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Heritability of Powdery Mildew and Scab Resistance within Apple Progenies

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Abstract

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The occurrence of both diseases was evaluated for four years in a selected orchard where 22 different apple progenies, totalling 699 seedlings were planted. During this period, no chemical protection against the diseases was applied in the orchard, and the incidence of the diseases was rated using a 9-point scale (from 9 = not infected to 1 = very highly infected). For the finalisation of the results, each seedling was characterised by the highest rate of infection from all four years of the evaluation. The lowest mean level of mildew infection equal to 7.47 was observed in the progeny of Resista × McIntosh Wijcik. Concerning the scab, the best was the progeny of Resista × Karmína having a rating equal to 8.27. The highest level of segregation of seedlings having joint resistance to both diseases was found out in the progenies obtained by crossings of HL665 × HL782 and Resista × HL447.

Keywords: *Malus* × *domestica*; joint resistance; progeny segregation; apple breeding

Scab and powdery mildew – *Podosphaera leucotricha* (Ell. and Ev.) Salm. belong on a worldwide scale among the most important apple diseases, and resistance breeding has long been applied to apples as a means to control their incidence (Bus *et al*. 2010). Both fungal diseases can be controlled through treatments, but with considerable difficulties and costs, and with long-term consequences and negative effects both on the environment and on the quality of fruits (Holb 2009). According to early studies of apple progenies, the nursery selection for partial mildew resistance is not reliable enough and the process requires a much longer time (Janse *et al*. 1994). In a previous study on heritability of resistance to scab (*Venturia inaequalis*) done in New Zealand (Bus *et al*. 2002), only a relatively small percentage of progenies poses comparatively the highest potential for improving scab resistance in apples. The general combining ability of resistance from different sources, as well as the specific combining ability effects, proved to influence the transmission of the traits (Hampson *et al*. 2009).

Creating new apple cultivars largely depends on the availability of sufficient genetic diversity, while apple breeding has eroded in time the genetic base of domestic cultivars. The possibility to induce and exploit useful variability for selecting hybrids resistant to apple scab and powdery mildew attack was evaluated in interspecific descendants derived from five wild apple species (*Malus coronaria, M. floribunda, M. niedzwetzkyana, M. zumi*, and *M. prunifolia*), which were used in Romania (Sestras *et al*. 2011). Unfortunately, acquiring a completely resistant cultivar with high-quality fruits using these donors will involve a very long time process requiring several generations of back crossings. The development of genetically modified clones of grown cultivars seems to be another possible solution to the problem. Nevertheless, it is obvious that also this approach would require long-term research (Gesslera *et al*. 2006).

The first cultivar with resistance to scab that was bred in the Research and Breeding Institute of Pomology (RBIP) Holovousy is Resista. It was selected among

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progeny derived from a cross of Prima and NJ 56. Its fruit characteristics and storage life are similar to Golden Delicious (Blažek 1999). The second novelty possessing resistance to scab that arose at RBIP Holovousy after crossing the selected seedling HL A 28/39 (Antonovka o.p.) with Golden Delicious was Angold. It was registered in the Czech Republic in 1995. Its polygenic resistance is different from the *Vf* gene pattern and has been stable up to now (Blažek 1997).

According to the study of apple varieties in commercial orchards, relatively the most resistant to powdery mildew were Šampion, Gloster, Gold Bohemia, Rajka, Julia, Lord Lambourne Red, Rubinola, and Bohemia (Blažek & Křelinová 2006).

MATERIAL AND METHODS

This study was carried out in the Research and Breeding Institute of Pomology in Holovousy. The locality is characterised by a mean annual temperature of 8.4°C, mean rainfall of about 663.5 mm, and altitude around 300 m.

The experimental material originated from crossings of selected cultivars and genotypes in 1999. Stratified seeds were sown in a plastic greenhouse in 2000, where seedlings were then selected according to their disease resistance (e.g. scab, powdery mildew). Selected seedlings with the lowest levels of disease incidence were grafted onto the M9 rootstock and the subsequently grown 2-years-old trees were planted at the spacing of 4 × 1 m in an experimental orchard located in Holovousy in the spring of 2004. There, the assessed genotypes were evaluated for a broad spectrum of characteristics. This paper, however, is focussed on the incidence of powdery mildew and scab.

The experimental data were taken from the first four years of the orchard when the experimental orchard was not protected by any chemical treatments against diseases. Abundant sources of infection were older orchards in its surrounding grown without any protection. Seedlings were individually rated at the end of the growing season for the incidence of both diseases using a 9-point scale (9 = not infected, 5 = medium level of infection, and 1 = very highly infected) for the amount of these infections. For the finalisation of the results, each seedling was characterised by the highest rate of infection from all 4 years of the evaluation.

Data concerning the resistance or level of susceptibility of parental cultivars were acquired from results of their assessment in other selection plots or the gene bank collection of the Institute.

The standard statistical analysis based on analysis of variance was performed and mean intervals of the least significant differences (*LSD*) were calculated for the mean values. The standard regression analysis was applied to selected characteristics.

RESULTS

Incidence of diseases within parental cultivars. The latest ratings of the infection levels of parental cultivars and selections concerning powdery mildew and scab obtained during their evaluation in unprotected plots in Holovousy are shown in Table 1. In the case of powdery mildew, the relatively highest level of resistance, classified by a scoring value of 9, was observed in the cv. McIntosh Wijcik. A very low infection by the disease according to a scoring value of 8 was recorded in the cvs Benet, Discovery, and

Table 1. The highest infection levels of powdery mildew and scab in parental cultivars or selections

Cultivar (selections)	Powdery mildew	Scab	Cultivar (selections)	Powdery mildew	Scab
Angold	6	8	Karmína	7	9
Antonovka o.p.	6	8	McIntosh Wijcik	9	1
Benet	8	7	Meteor	5	3
Braeburn	3	3	Pink Lady	7	6
Discovery	8	6	Pidi	5	7
Freedom	7	9	Pohoda (HL1711)	8	8
HL447	7	6	Resista	4	9
HL665	5	8	Rosana	7	9
HL782	6	7	Rubinola	8	9
HL1737	6	8	Rucla	6	7
HL2219	5	6	Topaz	7	9

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Rubinola. On the other hand, relatively the most susceptible to powdery mildew, with a rating value of 3, was the cv. Braeburn. Next in the order of susceptibility (scoring value 4) was rated cv. Resista.

Concerning apple scab, the cvs Freedom, Karmína, Resista, Rosana, Rubinola, and Topaz were confirmed as absolutely resistant (scoring value 9). A very high level of resistance (scoring value 8) was recorded in cvs Angold, Antonovka o.p., HL665, HL1737, and Pohoda. On the contrary, the most susceptible was McIntosh Wijcik (scoring value 1). It was followed by the cvs Braeburn and Meteor, rated at the scoring level 3.

With respect to the resistance to both diseases, the most outstanding was Rubinola, having absolutely the highest sum of ratings. However, the resistance of other five cultivars (Freedom, Pohoda, Karmína, Rosana, and Topaz) was rated lower by one point only.

Heritability of powdery mildew resistance. The results of powdery mildew ratings in the evaluated progenies are presented in Table 2. The progeny of Resista × McIntosh Wijcik was characterised by the lowest mean level of mildew infection equal to 7.47. In descending order, it was followed by the progenies of Resista × Rubinola, Pohoda × HL665, HL665 × Pink Lady, HL665 × Rosana, Pink Lady × Discovery, and HL1737 × Pink Lady. On the contrary, the highest incidence of the disease (with a mean value 4.53) was recorded in the progeny of Braeburn × Angold. These values of infection were ranked in descending order in the following progenies: Resista × Pidi, Resista × Angold, Resista × Pink Lady, HL782 × Pink Lady, Resista × HL2219, and HL782 × HL665.

The progeny that originated by the crossing of the cultivars Resista and Pink Lady is distinguished by the highest span of values concerning the infection intensity (2–9). Among the seedlings, one was classified as completely resistant without any visible signs of the disease. Similar fully resistant seedlings were segregated in the progenies of Resista × HL447 and Pohoda × HL665. From the data it is obvious that the selection HL665 is a very good donor of powdery mildew resistance and should, therefore, be used in future breeding programmes to a larger extent.

There is a close relationship between the mean incidence of the disease in parents and in their progenies (Figure 1). The correlation is on the level $r^2 = 0.57$.

Table 2. The powdery mildew and scab incidence in evaluated progenies

Cross	Number of genotypes	Powdery mildew				Scab			
		mean	max.	min.	*LSD*	mean	max.	min.	*LSD*
Braeburn × Angold	17	4.53	3	7	0.26	6.56	3	8	0.47
Freedom × Antonovka o.p.	11	5.50	2	7	0.49	8.25	7	9	0.26
HL1737 × Pink Lady	15	5.53	3	7	0.31	5.41	2	7	0.43
HL665 × HL782	110	5.39	3	9	0.11	7.07	4	9	0.29
HL665 × Pink Lady	38	6.84	5	8	0.16	6.47	3	8	0.19
HL665 × Rosana	25	6.84	5	8	0.16	7.74	4	9	0.30
HL782 × HL665	25	5.32	3	8	0.24	7.18	4	9	0.21
HL782 × Pink Lady	36	5.17	2	7	0.25	6.50	4	9	0.25
Pohoda × HL665	16	7.19	6	9	0.23	7.84	5	8	0.28
Pink Lady × Discovery	19	6.79	5	8	0.25	6.15	3	7	0.32
Resista × Angold	17	4.82	3	7	0.47	8.02	7	9	0.16
Resista × Benet	14	5.93	4	7	0.40	7.41	5	9	0.22
Resista × HL2219	32	5.19	3	7	0.25	7.74	6	9	0.16
Resista × HL447	98	6.28	3	9	0.14	8.22	5	9	0.08
Resista × Karmína	42	5.74	2	7	0.24	8.27	6	9	0.17
Resista × McIntosh Wijcik	15	7.47	5	8	0.22	4.28	2	9	0.42
Resista × Pidi	37	4.62	2	7	0.23	7.25	5	9	0.19
Resista × Pink Lady	24	5.00	2	9	0.36	7.19	4	9	0.21
Resista × Rubinola	20	7.25	4	8	0.23	8.17	6	9	0.18
Resista × Rucla	33	5.55	3	7	0.23	7.64	4	9	0.21
Resista × Topaz	19	5.74	3	7	0.37	8.23	6	9	0.24
Rucla × HL665	36	6.33	4	8	0.18	5.72	2	7	0.26
Total	699	5.93	2	9	0.06	7.83	2	9	0.05

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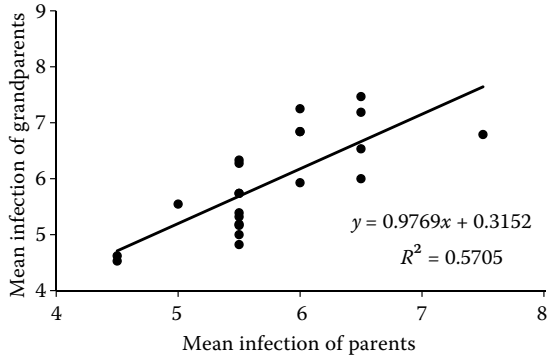

Figure 1. Relationship between the infection by powdery mildew in parents and their progenies

The largest difference in r^2 between them equal to 1.25 points appeared only in the progeny of Resista × Rubinola. Next, the r difference equal to 1.03 points occurred in the progeny of HL1737 × Pink Lady. All other differences were smaller than one point.

A distribution rating regarding infection levels in the progeny of Resista × HL447 is presented in Figure 2A. There, the highest frequencies are ranged around the partly resistant parent. In the progeny of HL665 × HL782, these values are around both parents and two seedlings are completely resistant (Figure 2B).

Heritability of scab resistance. The results of scab ratings among the evaluated progenies are also presented in Table 2. The progeny of Resista × Karmína was characterised by the highest mean level of scab resistance equal to a rating of 8.27. Nearly at the same level, the progenies of the following crossings were also evaluated: Freedom × Antonovka o.p., Resista × Topaz, Resista × HL447, and Resista × Rubinola. A negligibly higher incidence of seedlings infected by scab was found in the progenies of Resista × Angold and Pohoda × HL665. On the contrary, the highest mean level of disease infection (mean value 4.28) was recorded in the progeny of Resista × McIntosh Wijcik. Ranged in descending order of the mean level of scab infection are the following progenies: HL1137 × Pink Lady, Rucla × HL665 and Pink Lady × Discovery, HL782 × Pink Lady, Resista × HL2219, and HL782 × HL665.

The progeny that originated by the crossing of the cultivars Resista and McIntosh Wijcik is also distinguished by the highest span of values concerning the infection intensity (1–9). Next, the most diverse in this characteristic were the progenies of Braeburn × Angold and HL665 × Pink Lady, which had a span of two points less.

There is a close relationship between the mean incidence of the disease in parents and in their progenies (Figure 3). The correlation is on the level r^2 = 0.62. The largest difference in r^2 between them at the level of 2.53 points was found in the progeny of Braeburn × Angold. Next with the difference equal to 1.91 points followed the progeny of Resista × Pidi. All other differences were negligible.

From the data it is obvious that both selections HL665 and HL782 are valuable donors of scab resistance and should, therefore, be used in subsequent breeding programmes to a larger extent.

DISCUSSION

The results presented here are more or less in agreement with our previous findings (Blažek 2004). A very close relationship was found between midscores of parents and mean response to infections in progenies. Seedlings were on average significantly more infected than their parents.

The progeny obtained by the crossing of HL665 × HL782 was distinguished by the highest level of segregation of resistance both to powdery mildew and scab. Among the seedlings, one was found without any symptoms of the diseases. According to its pedigree, it obtained its unique performance by the desirable combination of properties of its ancestors. HL665

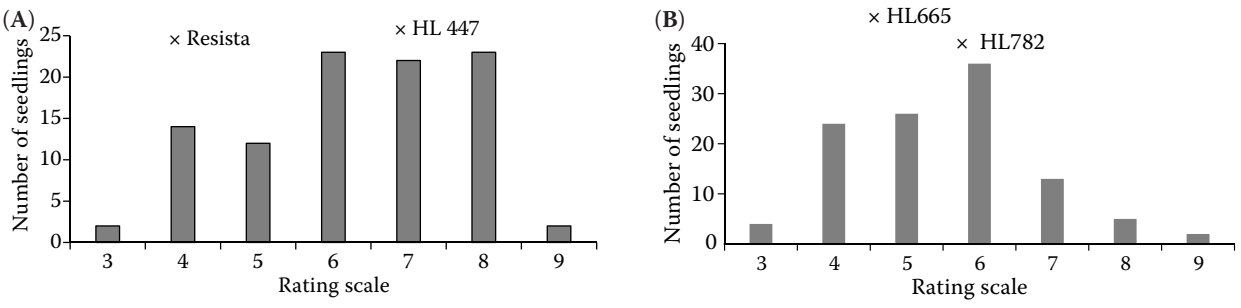

Figure 2. Distribution of seedlings according to powdery mildew rating in the progeny of (**A**) Resista × HL447 and (**B**) HL665 × HL782 (the level of parent response is indicated by their position)

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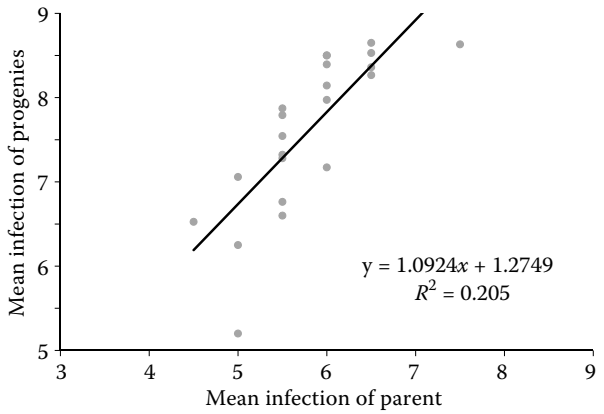

Figure 3. Relationship between the infection by scab in parents and their progenies

was selected in the progeny of Spartan crossed by HLA2830 (Antonovka o.p.). HL782 was obtained by the crossing of cvs Rubín and Priscila. This parental combination, therefore, should be chosen for larger utilisation in future breeding. Such a procedure is supported by broader recommendations in literature (Hampson *et al*. 2009; Bus *et al*. 2010).

Another progeny with joint resistance to both diseases was the combination of cv. Resista and HL447. The selection was found in the progeny of A28/74 (Spätblühender Taffetapfel × Court Pendu Plat) and Alkmene. Its ancestors are donors of resistance. In the case of cv. Alkmene, it was confirmed by Valetta *et al.* (2004).

Based upon the results presented above, the cultivar McInthosh Wijcik could be recommended as a donor of powdery mildew resistance. This is in agreement with our previous findings (Blažek & Křelinová 2011).

The methodical approach used in this study, applying the removal of the most strongly infected seedlings in the earliest stages of their development, does not allow any complete assessment of the inheritance. Nevertheless, this work indicates the best donors of resistance to both diseases and their mutual parental combinations.

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