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Resistance to Pathogens of the Potato Accessions from the Collection of N. I. Vavilov Institute of Plant Industry (VIR)

Nadezhda Zoteyeva · Mirosława Chrzanowska · Bogdan Flis · Ewa Zimnoch-Guzowska

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Abstract In total, 154 accessions of wild potato species from VIR's potato collection were screened at IHAR-PIB Młochów Research Center (Poland) for resistance to *Phytophthora infestans* and, a part of them, for resistance to Potato Virus X (PVX) and Potato Virus Y (PVY). High levels of leaf resistance to *P. infestans* were found in the accessions of Central American species *S. antipovichii* Buk., *S. cardiophyllum* Lindl., *S. demissum* Lindl., *S. guerreroense* Corr., *S. neoantipovichii* Buk., *S. papita* Rydb., *S. pinnatisectum* Dun., *S. polytrichon* Rydb., *S. stoloniferum* Schlechtd., and *S. verrucosum* Schlechtd., as well as South-American species *S. berthaultii* Haw., *S. microdontum* Bitt., *S. ruiz-ceballosii* Card., *S. simplicifolium* Bitt., and *S. vernei* Bitt. et Wittm. Tuber resistance was found in the accessions of Central American species *S. cardiophyllum*, *S. neoantipovichii*, *S. papita*, *S. polytrichon*, *S. pinnatisectum*, and *S. trifidum* Corr., and of South-American species *S. acaule* Bitt., *S. berthaultii* Hawk., *S. kurtzianum* Bitt. et Wittm. and *S. ruiz-ceballosii* Card. The majority of the accessions were characterized by within population variation of leaf and tuber resistance to late blight under laboratory testing conditions. A few accessions of *S. demissum*, *S. guerreroense* Corr., *S. neoantipovichii* and *S. stoloniferum* expressed combined resistance to late blight, PVX and two or three strains of PVY.

N. Zoteyeva
N.I. Vavilov Institute of Plant Industry (VIR),
St. Petersburg, Russia

M. Chrzanowska · B. Flis · E. Zimnoch-Guzowska (✉)
Plant Breeding and Acclimatization Institute – National Research Institute, (IHAR-PIB), Młochów Research Center,
05-831 Młochów, Poland
e-mail: e.zimnoch-guzowska@ihar.edu.pl

Resumen Se probaron en total 154 introducciones de especies silvestres de papa de la colección VIR en el Centro de Investigación Młochów IHAR-PIB (Polonia) para resistencia a *Phytophthora infestans* y una parte de ellas para resistencia al Virus X de la Papa (PVX) y Virus Y de la Papa (PVY). Se encontraron altos niveles de resistencia foliar a *P. infestans* en introducciones de las especies Centroamericanas *S. antipovichii* Buk., *S. cardiophyllum* Lindl., *S. demissum* Lindl., *S. guerreroense* Corr., *S. neoantipovichii* Buk., *S. papita* Rydb., *S. pinnatisectum* Dun., *S. polytrichon* Rydb., *S. stoloniferum* Schlechtd., y *S. verrucosum* Schlechtd, así como en las especies Sudamericanas *S. berthaultii* Haw., *S. microdontum* Bitt., *S. ruiz-ceballosii* Card., *S. simplicifolium* Bitt., *y S. vernei* Bitt. *et* Wittm. Se encontró resistencia en tubérculo en las introducciones de las especies Centroamericanas *S. cardiophyllum, S. neoantipovichii, S. papita, S. polytrichon, S. pinnatisectum,* y S. *trifidum* Corr, y de las Sudamericanas *S. acaule* Bitt., *S. berthaultii* Hawk., *S. kurtzianum* Bitt. *et* Wittm. y *S. ruiz-ceballosii* Card. La mayoría de las introducciones se caracterizaron por variación interna de la población en resistencia foliar y de tubérculo al tizón tardío bajo condiciones de prueba de laboratorio. Algunas introducciones de *S. demissum, S. guerreroense* Corr., *S. neoantipovichii* y *S. stoloniferum* expresaron resistencia combinada al tizón tardío, PVX y a dos o tres variantes de PVY.

Keywords Wild *Solanum* species · Resistance · *Phytophthora infestans* · PVX · PVY

Introduction

Due to the changes in the pathogen population, the late blight disease of potatoes caused by the oomycete *Phytophthora* *infestans*, has become more difficult to manage. Economic losses caused by late blight result from both: the foliage and tuber susceptibility of grown cultivars. The number of *P. infestans* resistant cultivars used in potato production is not sufficient for reducing yield losses. The cultivars developed in the 19th and early 20th century provided a narrow genetic base. In Europe, the cultivated potato might have originated from only a few introductions (Ross 1986). Until the end of the 20th century, the germplasm available consisted of a small number of potato cultivars with field resistance to late blight (Colon 1994). By the 1980s, 77 % of European (including the Russian cultivars) and North American cultivars had introduced genes of resistance to *P. infestans* derived only from *S. demissum*.

The All Russian Institute of Plant Industry (VIR) potato collection was initiated with the accessions collected in 1925–1926 by Bukasov, Voronov and Juzepczuk in Mexico, Guatemala and Colombia, and in 1926–1928 by Juzepczuk in South and Central Peru, North Bolivia and Chile (Juzepczuk and Bukasov 1929, 1936). This wild potato germplasm was intensively evaluated and used in potato breeding in Russia over many years of research. However, the financial crisis of the 1990s caused difficulties in collection propagation and increased the risk of the accession losses.

In 1998–2000, the accessions from the VIR collection were reconstructed from old true seeds at IHAR-PIB, Młochów Research Center (Poland) with financial support of CEEM (Cornell-Eastern Europe-Mexico) Project on Late Blight Control. During those 3 years, the 305 accessions of wild potato species from VIR collection were sown in Młochów. Seed or tuber reproductions were obtained for 147 accessions. Reproduced seed samples were divided into three parts and distributed to the potato collections of VIR, IHAR-Młochów and PI, Sturgeon Bay (Wisconsin, USA). All of the grown accessions had been screened for resistance to *Phytophthora infestans* and a part of them - for resistance to Potato virus X (PVX) and Potato virus Y (PVY). This paper presents the results of this study.

Material and Methods

Plant Material A total of 154 accessions of tuber-bearing *Solanum* species was screened for resistance to pathogens. Plant material used in this study is listed in Table 1. Plants obtained from the botanical seeds in the glasshouse were transplanted into the field (30 plants/acc.) in mid-May and in the screenhouse (10–30 pot-plants/acc.) in the beginning of June.

Leaflet and tuber tests were applied for evaluation of resistance to *P. infestans*. The resistance to viruses PVX and PVY was assessed in the laboratory tests.

In the three years of testing for resistance to *P. infestans* 128 accessions of 48 species were evaluated for leaf resistance and 63 accessions of 35 species were evaluated for tuber resistance. For testing resistance to PVX and PVY artificial inoculations were used. The resistance to PVX was examined in 65 accessions of 20 species and 66 accessions of 20 species were tested for resistance to PVY.

Evaluation for Resistance to P. Infestans

Pathogen Material The inoculation of detached leaflets was conducted using two highly pathogenic isolates of *P. infestans*: MP-322 (1.2.3.4.6.7.8.10.11.) in 1998 test and MP-324 (1.2.3.4.5.7.8.10.11.) in 1999 and 2000 tests. The virulence of isolates was examined using Black's differentials carrying single *R*-genes from R1 to R11.

Inoculation Detached leaflets collected from plants grown in the field were inoculated in mid-June to mid-July. For plants kept in the screenhouse, testing was done in mid-July. For inoculation, the samples of mycelia were multiplied on leaves of susceptible cv. Tarpan. Washed mycelium was used for preparation of the inocula, which comprised 50 sporangia per mm^3. Inoculum was incubated at 4 °C for 1 h. Thirty plants from each accession were tested. Three leaflets detached from each plant in two replications were drop inoculated. For each accession from 10 to 30 plants were assessed. Incubation proceeded during 7 days at 23 °C (day) and 17 °C (night). Cultivars, which differ in resistance level were used as standards, namely Meduza (R), Bzura (MR), Irys (S) and Sokół (S). Each accession was tested once, twice or three times, however tests were performed six times in three-year period for field or screenhouse grown plants.

Disease Score Leaflet disease rating was recorded using 1–9 grade scale, where 9 is the most resistant. General score criteria was a combination of a percent of affected leaf area and mycelia development intensity (Zarzycka 2001).

For evaluation of tuber resistance the method of decapitated tubers was applied (Zoteyeva and Zimnoch-Guzowska 2004). The decapitated tubers were drop inoculated with the inoculum comprising 50 sporangia/mm^3. Tubers were incubated in the dark at 17°C during 10–14 days depending on the applied isolate aggressiveness. One or two tubers per plant, harvested from 6 up to 32 plants per accession were tested once at one of three tests performed. The number of plants and tubers per tested accession varied due to differences in tuberization among accessions.

Aerial mycelia growth on the decapitated surface was scored using scale 0–3, where 0 is the lack of mycelium growth and 3 is the most intensive growth. Lesion size on a longitudinal surface of cut tubers was scored using 1–9 scale, where 9 is the most resistant.

Table 1 The accessions of *Solanum* species in the VIR collection evaluated (V) for resistance to *P. infestans* (in leaflets = PhL, in tubers = PhT) PVX and PVY

Solanum species	PL	PhT	PVY PVX	No in VIR catalogue	Geographical origin and donor data	Collector No*	Other collections No
S. *acaule* Bitt.	V	V		k-4250	Peru	JUZ 1186	
S. acaule	V			k-4253	Peru	JUZ 1199	
S. acaule			V	k-9786	Bolivia, D. La Paz. Pukhalsky, Zykin exped., 1971	ZYK 206	
S. acaule	V			k-9787	Bolivia, D. La Paz. Pukhalsky, Zykin exped., 1971	ZYK 211	
S. acaule	V			k-9789	Bolivia, D. La Paz. Pukhalsky, Zykin exped., 1971	ZYK 216	
S. acaule	V		V	k-9794	Bolivia, D. La Paz. Pukhalsky, Zykin exped., 1971	ZYK 221	
S. acaule	V	V	V	k-9795	Bolivia, D. La Paz. Pukhalsky, Zykin exped., 1971	ZYK 226	
S. acaule			V	k-10678	Bolivia, D. La Paz	HHCH 5052	CPC5052; PI473326
S. acaule			V	k-10679	Peru, D. Puno	HHCH 5071	CPC5071; PI473327
S. acaule			V	K-17901	Argentina	GBT 349	
S. acaule			V	k-18002	Argentina	GBT 349	
S. acaule			V	k-18004	Bolivia		
S. acaule			V	k-18007	Bolivia		
S. acaule			V	k-18010	Bolivia		
S. acaule			V	k-18014	Bolivia, D. La Paz	VSOA 54	
S. acaule			V	k-18021	Bolivia, D. La Paz	SZC 166	
S. acaule			V	k-18522	Peru	GBT 13	
S. ajuscoense Buk.	V			k-3352	Mexico, Zhukovsky exped.,1958	BUD 36	
S. albicans Ochoa			V	k-9813	Bolivia, Pukhalsky, Zykin exped., 1971	ZYK 199	
S. ambosinum Ochoa	V	V		k-9700	Peru	BUD 1026	
S. angustisectum Hassl.	V	V		k-2733	Argentina, VIR's exped.,1955	JUZ 1324	
S. antipovichii Buk.	V	V		k-2354	Mexico	BUK 59b	
S. arrac-papa Juz.	V	V		k-9742		JUZ 892	
S. berthaultii Hawes	V	V		k-7635	Bolivia		GLKS 62.70.5.3
S. berthaultii	V	V	V	k-23047	Bolivia	EBS127xEBS128	GLKS 72/9
S. bukasovii Juz.	V			k-9708	Peru	ROR 1159	GLKS115/4; PI265876; EBS 1899
S. cardiophyllum Lindl.		V		k-10456	Mexico		PI251725; WRF1276
S. cardiophyllum	V	V		k-16828	Mexico	GRA s.n.	PI 283063;
S. cardiophyllum	V			k-17380	Mexico	LEM 319	GRA289 x GRA 290
S. cardiophyllum	V	V		k-18086	Mexico	HAW 1466	PI251729; WRF1277
S. cardiophyllum	V	V		k-19986	Mexico, D. Zacatecas	HAW 1100	PI 186548
S. cardiophyllum		V		k-22683	Mexico		PI 283062
S. chacoense Bitt.	V			k-2729			
S. chacoense	V		V	k-2731	Argentina, Zhukovsky exp., 1955	ZHK 574	
S. chacoense	V		V	k-2914	Argentina		H 46/1 x H 46/2
S. chacoense	V		V	k-2917	Argentina, D. Chaco,	H 87	
S. chacoense	V		V	k-2926	Argentina	EBS 43	GLKS 8.1.; R 49/55
S. chacoense	V			k-2954			
S. chacoense	V		V	k-3674	Argentina, Zhukovsky exped., 1958	HORT 1953	
S. chacoense	V		V	k-3678	Argentina, Zhukovsky exped., 1958	ZHK 780b	

Table 1 (continued)

Solanum species	PL	PhT	PVY PVX	No in VIR catalogue	Geographical origin and donor data	Collector No*	Other collections No
S. chacoense	V			k-3679	Argentina, Zhukovsky exped., 1958	HORT 1930	
S. chacoense	V		V	k-3702	Argentina, Zhukovsky exped., 1958	ZHK 802	
S. chacoense	V		V	k-4236	Argentina	PEH 76	
S. chacoense	V			K-4237			
S. chacoense	V		V	k-5257	Argentina		GLKS 61.100.42.1.
S. chacoense	V	V	V	k-15994	Argentina	GBT 210	
S.chacoense	V			k-18220	Argentina	Hje 297	PI 275 139
S.chacoense	V			k-18221	Argentina	HHRO 3297	PI 320 286
S. chomatophilum Bitt.	V			k-20136	Peru	GBT 288	
S. demissum Lindl.	V			k-2353	Mexico	BUK 35	
S. demissum	V		V	k-3287	Mexico	BUK 67a	
S. demissum	V		V	k-3341	Mexico	BUK 72	
S. demissum	V	V	V	k-3342	Mexico	BUK 76	
S. demissum	V		V	k-3345	Mexico	BUK 81	
S. demissum	V	V		k-3355	Mexico	BUK 82	
S. demissum	V		V	k-3362	Mexico	BUK 84	
S. demissum			V	k-3540	Mexico	BUK 86	
S. demissum	V			k-4445	Mexico		GLKS 59.40.2.3.
S. demissum	V		V	k-8446	Mexico, VIR's exped., 1968	ZHK 842	
S. demissum	V		V	k-8462	Mexico, VIR's exped., 1968	ZHK 2239	
S. demissum	V		V	k-8466	Mexico, VIR's exped., 1968	ZHK 2278	
S. dolichostigma Buk.	V	V	V	k-7610	Argentina	ZHK 445b	Hungary 2882
S. dolichostigma	V		V	k-7613	Argentina	ZHK 449	Hungary 2892
S. famatinae Bitt. et Wittm	V			k-4304	Argentina, D. La Rioja	PEH 1893	CPC5836 x CPC5838
S. famatinae	V			k-7466	Argentina	HHR 3425×6	
S. fendleri Asa Gray	V			k-5671	Mexico	BUK 109	
S. fendleri	V	V		k-5747	Mexico	BUK 116	HAW 2602a
S. fendleri			V	k-18241	Mexico	HAW 1157	PI 255 531
S.gibberulosum(Juz.etBuk.) Corr.	V	V		k-2725	Argentina	JUZ 929	
S. gibberulosum	V		V	k-2937	Argentina	JUZ 944	GLKS 16/3 (1954)
S. gourlayi Hawkes	V			k-11973	Argentina	OKA 4893	PI 473088
S. guerreroense Corr.	V		V	k-18407	Mexico		PI 161727
S. hougasii Corr.	V	V		k-8818	Mexico, Japan	ZHK 1456	W 666; N 32(141)
S. kurtzianum Bitt. et Wittm.	V			k-2301			
S. kurtzianum	V		V	k-9719			
S. kurtzianum		V		k-12479	Argentina	OKA 4937	PI472931;
S. kurtzianum	V	V		k-12488	Argentina	OKA 4964	PI 472938
S. kurtzianum	V	V		k-12489	Argentina	OKA 4966	PI 472939
S. latisectum Hassl.	V	V		k-2722	Argentina, Zhukowski exped., 1955		
S. leptophyes Bitt.	V	V	V	k-5764	Bolivia	ZYK 140	HAW 3484
S. maglia Schlechtd.	V			k-2883	Argentina		
S. marinasense Vargas	V			k-18500	Peru	GBT 315	
S. michoacanum (Bitt.) Rydb.	V		V	k-5763	Mexico	BUD 133	HAW2643 x HAW2642
S. microdontum Bitt.	V	V		k-9726	Bolivi, Pukhalsky, Zykin exped., 1971	ZYK 214	

Table 1 (continued)

Solanum species	PL	PhT	PVY PVX	No in VIR catalogue	Geographical origin and donor data	Collector No*	Other collections No
S. microdontum	V			k-20320	Argentina	OKA 4820	PI 458358,
S. multidissectum Hawkes	V	V		k-4289	Peru	JUZ 1390	Denmark,multid. 1366 (1956)
S. neoantipovichii Buk.	V	V	V	k-8505	Mexico.	BUD 122	GLKS93.1(67.93.1)
S. oplocense Hawkes	V			k-16883	Argentina	OKA 3955	PI 458361
S. oplocense	V			k-18811	Peru	OCH 11947	
S. papita Rydb.	V	V		k-8816	Mexico	ZHK 445a	Japa, W 273
S. papita	V		V	k-9145	Mexico	COR 20075	PI 249929
S. papita	V	V	V	k-16888	Mexico	LEM 281	PI 251740
S. papita	V	V		k-16889	Mexico	LEM 162	PI 251741
S. papita		V		k-17454	Mexico	HHLs 1314	PI 283102
S. papita	V			k-17455	Mexico	HHLs 1475	PI 283105
S. parodii Juz. et Buk	V			k-3701	Argentina		Hort 37731
S. parodii	V	V	V	k-8280	Argentina	GBT 165	Hungary, par. 3093
S. parvicorollatum Lechn.	V	V		k-9128	Peru, D. Junin.		Huancayo Univ., 366a
S. pinnatisectum Dun.	V			k-4330	USA		Denmark, pnt 2300
S. pinnatisectum	V	V	V	k-4455	USA. Canada		S.29 x S.345
S. pinnatisectum	V	V	V	k-4459	USA. Canada		S.67 x S.339
S. pinnatisectum	V	V	V	k-9174	Mexico	ZHK 733	
S. pinnatisectum		V		k-15252	Mexico	HAW 1093	PI 186554
S. pinnatisectum	V		V	k-15253	Mexico	ROC S. 44	PI 230489
S. pinnatisectum			V	k-15254	Mexico	HHLs 1456	PI 275234
S. pinnatisectum	V		V	k-19157	Mexico	HHLs 1424	PI 275230
S. pinnatisectum		V		k-21955	Mexico	TRN 205a	PI 347766
S. polytrichon Rydb.	V	V	V	k-5347	Mexico	R.61.1061 a	GLKS 62.102.6.3.
S. polytrichon	V	V	V	k-5682	Mexico	ZHK 553	Germany, plt. 102.
S. polytrichon	V			k-7423	Mexico		
S. polytrichon	V	V		k-15258	Mexico	GRA 250	PI 255545
S. punae (Juz.) Hawk. et Hjert.	V			k-4263	Peru	JUZ 1421	Denmark, punae 1341
S. ruiz-ceballosii Card.	V	V	V	k-7370	Bolivia Cardenas		Horlahon, 8664
S. ruiz-ceballosii	V	V		k-7381	Bolivia Cardenas	JUZ 1604	
S.schickii Juz. et Buk.	V			k-2727	Uruguay		
S. simplicifolium Bitt.	V	V		k-5400	Argentina		GLKS 62.31.8.1.
S. simplicifolium	V	V		k-5684	Argentina	ZHK 392	
S. sparsipilum (Bitt.) Juz. et Buk.	V	V		k-9741	Bolivia	ZHK 230	Germany, spl. 49
S. sparsipilum	V	V	V	k-9808	Bolivia, Pukhalsky, Zykin exped., 1971	ZYK 158	
S. sparsipilum	V	V		k-10706	Bolivia	HHCH 4498	PI 473378
S. spegazzinii Bitt.	V	V	V	k-9746	Argentina		Germany, spg. 160.
S. spegazzinii	V		V	k-16798	Argentina	BRU 15b	PI 208562
S. stoloniferum Schlecht.	V	V	V	k-2492	Mexico	BUK 142	
S. stoloniferum	V	V	V	k-2534	Mexico	BUK159	
S. stoloniferum	V	V	V	k-2536	Mexico	BUK 163	
S. stoloniferum			V	k-3326	Mexico, Zhukowsky exped., 1958	ZHK 774	
S. stoloniferum	V			k-3335	Mexico, Santa Fe		
S. stoloniferum	V	V		k-3336	Mexico, Zhukowsky exped., 1958	ZHK 789a	
S. stoloniferum	V		V	k-3360	Mexico, Zhukowsky exped., 1958	ZHK 796	

Table 1 (continued)

Solanum species	PL	PhT	PVY PVX	No in VIR catalogue	Geographical origin and donor data	Collector No*	Other collections No
S. stoloniferum			V	k-3527	Mexico, Zhukowsky exped., 1958	ZHK 842	
S. stoloniferum	V		V	k-3533	Mexico, Zhukowsky exped., 1958	ZHK 848	
S. stoloniferum	V		V	k-3554	Mexico, Zhukowsky exped., 1958	ZHK 879	
S. stoloniferum	V	V	V	k-4226	Mexico, Zhukowsky exped., 1958	ZHK 936	
S. stoloniferum	V		V	k-8416	Mexico, Zhukowsky exped., 1958	BUD 356	
S. stoloniferum			V	k-8475	Mexico, Zhukowsky exped., 1958	BUD 491	
S. subtilius Hawkes	V	V		k-2064	Argentina	ZHK 103	
S. subtilius	V			k-2728	Uruguay		
S. subtilius	V			k-2868	Argentina, Tucuman		
S. sucrense Hawkes		V		k-15300	Bolivia	HHC 4615	PI 473367
S. tarijense Hawkes	V	V		k-7642	Argentina		GLKS 65.70.7.7.
S. tarijense	V			k-10712	Bolivia	HHCH 4574	PI 473336
S. tarijense	V	V		k-11976	Argentina	GBT 340	PI 473217
S. tarijense	V			k-16916	Argentina	HJR 0151	PI 275154
S. tarijense	V			k-17497	Argentina	Hof 1876	PI 473218
S. trifidum Corr.	V	V		k-4451	Mexico, Canada		Gra301x244; PI 283064
S. vernei Bitt. et Wittm.		V		k-2502	Argentina		Libramont, R 51/176
S. vernei	V			k-4066	Argentina		58.100.76.91
S. vernei	V			k-17517	Argentina	OKA 5650	PI473306
S. vernei	V			k-20330	Argentina	OKA 7500	PI 558147
S. verrucosum Schlechtd.	V	V	V	k-4220	Mexico	ZHK 155	
S. verrucosum	V	V		k-10556	Mexico	COR 14217b	PI 160228
S. verrucosum	V	V		k-18163	Mexico	LEM 431	CPC1340.2;PI195171
S. virgultorum (Bitt.) Card. et Hawkes	V	V		k-3954	Argentina	ZHK 22	
S. weberbaueri Bitt.	V			k-3971	Argentina		

*) - abbreviations acc. to the Centre for Genetic Resources, Wageningen, The Netherlands

Evaluation for Resistance to PVX and PVY

The experiments were done in the greenhouse at Młochów. For evaluation of resistance to PVX, about 30 pot-plants from each accession were sap inoculated with the isolate of PVX^{O} strain from potato cv. Osa in the presence of control cultivars (susceptible to PVX cvs Irys and Sokół and extremely resistant cv. Bzura). Four weeks after inoculation, ELISA was performed on inoculated plants with antibodies produced in the Gdańsk Laboratory of IHAR to test for the presence of virus (Zoteyeva et al. 2000).

For evaluation of resistance to PVY accessions were inoculated mechanically with three strains of PVY: PVY^{o} (isolate $PVY^{O\ LM}$), PVY^{NW} (isolate $PVY^{N\ WI}$) and PVY^{NTN} (isolate 12/94) from the virus collection of the Młochów Research Center. For each accession 8 to 24 pot-plants were inoculated with each normal or necrotic strains using methods presented by Chrzanowska (2001).

The disease symptoms observed ranged from necrotic local lesions, systemic mosaic, top necrosis to systemic necrosis. Presence of the virus was tested 4 weeks after inoculation by ELISA with the cocktail mAb (Bioreba 112911) that recognizes all known isolates of all groups/subgroups of PVY and mAb PVY^{N} specific (Bioreba 112712) that recognizes the necrotic strain group PVY^{N}. Accessions were grouped into 5 groups: R - resistant – all plants were uninfected in greenhouse conditions, MR – moderately resistant, S – all plants were susceptible, and two groups R>S and R<S, which expressed different percentage of resistant/susceptible plants.

Results

Resistance to P. Infestans

Foliage Resistance

Four standard cultivars Irys (S), Sokół (S), Bzura (MR) and Meduza (R) performed as expected with the leaflet test applied (Table 2). In comparison with 1998 and 1999, the

Table 2 Leaflet resistance to *P. infestans* of wild potato species accessions from the VIR collection tested for 3 years 1998 (one test for field grown plants, 1999 (two tests for field and screenhouse grown plants) and 2000 (three tests: two for field and one for screenhouse grown plants)

Species	No in VIR catalogue	1998			1999						2000									Weighted mean
		Field			Field			Screenhouse			Field-1 (13th July)			Field-2 (18th July)			Screenhouse			
		7–9*	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	
S. acaule	k-4250										0 %	1.0	1–1				0 %	1.3	1–2	1.1
	k-4253																0 %	1.0	1–1	1.0
	k-9787										0 %	1.0	1–1				33 %	4.0	1–9	1.9
	k-9789																27 %	3.1	1–9	3.1
	k-9794										0 %	1.0	1–1				47 %	6.1	1–9	3.6
	k-9795										0 %	1.0	1–1				7 %	4.1	1–9	2.0
S. ajuscoense	k-3352	20 %	3.4	1–9							0 %	1.3	1–2				47 %	6.6	1–9	3.8
S. ambosinum	k-9700																100 %	9.0	9–9	9.0
S. angustisectum	k-2733										0 %	1.0	1–1				0 %	1.0	1–1	1.0
S. antipovichii	k-2354				100 %	7.9	7–9	70 %	6.8	4–9				93 %	8.6	6–9				7.8
S. arrac-papa	k-9742										4 %	2.0	1–9				20 %	3.5	1–9	2.5
S. berthaultii	k-7635										0 %	1.9	1–4				0 %	2.0	1–3	1.9
	k-23047				89 %	8.2	5–9							33 %	4.6	1–9				6.4
S. bukasovii	k-9708										0 %	2.0	1–3				0 %	1.0	1–1	1.5
S. cardiophyllum	k-16828				95 %	8.3	6–9													8.3
	k-17380				90 %	8.0	6–9													8.0
	k-18086				80 %	7.6	5–9													7.6
	k-19986				85 %	8.0	6–9													8.0
S. chacoense	k-2729	45 %	5.2	1–9																5.2
	k-2731	40 %	4.6	1–9																4.6
	k-2914	45 %	5.0	1–9																5.0
	k-2917	55 %	5.4	1–9																5.4
	k-2926	30 %	3.8	1–9																3.8
	k-2954	10 %	2.4	1–9																2.4
	k-3674	0 %	1.2	1–2																1.2
	k-3678	35 %	4.6	1–9																4.6
	k-3679	60 %	6.4	1–9																6.4
	k-3702	30 %	3.4	1–9																3.4
	k-4236				4 %	4.3	1–9													4.3
	k-4237				0 %	3	1–6													3.0
	k-5257				15 %	3.2	1–9													3.2

Table 2 (continued)

Species	No in VIR catalogue	1998			1999						2000									Weighted mean
		Field			Field			Screenhouse			Field-1 (13[th] July)			Field-2 (18[th] July)			Screenhouse			
		7–9*	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	
	k-15994				3 %	3	1–7	30 %	4.3	2–7										3.6
	k-18220	30 %	3.9	1–9																3.9
	k-18221	50 %	5.1	1–9																5.1
S. chomatophilum	k-20136	50 %	5.8	1–9																5.8
S. demissum	k-2353										100 %	8.7	8–9				80 %	7.1	7–9	8.1
	k-3287	90 %	8.7	6–9																8.7
	k-3341	100 %	8.8	8–9																8.8
	k-3342	100 %	9.0	9–9																9.0
	k-3345	100 %	9.0	9–9																9.0
	k-3355	100 %	9.0	9–9																9.0
	k-3362	100 %	9.0	9–9																9.0
	k-4445										100 %	8.7	7–9				100 %	8.5	8–9	8.6
	k-8446	95 %	8.4	5–9																8.4
	k-8462	100 %	8.4	7–9																8.2
	k-8466	90 %	8.6	5–9																8.6
S. dolichostigma	k-7610				29 %	3.9	1–9													3.9
	k-7613				0 %	2.5	1–4													2.5
S. famatinae	k-4304										0 %	1.5	1–3				0 %	2.0	1–3	1.7
	k-7466				33 %	5.3	1–9	50 %	5.2	1–7										5.3
S. fendleri	k-5671				21 %	4.6	1–9	13 %	3.8	2–9										3.8
	k-5747										0 %	1.0	1–1				0 %	1.0	1–1	1.0
S. gibberulosum	k-2725																0 %	1.0	1–1	1.0
	k-2937				40 %	4.6	1–9													4.6
S. gourlayi	k-11973										0 %	1.0	1–1				0 %	1.0	1–1	1.0
S. guerreroense	k-18407	100 %	8.0	7–9																8.0
S. hougasii	k-8818																33 %	4.0	1–9	4.0
S. kurtzianum	k-2301																0 %	1.7	1–3	1.0
	k-9719				29 %	4.1	1–9													4.1
	k-12488				8 %	4.8	1–9													4.8
	k-12489				0 %	3.8	1–6													3.8
S. latisectum	k-2722	10 %	2.1	1–9							0 %	1.7	1–3				0 %	1.5	1–2	1.7
S. leptophyes	k-5764				42 %	5.2	1–9													5.2

Table 2 (continued)

Species	No in VIR catalogue	1998			1999						2000									Weighted mean
		Field			Field			Screenhouse			Field-1 (13th July)			Field-2 (18th July)			Screenhouse			
		7–9*	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	
S. maglia	k-2883										0 %	1.7	1–3				42 %	1.7	1–3	3.5
S. marinasense	k-18500	45 %	5.0	1–9																5.0
S. michoacanum	k-5763	54 %	5.9	1–9										51 %	6.0	1–9				5.9
S. microdontum	k-9726										50 %	6.3	2–9				50 %	6.4	2–9	6.4
	k-20320							86 %	7.8	5–9										7.8
S. multidissectum	k-4289										0 %	1.0	1–1				0 %	4.3	1–5	3.7
S. neoantipovichii	k-8505				85 %	7.4	5–9	80 %	6.6	2–9				96 %	8.7	5–9				7.6
S. oplocense	k-16883	30 %	4.5	1–9																4.5
	k-18811				56 %	5.9	1–9	47 %	5.2	2–7										5.9
S. papita	k-8816										57 %	5.9	1–9				54 %	7.1	1–9	6.5
	k-9145	100 %	9.0	9–9																9.0
	k-16888										83 %	7.6	1–9	51 %	5.5	1–9	66 %	7.4	1–9	6.8
	k-16889										86 %	7.7	2–9	42 %	6.0	1–9	39 %	5.7	1–9	6.3
	k-17455										33 %	3.7	1–9							3.7
S. parodii	k-3701	30 %	3.5	1–9																3.5
	k-8280				40 %	4.7	1–9	4 %	3.6	1–7				21 %	2.9	1–8				3.8
S. parvicorollatum	k-9128										0 %	1.5	1–2							1.5
S. pinnatisectum	k-4330										54 %	4.7	1–9				7 %	1.9	1–9	3.2
	k-4455				63 %	6.2	1–9							41 %	5.2	1–9				5.7
	k-4459				47 %	5.3	1–9							20 %	3.0	1–9				3.9
	k-9174				45 %	4.9	1–9							52 %	5.5	1–9				5.3
	k-15253	50 %	6.3	1–9																6.3
	k-19157	30 %	6.5	3–9																6.5
S. polytrichon	k-5347				77 %	7.6	1–9							46 %	4.9	1–8				6.3
	k-5682				63 %	6.9	1–9													6.9
	k-7423	80 %	8.1	4–9																8.1
	k-15258													55 %	5.6	1–9				5.6
S. punae	k-4263																22 %	3.8	1–9	3.8
S. ruiz-ceballosii	k-7370	95 %	8.9	6–9										56 %	5.4	1–9				7.2
	k-7381										0 %	1.7	1–6				8 %	4.1	2–8	2.5
S. schickii	k-2727	30 %	3.4	1–9																3.4
S. simplicifolium	k-5400										89 %	8.4	5–9				50 %	5.6	1–9	7.5

Table 2 (continued)

Species	No in VIR catalogue	1998			1999						2000									Weighted mean
		Field			Field			Screenhouse			Field-1 (13th July)			Field-2 (18th July)			Screenhouse			
		7–9*	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	
	k-5684										60 %	6.8	1–9							6.8
S. sparsipilum	k-9741				53 %	5.4	1–9													5.4
	k-9808				52 %	6.6	2–9	41 %	5.9	2–9				36	5.2	1–8				5.9
	k-10706										0 %	1.1	1–2				0 %	2.9	2–4	1.8
S. spegazzinii	k-9746				3 %	2.6	1–9													2.6
	k-16798				0 %	4.5	2–6	20 %	4.2	1–7										4.4
S. stoloniferum	k-2492				66 %	6.8	3–9	60 %	6.6	3–9				86 %	8.2	5–9				7.2
	k-2534				71 %	7.1	1–9	64 %	6.2	1–9				43 %	3.7	1–9				5.7
	k-2536				45 %	5.5	1–9													5.5
	k-3335																48 %	5.0	3–9	5.0
	k-3336																0 %	1.0	1–1	1.0
	k-3360	100 %	8.6	7–9																8.6
	k-3533	100 %	8.3	6–9				90 %	8.3	6–9										8.3
	k-3554	80 %	8.4	4–9				80 %	8.4	4–9										8.4
	k-4226				82 %	8	4–9							86 %	8.4	6–9				8.2
	k-8416	70 %	6.8	1–9																6.8
S. subtilius	k-2064																0 %	1.0	1–1	1.0
	k-2728	20 %	2.6	1–9																2.6
	k-2868	30 %	3.4	1–9																3.4
S. tarijense	k-7642										6 %	2.7	1–7				0 %	3.0	1–5	2.8
	k-10712										50 %	6.3	1–9				50 %	5.9	1–9	6.1
	k-11976																0 %	1.3	1–2	1.3
	k-16916	55 %	6.1	1–9																6.1
	k-17497	45 %	5.2	1–9																5.2
S. trifidum	k-4451																0 %	1.2	1–2	1.2
S. vernei	k-4066										0 %	1.7	1–2							1.7
	k-17517				39 %	4.4	1–9													4.4
	k-20330				52 %	6.2	1–9	67 %	6.0	5–7										6.1
S. verrucosum	k-4220	70 %	7.3	2–9																7.3
	k-10556										78 %	6.9	1–9	56 %	6.0	2–9	42 %	4.7	1–9	5.8
	k-18163				55 %	6.6	2–9	36 %	5.5	2–8										6.0
S. virgultorum	k-3954										4 %	4.5	4–5				25 %	3.8	2–9	4.1

Table 2 (continued)

Species	No in VIR catalogue	1998			1999						2000									Weighted mean
		Field			Field			Screenhouse			Field-1 (13th July)			Field-2 (18th July)			Screenhouse			
		7–9*	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	7–9	mean	range	
S. weberbaueri	k-3971	60 %	5.7	1–9																5.7
Standard cvs																				
cv. Bzura		0 %	5.8	5–6	0 %	5.1	3–6	0 %	5.7	5–6	0 %	5.5	4–6	0 %	1.2	1–2	17 %	5.7	5–7	3.7
cv. Irys		0 %	1.2	1–2	0 %	1.9	1–3	0 %	1.3	1–4	0 %	1.2	1–2	0 %	1.1	1–2	0 %	1.0	1–1	1.3
cv. Sokół		0 %	2.2	1–3	0 %	3.4	3–4	0 %	3.3	2–5	0 %	2.2	2–3	0 %	1.1	1–2	0 %	2.2	2–3	2.8
cv. Meduza								100 %	7.7	7–9	67 %	6.5	5–7	22 %	3.9	2–8	50 %	6.3	5–7	6.1

*7–9 – percentage of leaflets scored from 7.0 to 9.0 in tested accession.

aggressiveness of the isolate applied in 2000 was significantly higher, which was accompanied by a higher infection of tested standards especially in the test of 18th July. Leaflets of cvs. Irys and Sokół were rated as susceptible in all tests (mean resistance scores varied form 1.0 to 3.4) indicating sufficient infection pressure for reliable characterization of resistance of assessed accessions.

Out of the 128 accessions tested over 3 years, 30 were highly resistant, with weighted mean scores varying from 7.0 to 9.0 in 1–9 grade scale. This group included 6, extremely resistant accessions (with 100 % resistant plants assessed as 9.0), 16 accessions scored from 8.0 to 8.9 (with >80 % of resistant plants), and 8 accessions scored from 7.0 to 7.9 (with >50 % of resistant plants). On the other extreme, 60 accessions were susceptible, scored <5.0 (with up to 100 % of susceptible plants) and the other 38 accessions were moderately resistant, with scores from 5.0 to 6.9 (with variable number of resistant plants) (Table 2).

Among species from the Central America, the highest resistance to *P. infestans* was observed for those belonging to taxonomic series *Demissa* Buk. All 11 accessions of *S. demissum* were highly resistant with mean scores from 8.1 to 9.0. Among them six accessions possessed 100 % of resistant plants classified from 7.0 to 9.0 (k-3341, k-3342, 4-3345, k-3362, k-4445 and k-8462). It was also true for one accession of S. *guerreroense* (species closely related to *S. demissum*) k-18407. A large percentage of plants scored at 7.0–9.0 grade was found in the six out of ten tested accessions of *S. stoloniferum* (k-2492, k-3360, k-3533, k-3554, k-4226 and k-8416). The weighted mean scores ranged from 6.8 to 8.6. An accession of *S. antipovichii,* a species closely related to *S. stoloniferum* (Hawkes 1990), also showed a high foliage resistance with mean score of 7.8 and a significant predominance of resistant plants. The accession of *S. neoantipovichii* (k-8505), another relative of *S. stoloniferum*, expressed more than 80 % of resistant plants in three tests performed and its mean score was 7.6. The mean score of the three *S. verrucosum* accessions tested ranged from 5.8 to 7.3, reflecting a moderate resistance, however the plants scored at 9.0 in each test indicates probability of the presence of R genes. The percentage of resistant plants depended on the test and ranged from 42 % to 78 %. Out of five assessed *S. papita* accessions four possessed high mean scores: 6.3 (k-16889), 6.5 (k-8816), 6.7 (k-16888) and 9.0 (k-9145). The remaining one accession was susceptible with mean score 3.7. The weighted mean values of resistance in four accessions of *S. polytrichon* ranged from 5.6 (k-15258) to 8.1 (k-7423) with increased frequency of resistant plants (from 46 % to 80 % in individual tests). The tested four *S. cardiophyllum* accessions were characterized by high scores (from 7.6 to 8.3) and over 80 % of resistant plants. Within the six accessions of *S. pinnatisectum,* the highest level of foliage resistance was observed in k-15253 and k-19157 accessions (scored as 6.3 and 6.5, respectively). The accessions k-9174 and k-4455 (scored 5.3 and 5.7, respectively) were found to be relatively resistant. In the remaining accessions, approximately less than half of inoculated plants were resistant. It is important to note in all tested segregating populations the presence of plants scored as 9, a possible indication of the presence of major genes in evaluated accessions.

Among the South American species, a high score was found in the following accessions: *S. berthaultii* k-23047 (6.4), *S. microdontum* k-20320 (7.8), *S. simplicifolium* k-5400 (7.5) *S. ruiz-ceballosii* k-7370 (7.2), *S. vernei* k-20330 (6.1) and in one accession of *S. chacoense* k-3679 (6.4) out of 16 ones tested. In populations of *S. chacoence* resistance was clearly segregating, since the frequency of resistant plants fluctuated from 0 % up to 60 %. Generally, the South American species were characterized by a lower frequency of highly resistant plants within populations as compared to the Central American accessions.

Tuber Resistance

The tuber resistance reaction of two susceptible standards - cultivars Irys and Sokół indicated sufficient infection pressure in all tests performed. The resistance reaction of the set of applied standards was similar in all three tests, hence the results of evaluation of *Solanum* accessions from each test might be compared (Table 3). Mycelial development reflected the resistance levels of the standards: the least mycelium growth was observed on tubers of two resistant breeding forms: breeding line DG 94-15 and cv. Meduza while abundant mycelium growth was observed on tubers of susceptible cvs. Irys and Sokół. The most prolific mycelium growth was noted on decapitated tubers of susceptible cv. Irys in all tests.

Tuber resistance data for 63 accessions of 35 species are shown in Table 3. All of the five tested accessions of *S. pinnatisectum* were characterized by a very high tuber resistance to *P. infestans*: the mean score varied from 7.7 to 8.5, without mycelium growth. Among the other Central American species, the high frequency of resistant individuals was found in the five accessions of *S. cardiophyllum* with mean scores ranging from 6.5 to 8.1. A lack of aerial mycelium was observed in four of its accessions. Abundant mycelium growth was observed in individual tubers of accessions k-18086 and k-19986.

In tests performed in Młochów a high frequency of tuber resistant plants was noted within the following accessions: *S. berthaultii* k-23047 (6.9), *S. fendleri* k-5747 (7.9), *S. kurtzianum* k-12479 (6.8) and k-12488 (7), *S. neoantipovichii* k-8505 (6.5), *S. papita* k-16888 (6.4) and k-16889 (6.8), *S. polytrichon* k-15258 (7.5), *S. ruiz-ceballosii* k-7370 (7.1) and k-7381 (6.5), *S. stoloniferum* k-2536 (6.4), *S. trifidum* k-4451 (7.9) and *S. verrucosum* k-10556 (6.5). Two accessions of *S. acaule* were characterized by relatively high and uniform tuber resistance, their disease ratings were 5.9 and 6.7. The accessions *S. arrac-papa* k-9742, *S. demissum* k-3355, *S. hougasii* k-8818, *S. polytrichon* k-5682, *S. subtilius* k-2064 and *S. verrucosum* k-4220 were found to be relatively resistant.

The mycelium growth was highly variable within the species and within the accessions (Table 3). The high variation in intensity of mycelium growth was noted within the accessions of *S. papita*, *S. polytrichon* and *S. stoloniferum*. Tubers of *S. berthaultii* k-23047, *S. cardiophyllum* k-16828, *S. ruiz-ceballosii* k-7370 and of all tested accessions of *S. pinnatisectum* reacted to inoculation with local lesions.

Resistance to Viruses

In total, 70 accessions of 21 species were evaluated for resistance to PVX and three strains of PVY (Table 4).

The accessions of: *S. acaule* k-9786, k-10678, k-18007, k-18021, k-18522; *S. albicans* k-9813; *S. berthaultii* k-23047 and *S. sparsipilum* k-9808 expressed resistance to PVX in all tested plants (Table 4). Predominance of plants resistant to PVX was found in two *S. acaule* accessions. In 12 accessions of several *Solanum* species the segregation for PVX resistance with predominance of susceptible plants was noted. Among them were single accessions of *S. acaule*, *S. chacoense S. guerreroense, S. kurtzianum, S. demissum, S. parodii* and *S. stoloniferum.*

Resistance to three strains of PVY was found in 9 out of 11 tested accessions of *S. stoloniferum*: k-2492, k-2534, k-2536, k-3326, k-3360, k-3527, k-3533, k-3554 and k-4226. A single accession of *S. neoantipovichii* (k-8505) was also characterized by resistance to three strains of PVY. In *S. polytrichon,* resistance to three strains of PVY was expressed in accession k-5682, and for two strains ($PVY^{N\ WI}$ and PVY^{O}) in accession k-5347. Two tested accessions of *S. papita* were susceptible to both viruses.

The majority of accessions of *S. demissum* expressed higher susceptibility to PVX than to PVY. Out of 9 tested accessions only k-3540 was relatively resistant to PVY strains. It is worth noting that this group of accessions was susceptible to PVY^{NTN}. The accession of *S. guerreroense* species belonging to a taxonomic series *Demissa* Buk., did react to PVX and PVY similarly to some *S. demissum* accessions.

The accession k-4220 of *S. verrucosum* showed a variable reaction to PVY strains similar to some accessions of *S. demissium* and *S. guerreroense*.

Six accessions of *S. pinnatisectum* were susceptible to PVX, though three of them (k-4455, k-4459 and k-19157) were found to be highly resistant to the three strains of PVY. All ten accessions of *S. chacoense* were susceptible to PVX and only one accession (k-4236) was resistant to three strains

Table 3 Tuber resistance to *P. infestans* of wild potato species accessions from the VIR collection

Species	No. in VIR catalogue	Test No	No. of tested plants	No. of tested tubers	Mycelium growth, 0–3 scale*		Resistance, 1–9 scale**	
					mean	range	mean	range
S. acaule	k-4250	3	25	25	0.5	0–2	5.9	5–8
	k-9795	3	9	9	0.2	0–2	6.7	5–9
S. ambosinum	k-9700	3	12	12	2	2	5	2–7
S. angustisectum	k-2733	3	9	18	1.8	2–3	3.6	1–6
S. antipovichii	k-2354	2	29	57	1.6	1–2	5	1–8
S. arrac-papa	k-9742	3	15	15	1.1	0–2	5.8	1–8
S. berthaultii	k-7635	3	8	8	2	1–3	3.4	1–6
	k-23047	1	32	63	0	0	6.9	5–9
S. cardiophyllum	k-10456	1	13	13	0.6	0–1	6.9	2–9
	k-16828	1	11	11	0.2	0–1	7.9	6–9
	k-18086	1	6	6	0.5	0–1	6.6	4–9
	k-19986	1	9	15	0.6	1–2	6.5	5–7
	k-22683	1	8	16	0.2	0–1	8.1	6–9
S. chacoense	k-15994	2	10	20	1.3	1–2	1.2	3–4
S. demissum	k-3355	1	12	12	0	0	5.7	5–8
	k-3342	1	13	26	1.2	0–1	5.2	4–8
S. dolichostigma	k-7610	1	8	16	2	2	3.1	1–6
S. fendleri	k-5747	3	10	10	0.2	0–1	7.9	7–8
S. gibberulosum	k-2725	3	26	26	1.1	1–2	3	1–6
S. hougasii	k-8818	3	18	18	0.1	0–1	6	2–8
S. kurtzianum	k-12479	1	10	10	0.3	0–1	6.8	4–9
	k-12488	2	8	8	0.2	0–1	7	4–9
	k-12489	2	8	16	1.4	1–3	4.5	2–5
S. latisectum	k-2722	3	12	12	1.1	1–2	5.4	3–6
S. leptophyes	k-5764	1	15	15	1.2	1–2	3.7	1–7
S. microdontum	k-9726	3	12	12	2.4	2–3	3.8	1–6
S. multidissectum	k-4289	3	24	24	2.6	2–3	4	1–7
S. neoantipovichii	k-8505	2	20	39	0.3	0–2	6.5	3–9
S. papita	k-8816	3	18	18	0.7	0–2	5.8	4–8
	k-16888	3	18	18	0.4	0–1	6.4	5–7
	k-16889	3	12	12	0.3	0–1	6.8	5–8
	k-17455	3	9	9	1.7	1–2	6	6
S. parodii	k-8280	2	13	26	0.2	0–1	5.6	2–9
S. parvicorollatum	k-9128	3	10	10	2.2	0–3	3.7	1–6
S. pinnatisectum	k-4455	2	20	40	0	0	7.7	5–9
	k-4459	2	18	36	0	0	8	5–9
	k-9174	2	24	48	0	0	7.9	5–9
	k-15253	1	10	10	0	0	8.8	6–9
	k-21955	1	12	12	0	0	8.5	8–9
S. polytrichon	k-5347	2	30	50	1.8	0–3	4.6	2–9
	k-5682	1	22	22	1.3	0–2	5.9	2–7
	k-15258	2	6	12	0.8	0–2	7.5	5–9
S. ruiz-ceballosii	k-7370	1	30	24	0.2	0–1	7.1	6–8
	k-7381	3	12	12	0.8	0–1	6.5	6–7
S. simplicifolium	k-5400	3	10	10	1.6	1–3	4.1	1–6
	k-5684	3	12	12	1	0–2	5.7	4–7
S. sparsipilum	k-9808	2	12	24	1.1	1–2	5.7	1–9

Table 3 (continued)

Species	No. in VIR catalogue	Test No	No. of tested plants	No. of tested tubers	Mycelium growth, 0–3 scale*		Resistance, 1–9 scale**	
					mean	range	mean	range
	k-10706	3	18	18	1.9	1–3	5.2	1–7
S. spegazzinii	k-9746	1	12	12	1.1	0–2	4.6	2–6
S. stoloniferum	k-2492	2	19	38	1	0–2	5.8	4–9
	k-2534	2	17	34	1.6	1–3	5	2–7
	k-2536	1	21	42	1.6	1–2	6.4	2–8
	k-3336	3	9	9	1.5	1–2	5.5	4–7
	k-4226	2	19	38	1.8	0–3	5.3	2–7
S. subtilius	k-2064	3	12	12	0.4	0–1	6	3–8
S. sucrense	k-15300	1	8	8	0.2	0–1	5.6	4–7
S. tarijense	k-7642	3	16	16	0.2	0–1	4.9	2–6
	k-11976	3	11	11	2.4	1–3	3.1	2–5
S. trifidum	k-4451	1	8	8	0.2	0–1	7.9	7–9
S. verrucosum	k-4220	1	8	8	1	0–2	6.2	4–9
	k-10556	3	15	15	0	0	6.5	4–8
	k-18163	1	12	12	0.8	0–2	4.1	2–6
S. virgultorum	k-3954	3	12	12	2.4	2–3	3.7	1–6
Standards:								
cv. Irys		1		18	2.8	2–3	1.0	1–1
		2		18	2.9	2–3	1.0	1–1
		3		18	2.0	2–2	2.9	2–4
cv.Sokół		1		18	2.0	1–3	1.0	1–1
		2		18	2.4	2 –3	4.5	4–5
		3		18	2.0	1–3	3.7	3–5
cv. Meduza		1		18	1.0	1–1	5.5	5–7
		2		18	0.8	0–1	5.7	5–7
		3		18	1.0	1–1	6.7	6–8
DG 95-15		1		18	0.2	0–1	5.5	5–7
		2		18	0.5	0–1	5.5	5–7
		3		18	0.0	0–0	7.0	7–7
		2		18	0.8	0–1	5.7	5 – 7
		3		18	1.0	1–1	6.7	6–8

* Mycelium growth in 0–3 scale, where 0 is the lack of mycelium growth and 3 is the most intensive growth.

** Resistance in 1–9 scale, where 9 is the most resistant.

of PVY. Resistance to two PVY strains (PVY $^{N\ WI}$ and PVY ^{O}) was expressed by *S. chacoense* accessions: k-2731, k-2914, k-2917 and k-2926. The strong tendency to react with local necroses to PVY strains was noted in all *S. chacosense* accessions. The accessions of species: *S. dolichostigma* and *S. gibberulosum*, which are related to *S. chacoense*, expressed different levels of resistance to PVY and similarly to *S. chacoense* expressed hypersensitive responses to PVY isolates. The two accessions of *S. dolichostigma* k-7610 and k-7613 were extremely resistant to three PVY strains. The accession k-2937 of *S. gibberulosum* was found to be moderately resistant to PVY$^{N\ WI}$ and PVY^{NTN} strains.

Discussion

The world germplasm collections are a great source of valuable traits for potato breeding. For a large number of wild potato accessions preserved in world gene banks, the data on resistance to pathogenes have been already obtained (Hanneman and Bamberg 1986; Zoteyeva 1986; Darsow and Hinze 1991a; Colon 1994; Bradshaw et al. 1995; Bamberg et al. 1996; Ramsay et al. 1999; Angeli et al. 2000). However, the resistance value of many collected accessions is still unknown.

Wild potatoes are known as reservoir of resistance genes to many diseases and pests. They are widely distributed in geographic zones differing in ecological and climatic

Table 4 Resistance of wild potato species accessions from the VIR collection to Potato virus X (PVX) and Potato virus Y (PVY)

Species	No in VIR catalogue	Resistance to viruses				Species	No in VIR catalogue	Resistance to viruses			
		PVX	PVY					PVX	PVY		
			PVY ^{0}	PVY $^{N\ WI}$	PVY ^{NTN}				PVY ^{0}	PVY $^{N\ WI}$	PVY ^{NTN}
S. acaule	k-9786	R*	S	S	S	*S. dolichostigma*	k-7613	S	R ln	R n	R ln
	k-9794	S	-	-	-	*S. fendleri*	k-18241	S	S	S	S
	k-9795	S	-	-	-	*S. gibberulosum*	k-2937	S	S ln	MR ln	MR ln
	k-10678	R	S	S	-	*S. guerreroense*	k-18407	S>R	R	R	S
	k-10679	R>S	S	S	-	*S. kurtzianum*	k-9719	S>R	S n	S n	S
	k-17901	S>R	S	S	S	*S. leptophyes*	k-5764	S	MR ln	MR n	MR n
	k-18002	R>S	S	S	-	*S. michoacanum*	k-5763	S	R n	R tn	R
	k-18004	S	S	S	S	*S. neoantipovichii*	k-8505	-	R	R	R
	k-18007	R	S	S	S	*S. papita*	k-9145	S	S	S	S
	k-18010	S	S ln	S	S		k-16888	-	S	S	S
	k-18014	S	S	S	S	*S.parodii*	k-8280	S>R	MR ln	MR ln	MR
	k-18021	R	S	S	S	*S. pinnatisectum*	k-4455	S	R	R	R
	k-18522	R	S	S	S		k-4459	S	R	R	R
S. albicans	k-9813	R	-	-	-		k-9174	S	S	S	S
S. berthaultii	k-23047	R	S	S	S		k-15253	S	S	S	MR
S. chacoense	k-2731	S	R ln	R ln	-		k-15254	S	R	R tn	MR
	k-2914	S>R	R ln	R ln	-		k-19157	S	R	R tn	R
	k-2917	S	R ln	R ln	MR m	*S. polytrichon*	k-5347	S	R	R	S
	k-2926	S	R ln	R ln	S m		k-5682	S	R	R	R
	k-3674	S	MR m/ln	MR m		*S. ruiz-ceballosii*	k-7370	S	MR	S	-
	k-3678	S>R	R ln	S m	MR m	*S. sparsipilum*	k-9808	R	S	S	S
	k-3702	S	MR m/ln	MR m/ln	MR m	*S. spegazzinii*	k-9746	S	Sln	Sn	S m
	k-4236	S	R	R ln	R		k-16798	S	Sln	S	S
	k-15994	S>R	S ln	MR tn	S tn	*S. stoloniferum*	k-2492	-	R	R	R
	k-5257	S	S ln	MR ln	MR m		k-2534	S	R	R	R
S. demissum	k-3287	S	S	S	S		k-2536	-	R	R	R
	k-3341	S	MR	MR	Sm		k-3326	S>R	R	R	R
	k-3342	S>R	MR m	S m	S n/m		k-3360	S	R	R	R
	k-3345	S	R ln	R ln	S m		k-3527	S	R	R	R
	k-3362	S	R ln	R ln	S m		k-3533	S>R	R	R	R
	k-3540	S>R	R ln	R ln	MR ln		k-3554	S	R ln	R	R ln
	k-8446	S>R	S m	S m	S n		k-4226	-	R	R	R
	k-8462	S	S m	S m	S n		k-8416	S	S	S	S
	k-8466	S	S m	S m	S n		k-8475	S	S	S	S
S. dolichostigma	k-7610	S	R ln	R ln	R ln	*S. verrucosum*	k-4220	S	MR	MR	S

*Abbreviations used : R – resistant; S – susceptible; MR – moderately resistant; R>S –predominance of resistant plants; S>R – predominance of susceptible plants; ln – local necroses; m – mosaic; n – necroses; tn – top necroses

conditions. The principal centers of widest species diversity are characterized either by large number of species and subspecies variation or by large number of major genes, including the genes coding for disease resistance. These centers are considered to be characterized by parallel distribution of specialized parasites co-evolving with the host plants (Vavilov 1926). Due to this theory, mutation rates and selection pressure lead to formation of resistance in local plant populations.

In many potato production regions significant losses from late blight are noted. Currently grown cultivars possess a narrow gene base for *P. infestans* resistance, and this coupled with an increase in the genetic variation of *P. infestans* populations creates increased risk of disease spread in potato crops. The use of new resistance sources would enrich the genetic background of cultivated potato.

The data obtained showed that stable high leaf resistance to *P. infestans* exists mostly in Central-American species. Using inoculum concentration of 50 sporangia/mm^3, the high percentage of resistant plants (from 80–100 %) was registered in the accessions of *S. antipovichii*, *S. ambosinum*, *S. demissum*, *S. guerreroense*, *S. neoantipovichii* and several accessions of *S. stoloniferum*. In several accessions, namely *S. guerreroense* k-18407, *S. papita* k-9145 and seven accessions of *S. demissum*: k-3341, k-3342, k-3345, k-3355, k-3362, k-4445 and k-8462, the 100 % of tested plants expressed resistance.

Many wild potato species possess high variability for resistance to *P. infestans*. Variation for leaf resistance to late blight was found in the majority of 76 wild potato species from Central and South America evaluated in the field under epidemics conditions in Northwestern Russia and in laboratory studies conducted in the early 1980s (Zoteyeva 1986).

In this study a majority of the evaluated accessions were found segregating for leaflet resistance, while several accessions of *S. demissum*, and single accessions of *S guerreroense*, *S. papita* and *S. stoloniferum* were completely resistant. Accessions of Mexican species *S. demissum*, *S. guerreroense* and *S. stoloniferum* expressed full resistance also when inoculum concentration was 75 sporangia/mm^3 (Zoteyeva 2000). The application of inoculum concentration of 50 sporangia/mm^3 for resistance assessment could play an important role for the species with low and moderate foliar resistance (i.e. *S. chacoense*, *S. kurtzianum*, *S. spegazzinii* and many others) in the differentiation of their accessions for resistance to late blight.

In research for late blight resistance, little attention has been paid to tuber resistance, although several authors recognize that it is an essential component of potato resistance to *P. infestans* (Darsow 1987; Świeżyński and Guzowska 2001). The opinion that cultivars with foliage resistance minimize the risk of tuber blight was the reason that interest in foliage resistance to late blight persisted. However, even slightly blighted foliage during the growing season can lead to a high proportion of infected tubers (Schwinn and Margot 1991). There are limited data for the assessment of *Solanum* species for tuber resistance. Among 128 tuber-bearing *Solanum* species studied by Darsow and Hinze (1991b) nearly 60 were found exhibiting foliage resistance. Within these species only 27 were found with tuber resistance.

For evaluation of the tuber resistance to *P. infestans*, the methods of whole tubers and tuber slice inoculation are usually used (Dorrance and Inglis 1998; Stewart et al. 1996). To evaluate the tuber resistance to *P. infestans* in wild potatoes characterized by small tuber size, we have developed a method of inoculation of decapitated tubers, which was applied in our study (Zoteyeva and Guzowska 2004). Among 35 species represented by 63 accessions, the accessions of *S. cardiophyllum* and *S. pinnatisectum* were those with the highest frequency of tuber resistant individuals. Variation for tuber resistance to *P. infestans* within accession was observed in all species tested with the exception of *S. pinnatisectum*. Accessions with resistant individuals were observed in *S. acaule*, *S. berthaultii*, *S. kurtzianum*, *S. ruiz-ceballosii*, *S. fendleri* and *S. trifidum*.

In potato, foliar and tuber susceptibility to late blight are not correlated. It is necessary to find new genetic sources of resistance either in leaves or in tubers (Kirk et al. 2001). Among the large number of accessions tested, several (*S. berthaultii* k-23047, *S. cardiophyllum* k-16828, *S. ruiz-ceballosii* k-7370, *S. neoantipovichii* k-8505 and *S. pinnatisectum*) contained individual clones with combined resistance expressed in leaves and in tubers. These accessions are promising breeding materials, possessing *P. infestans* resistance and good tuberization ability.

Evaluation of VIR's collection for late blight and PVX and PVY resistance has resulted in the identification of accessions combining high resistance to *P. infestans* and to the viruses. The selected accessions of *S. demissum*, *S. guerreroense*, *S. neoantipovichii*, *S. polytrichon* and *S. stoloniferum,* are combining resistance to *P. infestans* and two or three strains of PVY and/or to PVX. These forms might be of special value for prebreeding purposes.

Testing the set of 66 accessions of 20 *Solanum* species for resistance to three strains of PVY is of particular value. Assessment of this gene pool for resistance to the recently found PVY^{NTN} strains, which evoke Potato Tuber Necrotic Ringspot Disease on tubers in potato crops in Europe and other continents, has shown that several accessions resistant to older PVY strains (PVY^{O} and PVY^{NW}) are susceptible to PVY^{NTN}. Among them were accessions of *S. demissum, S. chacoense*, *S. guerreroense, S. polytrichon* and *S. verrucosum.* It might be an indication of the virulence of this strain and possible breakdown of field resistance of currently grown cultivars. However, sources of resistance against PVY^{NTN} were identified in accessions of *S. stoloniferum*, *S. pinnatisectum* and *S. neoantipovichii* and in selected accessions of *S. chacoense*, *S. dolichostigma* and *S. polytrichon.*

In the past decade, several accessions evaluated in this study from 1998 to 2000 have been exploited in genetic studies and prebreeding program conducted at Młochów Research Center, IHAR-PIB (Jakuczun and Wasilewicz – Flis 2004) and at the Swedish University of Agricultural Sciences (SLU) in collaboration with VIR's Genetics Department (Zoteyeva and Carlson-Nilsson 2011). Recently, the accession k-5763 of *S. michoacanum* was the parental line for a population used in mapping the *P. infestans* resistance gene *Rpi-mch1* on potato chromosome VII

(Śliwka et al. 2012a). The *Rpi- rzc1* gene was mapped to chromosome X by using accession k-7370 of *S. ruiz-ceballosii* as a parent of a mapping population. In addition, the first two maps of *Solanum* species with DArT markers were constructed (Śliwka et al. 2012b), providing proof of the ample possibilities of exploitation of the described pool of *Solanum* germplasm.

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