Tabela 6. Liczba pędów z objawami mączniaka jabłoni (szt. $drzewo^{-1}$) – suma z lat 2000–2003

| Cultivar/Rootstock<br>Odmiana/Podkładka | M.9 | P2 | P60 | P16 | P22 | M.27 | Mean for cultivar<br>Średnia dla odmiany |
|---|---|---|---|---|---|---|---|
| Waleria | 0.5 | 1.2 | 3.9 | 2.0 | 1.0 | 0.8 | 1.6 |
| Sawa | 2.6 | 4.1 | 4.7 | 2.9 | 1.0 | 1.0 | 2.7 |
| Rosana | 1.7 | 3.8 | 6.5 | 3.2 | 1.2 | 0.5 | 2.8 |
| Rubinola | 1.2 | 1.8 | 0.4 | 1.1 | 0.2 | 0.0 | 0.8 |
| Rajka | 1.2 | 2.4 | 1.9 | 0.7 | 0.9 | 0.0 | 1.2 |
| Topaz | 3.5 | 4.9 | 7.5 | 4.3 | 1.7 | 1.3 | 3.9 |
| Mean for rootstock<br>Średnia dla podkładki | 1.8 | 3.0 | 4.2 | 2.4 | 1.0 | 0.5 | |
| $LSD_{0.05}$ for – $NIR_{0.05}$ dla | | | | | | | |
| cultivar – odmiany | 1.8 | | | | | | |
| rootstock – podkładki | 0.9 | | | | | | |
| interaction – interakcji | 2.3 | | | | | | |
| | 2.8 | | | | | | |

The greatest susceptibility to powdery mildew was observed for 'Topaz' (tab. 6). Similar data are presented by Kellerhals et al. [2001]. In the case of 'Rubinola' and 'Rajka' shoots with powdery mildew symptoms occurred only occasionally. None of the tested cultivars required heavy chemical protection against this disease. The number of fungicide sprays was reduced to minimum and the percentage of infected shoots, even in the case of 'Topaz', was not large. The occurrence of the fungus *Podosphaera*

*leucotricha* was strongly correlated with the vigour of trees. The most vigorous trees on rootstock P60 had the largest number of shoots with powdery mildew symptoms, whereas the weakest trees on rootstock M.27 were hardly infected.

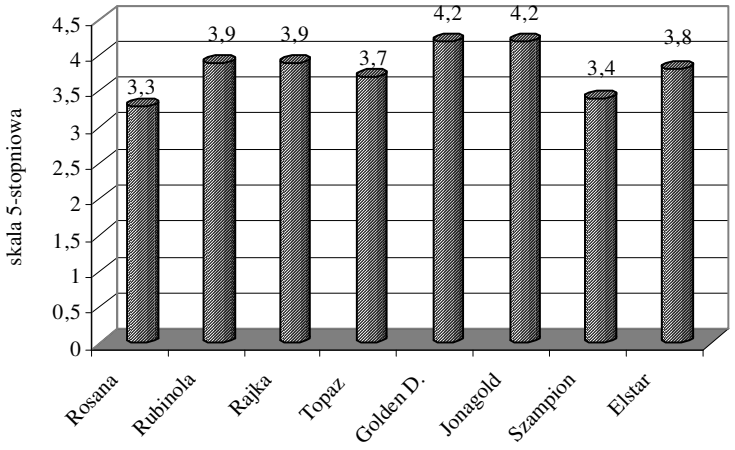


Fig. 2. Estimation of fruit taste of several winter apple cultivars (average 2000–2003)
Rys. 2. Ocena smaku owoców kilku zimowych odmian jabłoni (średnia z lat 2000–2003)

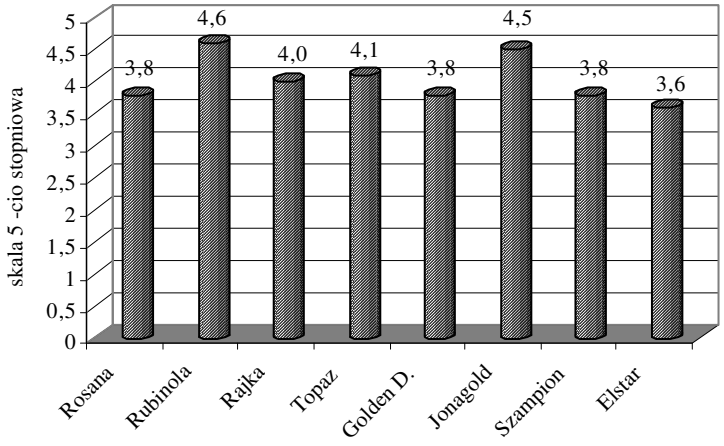


Fig. 3. Estimation of fruit presentation of several winter apple cultivars (average 2000–2003)
Rys. 3. Ocena wyglądu owoców kilku zimowych odmian jabłoni (średnia z lat 2000–2003)

As far as taste is concerned, the fruit were evaluated four times. The cultivars 'Jonagold' and 'Golden Delicious' were regarded as the most attractive in this respect (fig. 2). Among the scab-resistant cultivars 'Rubinola' and 'Rajka' were rated the highest, and 'Rosana' the lowest. In terms of presentation, the most attractive apples were those of 'Rubinola' with their intensely red blush. This cultivar was ranked even higher than 'Jonagold'. 'Topaz' and 'Rajka' took the following places before 'Golden Delicious', 'Szampion' and 'Elstar', the cultivars commonly grown in the orchards of Lower Silesia. The high fruit quality of 'Rubinola', 'Topaz' and 'Rajka' was also reported by other authors [Kellerhals et al. 2001, Kühn and Thybo 2001].

## CONCLUSIONS

1. The six-year-long experiment showed that, as far as the productivity and fruit quality are concerned, the cultivars 'Sawa', 'Rubinola' and 'Topaz' belong to the most valuable apple trees in the weather and soil conditions of the Wroclaw region.

2. The trees on rootstocks M.9 and P60 gave high yields of fine fruit. The superdwarfing rootstocks P22 and M.27 proved to be completely useless for the cultivars 'Waleria' and 'Rosana', characterised by weak growth.

3. The 'Topaz' trees had the largest number of shoots with powdery mildew symptoms. However, with minimal fungicide application, the susceptibility to the fungus *Podosphaera leucotricha* was very small, even in the case of 'Topaz'.

4. Among the winter scab-resistant cultivars 'Rubinola' had the most attractive fruit in terms of taste and presentation, whereas the fruit of 'Rosana' were described as the least attractive.

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## WZROST I PLONOWANIE KILKU ODMIAN JABŁONI GENETYCZNIE ODPORNYCH NA PARCHA NA SZEŚCIU PODKŁADKACH

**Streszczenie**. W latach 1998–2003, w Sadowniczej Stacji Badawczo Dydaktycznej w miejscowości Samotwór koło Wrocławia, przeprowadzono badania mające na celu ocenę wartości gospodarczej kilku nowych parchoodpornych odmian jabłoni uszlachetnionych na sześciu podkładkach. Badaniami objęto 2 odmiany polskie – Waleria i Sawa oraz 4 czeskie – Rosana, Rubinola, Rajka i Topaz. Jednoroczne okulanty na podkładkach M.9, P2, P60, P16, P22 i M.27 wysadzono wiosną 1998 r. w rozstawie 3,5×1,2 m. Na podstawie 6–letnich badań stwierdzono, że najsilniej rosły drzewa odmian Rubinola i Rajka (najniższe współczynniki plenności), natomiast najsłabiej Rosana (najwyższy współczynnik plenności). Najwyższą ocenę degustacyjną uzyskały jabłka 'Rubinoli'. Największą przydatność do uprawy w sadach towarowych wykazały odmiany Sawa, Rubinola oraz Topaz. Najbardziej przydatne dla badanych odmian jabłoni okazały się podkładki M.9 oraz P60.

**Słowa kluczowe**: jabłoń, odmiany parchoodporne, podkładka, wzrost, plon, jakość

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