

Evaluation of reactions of commercial and autochthonous apple cultivars to common diseases in Serbia under natural infection

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SUMMARY

This study presents the results of a multiple-year evaluation (1991-1996; 2005-2007) of susceptibility of more than 100 apple cultivars to *Venturia inaequalis*, *Podosphaera leucotricha* and *Erwinia amylovora* under agroecological conditions existing in Serbia. Some of the most popular cultivars were found highly susceptible to *V. inaequalis* (Cripps Pink, Mutsu, Gloster 69, Wellspur); while Golden Delicious, Richared, Gala, Čačanska pozna, Čadel and Jonagold were susceptible; Idared, Granny Smith and Jonathan moderately susceptible; Lord Lamburne and London Pepping, as well as several autochthonous cultivars were moderately resistant; and a group of resistant cultivars included Prima, Priscilla, Williams Pride, Dayton, Enterprise, Gold Rush, Golden Orange, many of the Re-cultivars (Germany), as well as Baujade, Selena, Dukát, Produkta, Topaz, some older cvs. (Worcester Pearmain, Merton Worcester, James Grieve, Akane, Astilish, Astrachan Red and Discovery), some Co-op selections (USA) and NS hybrids (Serbia). Regarding powdery mildew, Idared and Jonathan were highly susceptible; Gala, Akane, Jonagold, Priscilla, Mutsu, Čačanska pozna, Golden Delicious, Granny Smith, Čadel and GoldRush were susceptible; Wellspur, Astrachan Red, Richared, Jonadel, Dayton and several autochthonous cultivars were moderately susceptible; Lord Lamburne, Astilish, Prima, Champagne Reinette, Discovery and many autochthonous cultivars were moderately resistant; while most Re-cvs. (Germany), several cultivars from the Czech Republic, some selections from the USA and UK and most NS hybrids (Serbia) were resistant. Also, some cultivars showed variable susceptibility depending on location (Williams Pride, Gloster 69, Baujade and Produkta). *E. amylovora* was observed only in 2007 and at relatively low intensity (up to 12% infection). The highest disease severity was observed on cv. Elstar, then Granny Smith, Idared and Jonagored; while the lowest was found on Red Chief and Hapke apple trees.

Keywords: Apple; Cultivars; Apple scab; Powdery mildew; Bacterial fire blight; Serbia

INTRODUCTION

Intensive apple production can ensure high yields and fruit quality, but it also requires high investments, largely in chemical control, which is performed for the purpose of suppressing some economically most significant diseases, such as scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leucotricha*) and bacterial fire blight (*Erwinia amylovora*). In some European regions, the number of fungicide treatments against apple diseases exceeds 30, with around 20 to control scab (Evans et al., 2000). In Serbia, the whole program of chemical control for apple trees is focused on scab disease (Balaž & Petrina, 2003). Fungicides account for 30% of total pesticides used in Europe, emphasizing their use in contemporary production systems, such as fruit orchards (Gullino & Kuijpers, 1994). Many European governments presently take measures to reduce the use of pesticides in order to alleviate toxicological and environmental problems. In the late 1970s, European countries accepted the now well-known concept of Integrated Pest Management (IPM) as the most optimal trend in plant protection. Within that framework, cultivation of resistant apple varieties has a special significance. Fungicide treatments required on a plantation of resistant apple cultivars could be one fourth of those needed to protect susceptible cultivars (Parisi et al., 1995). In the last few decades, several breeding centers have been developed across the world (USA, Canada, France, England, Germany, Switzerland, Czech Republic) in which significant results have been achieved in developing apple cultivars either resistant or with low susceptibility to economically harmful diseases. Using various sources of resistance to scab, powdery mildew and fire blight, as well as conventional and modern molecular methods, a number of cultivars, lines and other selection material have been created. Today, one of the basic aims of selection efforts is to create apple cultivars with high fruit quality, high yield and long-term resistance against the most significant pathogens *V. inaequalis*, *P. leucotricha* and *E. amylovora*.

This paper presents the results of a long term study of the susceptibility/resistance of a variety of introduced and autochthonous apple cultivars and selections to the most common diseases that occur under Serbian agroecological conditions.

MATERIALS AND METHODS

A study of susceptibility of apple cultivars and genotypes to scab and powdery mildew conducted from 1991 to 1996

Apple orchard at Rimski Šančevi (Southern Bačka, Vojvodina). Thirty-seven apple cultivars were studied

in the orchard, which was planted in 1989 (Table 1). All cultivars were grafted onto rootstock M9, trained as a slender spindle with a planting distance of 4 x 1.75 m. Multiple-year testing of apple susceptibility to *V. inaequalis* (1991-1992; 1995-1996) and *P. leucotricha* (1992-1994) was performed. Between 5 and 8 preventive chemical treatments with fungicides such as mancozeb, captan, propineb and sulfur were applied in the orchard during each growing season. First treatment was usually performed with copper fungicides at the growth stage BB CH: 09-10.

Apple orchard at Gladnoš (Srem, Vojvodina). The orchard was planted in 1991. It comprised different genetic material: autochthonous, some standard and some more recent cultivars, wild apples, as well as some selected genotypes, 28 in total (Table 1). The training system was slender spindle on rootstock M26; planting distance 4 x 2 m. The susceptibility of apple cultivars to *P. leucotricha* was studied over the period 1993-1995, when conventional fungicides were not applied.

A study of susceptibility of apple cultivars and genotypes to scab, powdery mildew and fire blight from 2005 to 2007

Apple orchards at Rimski Šančevi and Kać (Southern Bačka, Vojvodina). Long term experiments were performed at two locations: Rimski Šančevi (fruit growing and viticulture experimental orchards of the Faculty of Agriculture, Novi Sad) and Kać (MAVM commercial nursery). The apple trees planted on these locations are mostly new cultivars with monogenic resistance to *V. inaequalis*, as well as some autochthonous and standard cultivars, as well as some promising genotypes. The orchards were planted over the period 2000-2002.

A total of twenty-three cultivars and some new genotypes and different autochthonous cultivars were studied in the experimental orchards Rimski Šančevi and Kać (Table 1). In both orchards, the susceptibility/resistance of those cultivars to *V. inaequalis* and *P. leucotricha* (2005-2006) was studied. The training system was slender spindle with rootstock M26, and the planting distance was 4 x 1.5 m. Conventional chemical control was not performed in any of the experimental orchards.

In another field experiment at Rimski Šančevi, several commercial cultivars (Golden Delicious clone B, Golden Delicious clone Reinders, Jonagored, Idared, Granny Smith, Elstar, Red Chief and Hapke) were tested for their susceptibility/resistance to *E. amylovora*. The training system was slender spindle on rootstock M9

(except for cv. Red Chief grafted onto rootstock M-26) and the planting distance was 4.00 x 1.50 m. Monitoring was performed during 2005-2007. Special chemical

control for prevention and suppression of fire blight was not applied, but chemical control of scab and powdery mildew was regularly performed.

Table 1. Cultivars evaluated for susceptibility to apple scab and powdery mildew over the periods 1991-1996 and 2005-2006

Location	Rimski Šančevi		Gladnoš	Rimski Šančevi		Kač	
Pathogen	<i>Venturia inaequalis</i>	<i>Podosphaera leucotricha</i>	<i>Podosphaera leucotricha</i>	<i>Venturia inaequalis</i>	<i>Podosphaera leucotricha</i>	<i>Venturia inaequalis</i>	<i>Podosphaera leucotricha</i>
Period	1991-1992; 1995-1996	1992-1994	1993-1995	2005-2006	2005-2006	2005-2006	2005-2006
	Discovery		Prancia		Reglindis		Regine
	Astilisch		Lipovača		Regine		Remo
	Summer Red		Kolačara		Remo		Remura
	James Grieve		Tetanka		Remura		Rewena
	Akane		wild apple		Rewena		Renora
	Merton Worcester		Kožara		Renora		Reanda
	Priscilla		Melresa		Reanda		Rebella
	Prima		Mušanika		Williams Pride		Reka
	Čadel		Pramenka		Dayton		Relinda
	Odin		Budimka		Selena		Baujade
	Jonagold		Kumovača		Produkta		Co-op 33
	Jonathan		Akpetrič		Dukát		Co-op 34
	Spencer		Jadrolika		Baujade		Co-op 36
	Worcester Pearmain		Bobovec		NS 11/111		Co-op 37
	Granny Smith		Krivopecelj		NS 11/46		Enterprise
	Lord Lambourne		Bela čejna		NS 25/83		GoldRush
	Mariborka		Gloster 69		NS 25/140		Golden Orange
	Ontario		Jonagold		Bobovec		Golden Supreme
	Baumann's Reinette		Golden Delicious		Krivopecelj		Jonagold Wilmuta
	Čačanska pozna		Granny Smith		Kožara		Golden Delicious clone Reinders
	Idared		Dayton		Budimka		Cripps Pink
	Gala		Produkta		Šumatovka		Topaz
	Stark Splendor		Williams Pride		Krstovača		Orahovača
	Mutsu		Baujade				
	Jonadel		A 878/19 (English origin)				
	Wellspur		A 810/222 (English origin)				
	Starking		79508-1316-4-59 (American origin)				
	Golden Spur		78221-1016-1-30 (American origin)				
	Golden Delicious						
	Golden Delicious clone B						
	Ananas Reinette						
	Summerland						
	Champagne Reinette						
	Gloster 69						
	Astrachan Red						
	London Pepping						
	Richared						

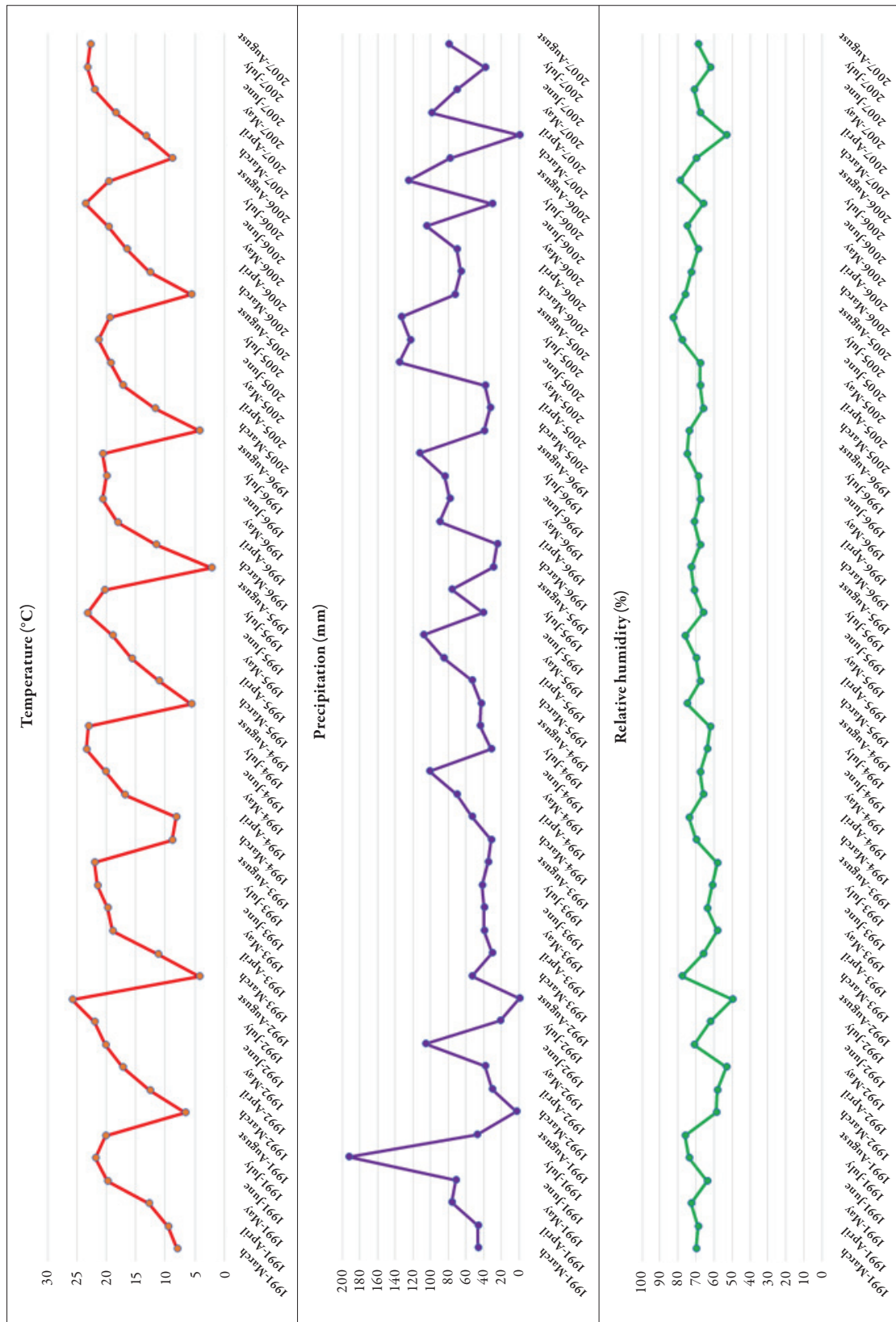


Figure 1. Meteorological data for study periods (1991-1996; 2005-2007), location Novi Sad

Susceptibility evaluation

The susceptibility of apple cultivars to *V. inaequalis* and *P. leucotricha* was checked on 3-8 trees representing each cultivar, two-to-three times during each vegetation season (mid-June, early July, and optionally early September). For *E. amylovora* infection, 100 trees were evaluated.

For disease severity evaluation under field conditions, a 1-9 point scale, based on the percentage of infected area of each crown tree was used (1=0-3%; 2=4-6%; 3=7-12%; 4=13-25%; 5=26-50%; 6=51-75%; 7=76-88%; 8=89-99%; 9=100%) (Watkins & Smith, 1982). The scale was modified by including a 0 point = no infection, and changing point 1 to 1=1-3% infection (instead of 1=0-3%), while all other percentage points remained the same as in the original scale. The results were statistically analysed (ANOVA and Duncan's test) using the software STATISTICA 12.

On the basis of our multiple-year testing of susceptibility/resistance of various apple cultivars and different genotypes to *V. inaequalis* and *P. leucotricha*, the mean value (M) of disease severity was calculated for each cultivar. According to these results, the tested cultivars were classified into specific groups based on their susceptibility or resistance:

resistant M=0; moderately resistant M=0.01-2.00; moderately susceptible M=2.01-3.00; susceptible M=3.01-5.00 and highly susceptible: M=5.01-6.00.

Regarding cultivar susceptibility to *E. amylovora*, only the percentage of disease was evaluated (without their classification into specific groups based on susceptibility/resistance) because a low severity fire blight infection occurred only during one year (2007).

Meteorological data (temperature, precipitation, relative humidity) were monitored over the study periods (1991-1996; 2005-2007) from March to August (Figure 1).

RESULTS

Study of cultivar susceptibility to apple scab and powdery mildew from 1991 to 1996

Apple orchard at Rimski Šančevi (Southern Bačka, Vojvodina). Over the four-year period (1991-1992; 1995-1996) of testing apple cultivars for susceptibility to *V. inaequalis* (under 5-8 chemical treatments), disease severity varied depending on cultivar susceptibility and weather conditions in each season (Figure 2).

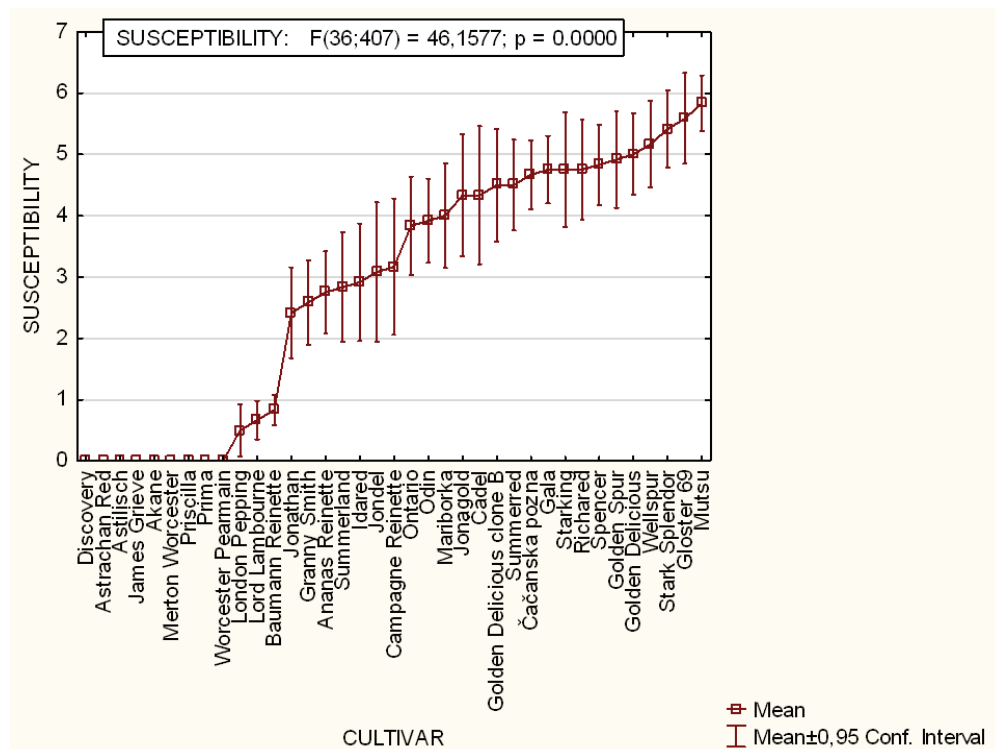


Figure 2. Susceptibility of apple cultivars to *Venturia inaequalis* as determined in Rimski Šančevi orchards in 1991-1992 and 1995-1996

During the extremely rainy 1991 season, disease symptoms were not detected on 9 cultivars, and symptoms were missing in 21 cultivars in the extremely dry 1992 season. During all of the 4 experimental seasons, scab was not detected in the following cultivars: Discovery, Astrachan Red, Astilisch, James Grieve, Akane, Merton Worcester, Priscilla, Prima and Worcester Pearmain, and these cultivars were consequently grouped as resistant ($M=0$). The cultivars London Pepping, Lord Lambourne and Baumann Reinette were moderately resistant ($M=0.01-2.00$); Jonathan, Granny Smith, Ananas Reinette, Summerland and Idared were moderately susceptible ($M=2.01-3.00$); Jonadel, Champagne Reinette, Ontario, Odin, Mariborka, Jonagold, Čadel, Golden Delicious clone B, Summerred, Čačanska pozna, Gala, Starking, Richared, Spenser, Golden Spur and Golden Delicious were susceptible ($M=3.01-5.00$); and Wellspur, Stark Splendor, Gloster 69 and Mutsu were highly susceptible ($M=5.01-6.00$) (Figure 2, Table 2). Mutsu was the most susceptible cultivar during all four years of testing.

Powdery mildew (*P. leucotricha*) regularly occurred in the orchard (1992-1994), although several chemical treatments per year were applied. The apple cultivars showed significant differences in susceptibility but without

significant variations over the years, and no cultivar could be classified as resistant (Figure 3). The cultivars marked as moderately resistant were: Discovery, Champagne Reinette, Prima, Astilisch and Lord Lambourne ($M=0.01-2.00$); the cultivars Ontario, Baumann Reinette, Jonadel, Richared, Astrachan Red, Wellspur, Starking, James Grieve, Worcester Pearmain, Gloster 69, Stark Splendor, Golden Spur and Golden Delicious clone B were moderately susceptible ($M=2.01-3.00$); while Merton Worcester, Čadel, London Pepping, Granny Smith, Golden Delicious, Čačanska pozna, Summerred, Spenser, Ananas Reinette, Mutsu, Priscilla, Mariborka, Odin, Summerland, Jonagold, Akane and Gala were rated as susceptible ($M=3.01-5.00$), and Jonathan and Idared as highly susceptible ($M=5.01-6.00$) (Table 3).

Apple orchard at Gladnoš (Srem, Vojvodina). Powdery mildew (*P. leucotricha*) was constantly present and spreading over the study period (1993-1995), which was expectable because fungicides were not applied. According to the results, the susceptibility of the examined cultivars to *P. leucotricha* varied in that orchard. The infection level was generally not very high (Figure 4) because the studied cultivars and some genotypes possess genetic resistance.

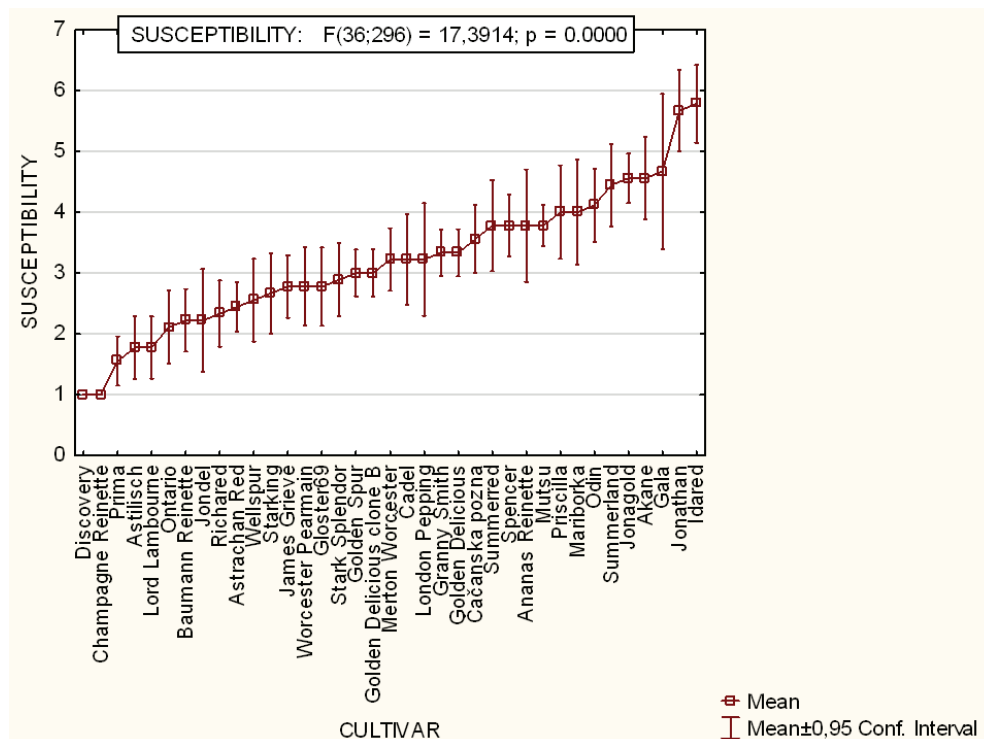


Figure 3. Susceptibility of apple cultivars to *Podosphaera leucotricha* as determined in Rimski šančevi orchards in 1992-1994

Disease symptoms were not detected in the genotypes coded as A 878/19 and 78221-1016-1-30, and they were consequently grouped as resistant ($M=0$); genotypes A 810/222 and 79508-1316-4-59, as well as several autochthonous cultivars (Prancia, Lipovača, Kumovača, Kolačara, Tetanka, Kožara, Melresa, Mušanika, Pramenka and Budimka) and wild apple were moderately resistant ($M=0.01-2.00$); Dayton, Baujade, Akpetrič, Produkta, Krivopecelj, Bobovec and Jadrolika were moderately susceptible ($M=2.01-3.00$); while Gloster 69, Granny Smith, Golden Delicious, Jonagold, Williams Pride and Bela čejna were susceptible ($M=3.01-5.00$) (Table 3).

Study of apple susceptibility to scab, powdery mildew and fire blight in 2005-2007

Apple orchards at Rimski Šančevi (orchards 1 and 2) and Kač (Southern Bačka, Vojvodina). The results of a two-year study (2005-2006) showed that some newer promising apple cultivars and different genotypes created in the most prominent breeding centers worldwide, expressed resistance to the most harmful diseases (scab and powdery mildew) under our agro-ecological

conditions. Some autochthonous cultivars included in this study also showed a high level of resistance, too (Figures 5 and 6, Tables 2 and 3).

In orchard 1 at Rimski Šančevi, scab (*V. inaequalis*) was not detected in any of the cultivars and genotypes with genetic resistance created in the world breeding centers (Reglindis, Regine, Remo, Remura, Rewena, Renora, Reanda, Williams Pride, Dayton, Selena, Dukát, Produkta and Baujade) or NS hybrids from Serbia (NS11/111, NS 11/46, NS 25/83 and NS 25/140). These cultivars were grouped as resistant ($M=0$). Disease severity on all autochthonous cultivars (Kožara, Krivopecelj, Budimka, Šumatovka, Bobovec and Krstovača) was also low, grouping them as moderately resistant ($M=0.01-2.00$) (Figure 5, Table 2).

The same cultivars also showed a high level of resistance to powdery mildew (*P. leucotricha*) in the period 2005-2006 (Figure 6). All German cultivars (Reglindis, Regine, Remo, Remura, Rewena, Renora and Reanda), several Czech cultivars (Selena and Dukát) and most of the promising hybrids from Serbia (NS 11/46, NS 25/83 and NS 25/140), as well as several autochthonous cultivars (Bobovec, Krivopecelj, Kožara, Budimka, Šumatovka and Krstavača) were grouped as resistant ($M=0$).

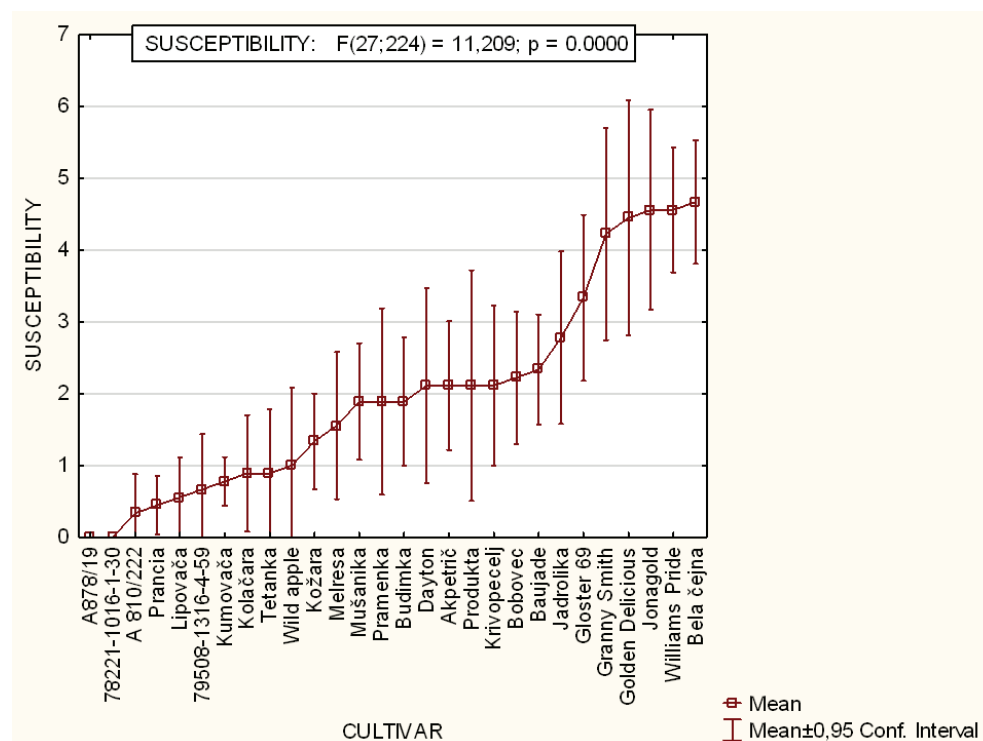


Figure 4. Susceptibility of apple cultivars to *Podosphaera leucotricha* as determined in Gladnoš orchard in 1993-1995

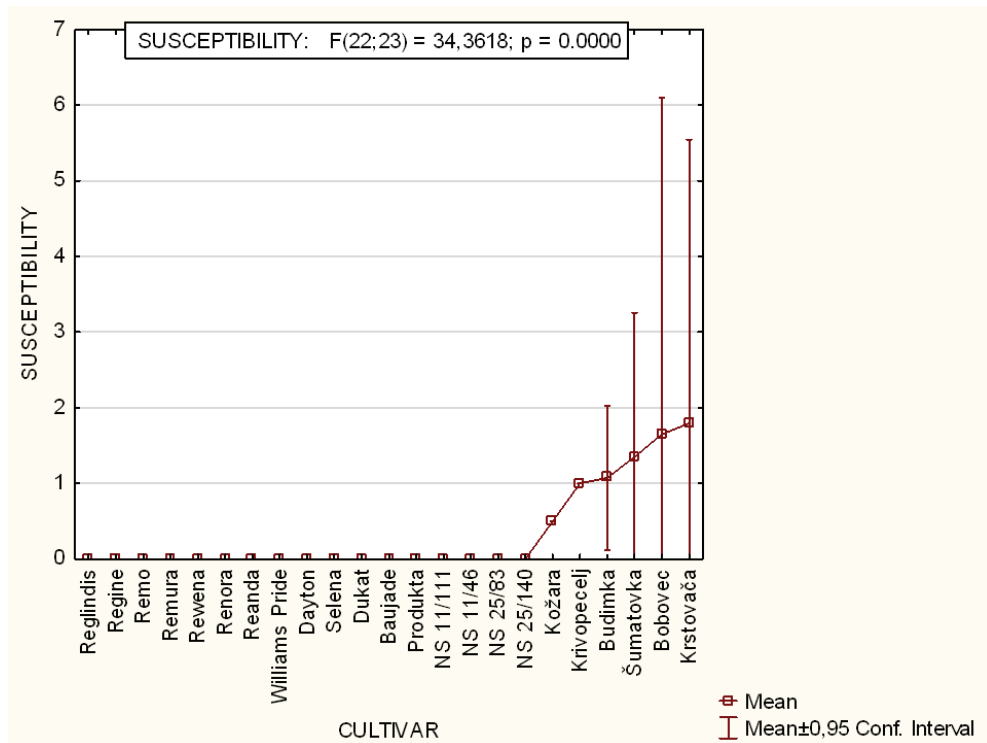


Figure 5. Susceptibility of apple cultivars to *Venturia inaequalis* as determined in Rimski Šančevi orchards in 2005-2006

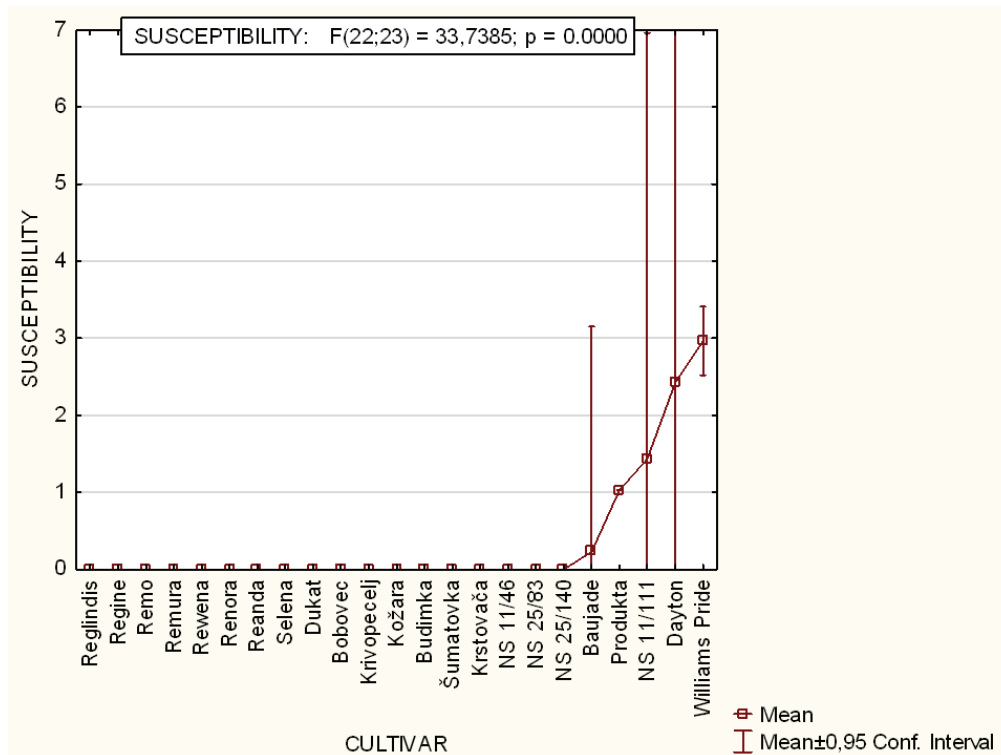


Figure 6. Susceptibility of apple cultivars to *Podosphaera leucotricha* as determined in Rimski Šančevi orchards in 2005-2006

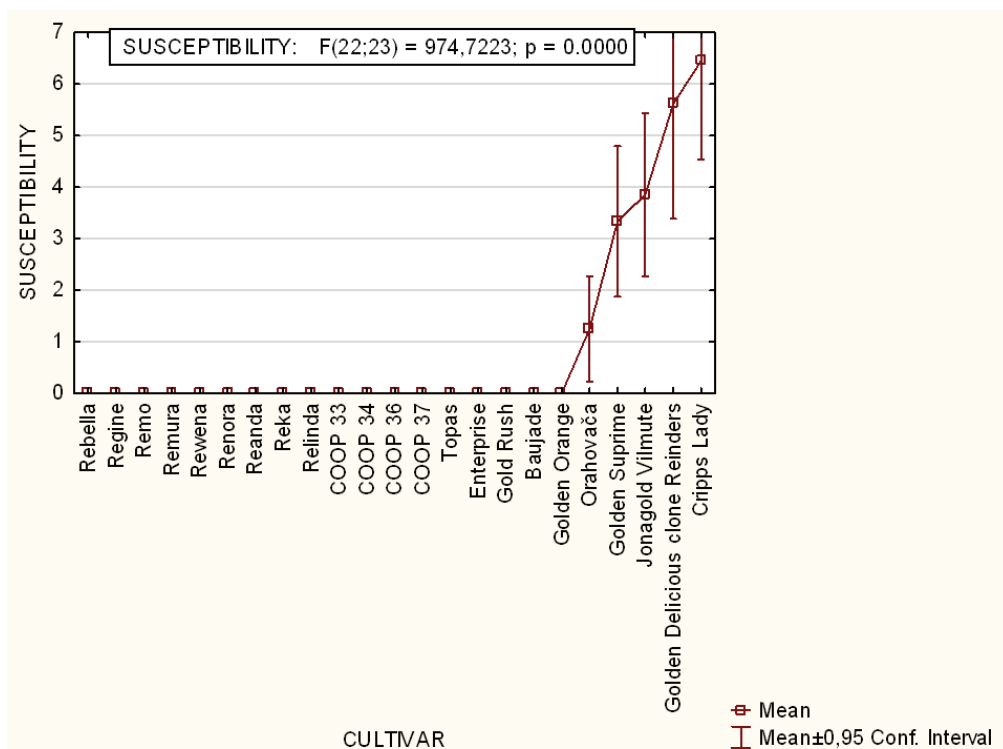


Figure 7. Susceptibility of apple cultivars to *Venturia inaequalis* as determined in Kač orchard in 2005-2006

Symptoms of powdery mildew were detected only at very low severity in the cultivars Baujade (France), Produkta (Czech Republic) and only in one Serbian genotype (NS 11/111), and they were grouped as moderately resistant ($M=0.01-2.00$). Two American cultivars (Dayton and William's Pride) were grouped as moderately susceptible ($M=2.01-3.00$) (Table 3).

In the orchard at Kač, symptoms of scab (*V. inaequalis*) were not detected in any of the apple cultivars with genetic resistance (originating from Germany, Czech Republic, Italy, France and Serbia) nor in several cultivars and genotypes from the USA (Figure 7). The cultivars Rebella, Regine, Remo, Remura, Rewena, Renora, Reanda, Reka, Relinda, Co-op 33, Co-op 34, Co-op 36, Co-op 37, Enterprise, GoldRush, Golden Orange, Topaz and Baujade were grouped as resistant ($M=0$). Very low disease severity (moderately resistant) was detected in the autochthonous cv. Orahovača ($M=0.01-2.00$). The commercial cvs. Golden Supreme and Jonagold Willmutte were grouped as susceptible ($M=3.01-5.00$), while Golden Delicious clone Reinders and Cripps Pink were found to be high susceptible ($M=5.01-6.00$) (Table 2).

In the same location (Kač), symptoms of powdery mildew (*P. leucotricha*) were not detected in most

of the examined cultivars (Regine, Remo, Rewena, Renora, Reka, Baujade, Co-op 33, Co-op 34, Co-op 36, Co-op 37, Golden Supreme, Jonagold Wilmutte, Golden Delicious clone Reinders and Topaz). They only appeared in traces on several cultivars (Enterprise, Orahovača, Golden Orange, Cripps Pink, Reanda, Rebella, Remura and Relinda). Such very low occurrence of powdery mildew in that orchard could possibly be attributed to a small amount of primary inoculum due to its more resistant apple assortment and isolation of that orchard from other fruit trees. Strong severity of powdery mildew occurred only in cv. GoldRush ($M\approx 4.00$).

The occurrence of *E. amylovora* was monitored at Rimski Šančevi in the period 2005-2007, but fire blight occurred only in 2007 (mainly as shoot blight symptoms) in all tested commercial cultivars. The disease continued to spread during June. Disease severity was relatively low (up to 12% of crown infection). The lowest severity of infection (in traces) was observed in cvs. Chief and Hapke ($\approx 0.3\%$), and a bit higher disease severity in the clones of Golden Delicious (B and Reinders) and Jonagored (1-3%). Higher disease severity was observed in the cvs. Jonagored, Idared and Granny Smith (4-6%) and the highest severity in cv. Elstar ($\approx 12\%$).

Table 2. Susceptibility/resistance of evaluated apple cultivars to scab over periods 1991-1996 and 2005-2006

Resistant		Moderately resistant		Moderately susceptible	Susceptible		Highly susceptible	
Rimski Šančevi	Kač	Rimski Šančevi	Kač	Rimski Šančevi	Rimski Šančevi	Kač	Rimski Šančevi	Kač
1991-1992; 1995-1996	2005-2006	1991-1992; 1995-1996	2005-2006	1991-1992; 1995-1996	1991-1992; 1995-1996	2005-2006	1991-1992; 1995-1996	2005-2006
Discovery	Reglindis	London Pepping	Orahovača	Jonathan	Jonadel	Golden Supreme	Wellspur	Golden Delicious clone Reinders
Astrachan Red	Regine	Lord Lambourne	Krivopecelj	Granny Smith	Champagne Reinette	Jonagold Willimute	Stark Splendor	Cripps Pink
Astrilisch	Remo	Baumann Reinette	Budimka	Ananas Reinette	Ontario		Gloster 69	
James Grievie	Remura		Šumatovka	Summerland	Odin		Mutsu	
Akane	Rewena		Bobovec	Idared	Mariborka			
Merton Worcester	Renora		Krstovača		Jonagold			
Priscilla	Reanda				Čadel			
Prima	Williams Pride				Golden Delicious clone B			
Worcester Pearmain	Dayton				Summerred			
	Selena				Čačanska pozna			
	Dukát				Gala			
	Produkta				Starking			
	Baujade				Richared			
	NS11/111				Spenser			
	NS 11/46				Golden Spur			
	NS 25/83				Golden Delicious			
	NS 25/140							
	Topaz							
	Baujade							

Table 3. Susceptibility/resistance of evaluated apple cultivars to powdery mildew over periods 1992-1995 and 2005-2006

Resistant		Moderately resistant		Moderately susceptible		Susceptible		Highly susceptible	
Gladnoš	Rimski Šančevi	Rimski Šančevi	Gladnoš	Rimski Šančevi	Gladnoš	Rimski Šančevi	Gladnoš	Rimski Šančevi	Rimski Šančevi
1993-1995	2005-2006	1992-1994	2005-2006	1993-1995	2005-2006	1992-1994	2005-2006	1993-1995	1992-1994
A 878 119	Reglindis	Discovery	Baujade	A 810/222	Ontario	Dayton	Dayton	Dayton	Merton Worcester
78221-1016-1-30	Regine	Champagne Reinette	Produkta	79508-1316-4-59	Baumann Reinette	William's Pride	Baujade	Baujade	Čadel
	Remo	Prima	NS 11/111	Prancia	Jonadel		Akpetrič	Golden Delicious	Granny Smith
	Remura	Astilisch		Lipovača	Richared		Produkta	Golden Delicious	London Pepping
	Rewena	Lord Lamburne		Kumovača	Astrachan Red		Krivopecelj	Williams Pride	Granny Smith
	Renora			Kolačara	Wellsipur		Bobovec	Bela čejna	Golden Delicious
	Reanda			Tetanka	Starking		Baujade		Čačanska pozna
	Selena			Kožara	James Grieve		Jadrolika		Summerred
	Dukát			Melresa	Worcester Pearmain				Spencer
	NS 11/46			Mušanika	Gloster 69				Ananas Reinette
	NS 25/83			Pramenka	Stark Splendor				Mutsu
	NS 25/140			Budimka	Golden Spur				Priscilla
	Bobovec			wild apple	Golden Delicious clone B				Mariborka
	Krivopecelj								Odin
	Kožara								Summerland
	Budimka								Jonagold
	Šumatovka								Alkane
	Krstavača								Gala
									Jonathan
									Idared

DISCUSSION

Scab (*V. inaequalis*) occurs on a regular annual basis wherever apple trees are grown in Serbia. Disease severity mostly depends on weather conditions (Visser et al., 1974; Sestraš, 2003a), cultivar susceptibility and quality of chemical control. Scab could be successfully suppressed by Integrated Pest Management (IPM), i.e. by creating and introducing new apple cultivars which ensure high yields, fruit quality and resistance to the most damaging diseases (Ciglar, 1998; Ciancio & Mukerji, 2008; Deguine et al., 2009). However, introduction of scab resistant cultivars has not been so successful because of a lack of fruit quality and broken scab resistance in some cultivars.

The results showed that under the specific agroecological conditions in Vojvodina, some of the well-known cultivars, such as Cripps Pink, Mutsu, Gloster 69 and Wellspur, were highly susceptible, while cvs. Golden Delicious, Richared, Gala, Čačanska pozna, Čadel, Jonagold and Jonadel were susceptible to *V. inaequalis*. These results are mostly matching reports by many other authors (Vojvodić & Vrabl, 1984; Jeger & Alston, 1986; Washington et al., 1998; Sestraš, 2003a; Beckerman, 2006; Ames, 2011). Cvs. Idared, Granny Smith and Jonathan were found to be moderately susceptible. Similar results were reported by Beckerman (2006). The group of moderately resistant cultivars included cvs. London Pepping, Lord Lambourne and Baumann Reinette, which are generally known in literature as being low susceptible (Viršček-Marn, 1994; Sestraš, 2003a). All autochthonous cultivars (Krstovača, Bobovec, Šumatovka, Budimka, Krivopecelj, Kožara and Orahovača) were classified as moderately resistant. Resistance of the autochthonous apple cultivars to most common diseases (scab, powdery mildew and fire blight) is in most cases controlled by a number of minor genes (horizontal non-race-specific resistance) (Ognjanov, 2005). Scab symptoms were not detected in numerous cultivars, such as Worcester Pearmain, Prima, Priscilla, Akane, Merton Worcester, James Grieve, Astilisch, Astrachan, Red Discovery, Williams Pride, Dayton, Enterprise, GoldRush, Golden Orange, Produkta, Selena, Dukát, Topaz, Baujade; all of the Re-cultivars (Germany), all NS hybrids (Serbia) and Co-op selections (USA).

The cultivars Prima, Priscilla and other cultivars with genetic resistance (V_f gene from *Malus floribunda* 821, named as Rvi6 according to new nomenclature given by Bus et al., 2011) are generally known as highly resistant to *V. inaequalis* (Cumminis, 2005; Beckerman, 2006; Ames, 2011). According to our long-term observation, race 6 never appeared under the production conditions of Vojvodina.

The resistance of other cultivars from this group, such as Akane, Discovery, James Grieve and Worcester Pearmain is mainly based on polygenic resistance (Fischer & Fischer, 2002; Sandskär, 2003; Quamme et al., 2003). All Re-cultivars created in the Institute for Fruit Research at Dresden-Pillnitz (Germany) are known as having a high degree of resistance, i.e. triple and multiple resistance (Fischer & Fischer, 2004). Our experiments confirmed that under Serbia's agro-ecological conditions resistance has not been overcome in any of the Germany cultivars carrying the V_f (Regine, Remo, Rewena, Renora and Reanda), V_A (Reglindis) or V_r gene (Remura).

The resistance of apple cultivars can be conditioned by monogenic or polygenic inheritance. Monogenetic inheritance is based on major genes (e.g. V_f gene in cvs. Prima and Priscila). This resistance is high (vertical) and easily transferrable by conventional crossing methods, but this type of resistance is risky because it can be easily overcome by appearance of new races of pathogens. The apple scab resistance genes and plant sources for monogenic genes inheritance for *V. inaequalis* are: *M. floribunda* 821 (V_f), *M. micromalus* (V_m), *M. pumila* R 12740-7A (V_r), *Hansen's baccata* #2 (V_b), *M. baccata jackii* (V_{bj}), Antonovka PI 172623 (V_a), Golden Delicious (V_g); for polygenic inheritance: *M. baccata* (selected seedlings), *M. sargentii* 843, *M. sieboldii* 2982-22, *M. x zumi calocarpa*, *M. toringo* 852 and Old European cultivars (Lespinasse, 1994; Crosby et al., 1992; Bénaouf & Parisi, 2000; Hemmat et al., 2002; Sandskär, 2003). The V_f gene from *M. floribunda* clone 821 as a source of monogenic resistance to *V. inaequalis* is the most frequently used gene in apple breeding programs. This gene determines high resistance (immunity). Prima is the first cultivar (1970) from a series of PRI apple cultivars (with the V_f gene) that have an acceptable fruit size and quality (Gessler & Pertot, 2012). During the period 1970-1990, 48 scab resistant cultivars were created worldwide, of which 37 cultivars contained the V_f gene from *M. floribunda* 821 (Crosby et al., 1992). Scab symptoms on leaves of the cultivar Prima (V_f), as well as on other apple cultivars and selections (originating from *M. floribunda* 821, and with the progenitor *M. floribunda* 821 remaining resistant) were noted in 1984 (Germany). The occurrence of scab symptoms on selection material originating from *M. floribunda* 821 (V_f gene) meant that a new race of *V. inaequalis* appeared which overcame the resistance conditioned by the V_f gene. That new race of *V. inaequalis* was named as race 6, and it was described by Parisi et al. (1993). After only a year, race 7 was described in England (Roberts & Crute, 1994), which could infect all progenies of *M. floribunda* 821. Five races

of *V. inaequalis* had been described in the earlier period: races 1-3 (Shay & Williams, 1956), race 4 (Williams & Kuć, 1969), race 5 (Williams & Brown, 1968).

Another type of inheritance is polygenic, conditioned by a number of genes. Polygenic resistance is not high (horizontal) and it depends on ecological factors, but it is more durable. The best way of preserving durable resistance is a combination of various sources of resistance. Such genetic base provides the best barrier against infection with pathogens (Evans et al., 2000). Polygenic resistance is usually a characteristic of older traditional apple cultivars, manifesting itself as field resistance to a certain degree.

Our data on *P. leucotricha* presence showed that cvs. Jonathan and Idared were highly susceptible to powdery mildew, confirming earlier findings (Vojvodić & Vrabl, 1984; Marine et al., 2010; Yoder & Biggs, 2011a). Many well-known cultivars, such as Gala, Akane, Jonagold, Priscilla, Mutsu, Čačanska pozna, Golden Delicious, Granny Smith, Čadel and Gloster 69, were found susceptible. According to literature sources, Golden Delicious, Mutsu, Summerred and Jonagold are susceptible (Yoder & Biggs, 2011a) but Granny Smith was reported as highly susceptible by several authors (Marine et al., 2010; Yoder & Biggs, 2011a). In our experiments, cvs. Priscilla and Williams Pride were susceptible to powdery mildew, but these cultivars are cited in literature as resistant to moderately resistant (Cline et al., 1998; Yoder & Biggs, 2011a; Beckerman, 2006). Apart from that, Williams Pride and Gloster 69 growing on the location Gladnoš were rated as susceptible, while being moderately susceptible on the location Rimski Šančevi. Such inconsistent reaction could be attributed to a difference in the quantity of primary inoculum and variation in climatic conditions on the observed locations. Similarly, cvs. Baujade and Produkta were moderately susceptible on the location Gladnoš, and moderately resistant at Kać. Many of the well-known cultivars, such as Worcester Pearmain, James Grieve, Wellsipur, Richared, Jonadel and Dayton, were classified as moderately susceptible cultivars. In literature, most of these cultivars have been described as low susceptible to powdery mildew (Sestraš, 2003b; Beckerman, 2006; Ames, 2011). In the category of moderately resistant cultivars were: Discovery, Champagne Reinette, Prima, Astilish and Lord Lambourne. The cultivar Prima has been reported as resistant to powdery mildew by many authors (Cline et al., 1998; Beckerman, 2006; Yoder & Biggs, 2011a). The cultivars Discovery, Champagne Reinette, Prima, Astilish, Astrachan Red, James Grieve and Worcester Pearmain have already been reported as

low susceptible, and suitable for integrated production (Keserović et al., 1993). All autochthonous cultivars showed a relative low susceptibility to powdery mildew. On the location Gladnoš, cvs. Jadrolika, Bobovec, Krivocepelj and Akpetrič were moderately susceptible, and Budimka, Pramenka, Mušanika, Melresa, Kožara, Tetanka, Kolačara, Kumovača, Lipovača and Prancia were moderately resistant. On the location Kać, some of these cultivars (Bobovec, Krivocepelj, Kožara and Budimka) showed resistant reactions, indicating that the quantity of primary inoculum here also had an influence on the severity of powdery mildew disease. A previous study reported by Balaž et al. (1996) indicated that some autochthonous Serbian cultivars (Prancia, Lipovača and Kumovača) were highly resistant to powdery mildew. All of the Re-cultivars (Germany) showed resistant reactions on the location Rimski Šančevi. In some of them, powdery mildew appeared on the location Kać, but only at very low severity (in traces). Fischer and Fischer (2004) reported that cvs. Remo and Rewena were resistant, and Reanda, Regine, Renora and Reglindis low resistant to powdery mildew. The cultivars created in other breeding centres, such as Selena, Dukát, Topaz (Czech Republic), most NS hybrids (Serbia) and some Co-op selections (USA) have also been found resistant. The NS hybrids are the result of multiple-year selection work in Serbia (Ognjanov et al., 2011). The donors of resistance for these hybrids were the leading commercial and autochthonous apple cultivars. On the location Kać (2005-2006), powdery mildew appeared with stronger severity only in cv. GoldRush ($M \approx 4.00$). In literature sources, this cultivar varies from being classified as resistant (Cumminis, 2005; Ames, 2011) to moderately resistant (Cline et al., 1998), and to susceptible (Beckerman, 2006) or high susceptible (Biggs et al., 2010).

E. amylovora, monitored in the commercial apple orchard at Rimski Šančevi from 2005 to 2007 occurred only in 2007 when weather in the spring was rainy and favourable for infection. Disease appeared only as “shoot blight” and not in a strong severity form (up to 12% of crown infection). The highest infection was noted on the cultivar Elstar, then Idared and Granny Smith; low disease severity was observed on Jonagored and Golden Delicious and the lowest (in traces) on Hapke and Red Chief. A relatively higher disease severity was expected in Idared and Granny Smith because literature references describe them as the most susceptible cultivars to fire blight (Sobiczewski et al., 1997; Beckerman, 2006; Arsenijević & Gavrilović, 2007; Yoder & Biggs, 2011b). In a fire blight epidemic that occurred in Vojvodina

in 2000, the highest disease severity was found on cvs. Idared and Gloster 69; medium severity on Granny Smith and Golden Delicious, and the lowest on Prima, Priscilla and Wellspur (Balaž, 2000). These data were supported by a later study (Aćimović et al., 2014), in which symptoms of fire blight on cv. Idared in Vojvodina province were significantly more severe than they were on Golden Delicious. In literature, Idared, Granny Smith and Golden Delicious have been reported as highly susceptible and/or susceptible cultivars; Prima and Priscilla as moderately resistant (Steiner, 2005); and cv. Elstar as moderately/highly susceptible (Koski & Jacobi, 2009) or moderately susceptible (Panić & Arsenijević, 1996; Sobiczewski et al., 1997). Red Chief was moderately resistant, which is consistent with other reports (Koski & Jacobi, 2009).

REFERENCES

- Aćimović, S.G., Balaž, J.S., Aćimović, D.Đ., & Reeb, P.D. (2014). High magnitude of fire blight (*Erwinia amylovora*) symptom development and canker formation from July onwards on two apple cultivars under severe natural infections. *Journal of Plant Pathology*, 96, 159-168. doi: 10.4454/JPPV96I1.035
- Ames, G. (2011). Disease resistant apple varieties. In T. Hinman & G. Ames (Eds.), *Apples: Organic production guide* (pp 26-31). NCAT, ATTRA. <http://ucanr.edu/sites/placernevadasmallfarms/files/112366.pdf>
- Arsenijević, M., & Gavrilović, V. (2007). Praktični priručnik o bakterioznoj plamenjači voćaka i ukrasnih biljaka. Belgrade, Serbia: Institute for Plant Protection and Environment.
- Balaž, J. (2000). Epifitotična pojava bakteriozne plamenjače na jabuci. *Biljni lekar*, 28(4), 272-274.
- Balaž, J., & Petrina, R. (2003). Krastavost jabuke – ekonomski najštetnija bolest jabuke. Novi Sad: Društvo voćara Vojvodine.
- Balaž, J., Vujanić-Varga, D., Gvozdrenović, D., Ognjanov, V., Keserović, Z., & Gašić, K. (1996). Ispitivanje osetljivosti raznih genotipova jabuke prema *Podosphaera leucotricha* u našim uslovima. In *10 kongres voćara Jugoslavije*, Čačak, Srbija (p 215).
- Beckerman, J. (2006). Disease susceptibility of common apple cultivars. Fruit Diseases, BP-132-W, Purdue Extension. Retrieved from <https://www.extension.purdue.edu/extmedia/BP/BP-132-W.pdf>
- Bénaouf, G., & Parisi, L. (2000). Genetics of host-pathogen relationships between *Venturia inaequalis* races 6 and 7 and *Malus* species. *Phytopathology*, 90(3), 236-242.
- Biggs, A.R., Sundin, G.W., Rosenberger, D.A., Yoder, K.S., & Sutton, T.B. (2010). Relative susceptibility of selected apple cultivars to apple scab caused by *Venturia inaequalis*. *Plant Health Progress*. doi:10.1094/PHP-2010-0408-01-RS.
- Bus, V.G., Rikkerink, E.H., Caffier, V., Durel, C.E., & Plummer, K.M. (2011). Revision of the nomenclature of the differential host-pathogen interactions of *Venturia inaequalis* and *Malus*. *Annual Review of Phytopathology*, 49, 391-413.
- Ciancio, A., & Mukerji, K.G. (eds.) (2008). Integrated management of diseases caused by fungi, phytoplasma and bacteria. Netherlands: Springer.
- Ciglar, I. (1998). Integralna zaštita voćnjaka i vinograda. Čakovec, Croatia: Zrinski.
- Cline, J., Warner, J., Wilson, K.R., & Zandstra, J. (1998). Disease-resistant apple cultivars. Ontario, Ministry of Agriculture, Food and Rural Affairs. Retrieved from <http://www.omafra.gov.on.ca/english/crops/facts/98-013.htm>
- Crosby, J.A., Janick, J., Pecknold, P.C., Korban, S.S., O'Connor, P.A., Ries, S.M., Goffreda, J., & Voordeskers, S. (1992). Breeding apples for scab resistance: 1945-1990. *Acta Horticulturae*, 317, 43-70.
- Cummins, J.N. (2005). Resistances of apple varieties. Retrieved from Cummins Nursery. <http://www.cumminsnursery.com/restable.htm>
- Deguine, J. P., Ferron, P., & Russell, D. (2009). *Crop protection: from agrochemistry to agroecology*. Boca Raton, FL: CRC Press.
- Evans, K., Lespinasse, Y., Parisi, L., Laurens, F., & Durel, C.E. (2000). Durable resistance to scab and mildew in apple – a European project. *Pesticide Outlook*, June. Retrieved from <http://www.researchinformation.co.uk/pest/2000/B0063471.PDF>
- Fischer, M., & Fischer, C. (2002). The Dresden-Pillnitz long-term apple breeding program and its results. *Compact Fruit Tree*, 35(1), 21-25.
- Fischer, M., & Fischer, C. (2004). Genetic resources as basis for new resistant apple cultivars. *Journal of Fruit and Ornamental Plant Research*, 12, 63-76.
- Gessler, C., & Pertot, I. (2012). Vf scab resistance of *Malus*. *Trees*, 26, 95-108.
- Gullino, M.L., & Kuijpers, L.A.M. (1994). Social and political implications of managing plant diseases with restricted fungicides in Europe. *Annual Review of Phytopathology*, 32, 559-579.
- Hemmat, M., Brown, S.K., & Weeden, N.F. (2002). Tagging and mapping scab resistance genes from R1270-7A apple. *Journal of the American Society For Horticultural Science*, 127(3), 365-370.

- Jeger, M.J., & Alston, F.H. (1986). Resistance in apple to shoot infection by *Venturia inaequalis*. *Annals of Applied Biology*, 108(2), 387-394.
- Keserović, Z., Gvozdenović, D., & Balaž, J. (1993) Ispitivanje pogodnosti sorti jabuke za primenu u integralnoj proizvodnji. *Savremena poljoprivreda, Novi Sad*, 6, 101-107.
- Koski, R.D., & Jacobi, W.R. (2009). Fire blight. Fact sheet No. 2.907. Retrieved from Colorado State University Extension at <http://extension.colostate.edu/docs/pubs/garden/02907.pdf>
- Lespinnasse, V. (1994). Apple scab, resistance and durability. New races and strategies for the future. In Schmidt, H., Kellerhals, M. (Eds.), *Progress in temperate fruit breeding* (pp 105-106). Dordrecht, Netherlands: Springer.
- Marine, S.C., Yoder, K.S., & Baudoin, A. (2010). Powdery mildew of apple. *Plant Health Instructor*. doi:10.1094/PHI-I-2010-1021-01
- Ognjanov, V. (2005). Autohtone sorte jabuka kao donori otpornosti na parazite (Autochthonous apple varieties as donors for disease resistance). *Voćarstvo* 39(150), 127-131.
- Ognjanov, V., Ljubojević, M., Bošnjaković, D., Barać, G., Mladenović, E., & Čukanović, J. (2011). Disease-resistant apple selections developed from the apple breeding program at the Faculty of Agriculture Novi Sad. In *22nd International Symposium "Food Safety Production"*, Trebinje, Bosnia and Herzegovina (pp 271-273).
- Panić, M., & Arsenijević, M. (1996). Bakteriозна plamenjača voćaka i ukrasnih biljaka – *Erwinia amylovora*. Beograd: Zajednica za voće i povrće; Novi Sad: Poljoprivredni fakultet.
- Parisi, L., Lespinasse, Y., Guillaumes, J., & Kruger, J (1993). A new race of *Venturia inaequalis* virulent to apples with resistance due to the Vf gene. *Phytopathology*, 83(5), 533-537.
- Parisi, L., Orts, R., Rivenez Damboise, M.O., Lefeuve, M., & Lagarde, M.P. (1995). Protection intégrée du verger de pommiers de l'an 2000, tavelure et oidium: variétés résistantes et lutte raisonnée. *L'Arboriculture Fruitière* 486, 25-29.
- Quamme, H.A., Hampson, C.R., Hall, J.W., Sholberg, P.L., Bedford, K.E., & Randall, P. (2003). Inheritance of apple scab resistance from polygenic sources based in the greenhouse and field evaluation. *Acta Horticulturae*, 622, 317-321.
- Roberts, T., & Crute, I. (1994). Apple scab resistance from *Malus floribunda* 821 (Vf) is rendered ineffective by isolates of *Venturia inaequalis* from *Malus floribunda*. *Norwegian Journal of Agricultural Science*, 17, 403-406.
- Sandskär, B. (2003). Apple scab (*Venturia inaequalis*) and pests in organic orchards. Dissertation. Swedish University of Agricultural Sciences. Retrieved from <http://pub.epsilon.slu.se/162/1/91-576-6416-1.fulltext.pdf>
- Sestraš, R. (2003a). Response of several apple varieties to apple scab (*Venturia inaequalis*) attack in Central Transylvania conditions. *Journal of Central European Agriculture*, 4(4), 355-362.
- Sestraš, R. (2003b). Response of several apple varieties to powdery mildew (*Podosphaera leucotricha*) attack in Central Transylvania conditions. *Journal of Central European Agriculture*, 4(4), 347-353.
- Shay, J.R., & Williams, E.B. (1956). Identification of three physiologic races of *Venturia inaequalis*. *Phytopathology*, 46, 190-193.
- Sobiczewski, P., Deckers, T., & Pulawska, J. (1997). *Fire blight (Erwinia amylovora). Some aspects of epidemiology and control*. Skiernewice, Poland: Research Institute of Pomology and Floriculture.
- Steiner, P.W. (2005). *Fire blight of apple*. Report on plant disease No. 801. Urbana-Champaign, IL: Department of Crop Sciences, University of Illinois. Retrieved from <https://ipm.illinois.edu/diseases/rpds/801.pdf>
- Viršček-Marn, M., Štampar, F., Smole, J., & Solar, A. (1994). Susceptibility of some apple cultivars to scab (*Venturia inaequalis* (Cooke) Aderh.) in Slovenia. In H. Schmidt & M. Kellerhals (Eds.), *Progress in Temperate Fruit Breeding, Developments in Plant Breeding* (pp 31-34). Springer Netherlands.
- Visser, T., Verhaegh, J.J., & Vries, D.P. (1974). Resistance to scab (*Venturia inaequalis*) and mildew (*Podosphaera leucotricha*) and fruiting properties of the offspring of the apple cultivar Antonovka. *Euphytica* 23(2), 353-364.
- Vojvodić, Đ., & Vrabl, S. (1984). Bolesti i štetočine jabuke i kruške. Belgrade, Serbia: Nolit, 195.
- Washington, W.S., Villalta, O.N., Ingram, J., & Bardon, D. (1998). Susceptibility of apple cultivars to apple scab and powdery mildew in Victoria, Australia. *Australian Journal of Experimental Agriculture*, 38(6), 625-629.
- Watkins, R., & Smith, R.A. (eds.) (1982). Descriptor list for apple (*Malus*). International Board for Plant Genetic Resources. Commission of European Communities: Committee on disease resistance breeding and use of genebanks. Brussels: CEC Secretariat; Rome: IBPGR Secretariat. Retrieved from http://www.biodiversityinternational.org/uploads/tx_news/Apple_descriptors_320.pdf
- Williams, E.B., & Brown, A.G. (1968). A new physiological race of *Venturia inaequalis* incitant of apple scab. *Plant Disease Reporter*, 52, 799-801.
- Williams, E.B., & Kuć, J (1969). Resistance in *Malus* to *Venturia inaequalis*. *Annual Review of Phytopathology*, 7, 223-246.

Yoder, K.S. & Biggs, A.R. (2011a). Table of apple cultivar susceptibility to powdery mildew. Retrieved from http://www.extension.org/pages/60617/table-of-apple-cultivar-susceptibility-to-powdery-mildew#.VO7wQ3zF9_Y

Yoder, K.S. & Biggs, A.R. (2011b). Table of apple cultivar fire blight susceptibility. Retrieved from <http://www.extension.org/pages/60613/table-of-apple-cultivar-fire-blight-susceptibility#.VVxYt9Kqqko>

Proučavanje osetljivosti komercijalnih i autohtonih sorti jabuke prema najznačajnijim bolestima u Srbiji u uslovima spontane zaraze

REZIME

Ovaj rad prikazuje rezultate višegodišnjeg proučavanja (1991-1996; 2005-2007) osetljivosti više od 100 sorti jabuke prema patogenima *Venturia inaequalis*, *Podospaera leucotricha* i *Erwinia amylovora* u agroekološkim uslovima Srbije. Neke od dobro poznatih sorti su visoko osetljive prema *V. inaequalis* (Cripps Pink, Mutsu, Gloster 69, Wellspur); osetljive su Golden Delicious, Richared, Gala, Čačanska pozna, Čadel i Jonagold; umereno osetljive su Idared, Granny Smith i Jonathan; umereno otporne su Lord Lamburne i London Pepping, kao i nekoliko autohtonih sorti; grupa otpornih uključuje sorte Prima, Priscilla, Williams Pride, Dayton, Enterprise, Gold Rush, Golden Orange, mnoge Re-sorte (Nemačka), Baujade, Selena, Dukát, Produkta, Topaz, neke starije sorte (Worcester Pearmain, Merton Worcester, James Grieve, Akane, Astilish, Astrachan Red i Discovery), neke Co-op selekcije (USA) i NS hibridi (Srbija). Prema pepelnici vrlo osetljive su bile sorte Idared i Jonathan; osetljive Gala, Akane, Jonagold, Priscilla, Mutsu, Čačanska pozna, Golden Delicious, Granny Smith, Čadel i GoldRush; umereno osetljive Wellspur, Astrachan Red, Richared, Jonadel, Dayton i nekoliko autohtonih sorti; umereno otporne su Lord Lamburne, Astlisch, Prima, Champagne Reinette, Discovery i mnoge autohtone sorte; i otporne su Re-sorte, nekoliko sorti iz Češke Republike, neke selekcije poreklom iz USA i UK i većina NS hibrida. Takođe, neke sorte su i varirale u osetljivosti (Williams Pride, Gloster 69, Baujade i Produkta). *E. amylovora* je beležena samo 2007. godine sa relativno malim intenzitetom bolesti (infekcija do 12%). Najveći intenzitet bolesti je primećen kod sorte Elstar, zatim slede sorte Granny Smith, Idared, Jonagored; a najmanji intenzitet je bio kod sorti Red Chief i Hapke.

Ključne reči: Jabuka; Sorte; Čađava krastavost jabuke; Pepelnica jabuke; Bakteriozna plamenjača; Srbija