The greenhouse provocation test for determination of resistance to potato common scab [*Streptomyces scabiei* (ex Thaxter 1982) Lambert and Loria 1989]

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ABSTRACT

Between 2002 and 2004 the evaluation method of resistance to common scab was tested on potato genetic resources. The resistance of potato tubers to common scab was evaluated in the greenhouse provocation tests with planting in naturally infested soil. The test was evaluated on the tubers of 26 varieties and hybrids of *Solanum tuberosum* derived from a potato genetic resource collection. Ten tubers of each sample were individually planted into three-liter pots containing infested soil. Analysis of variance confirmed significant differences among individual varieties and hybrids as well as among the years. A rating scale for the evaluation of resistance to common scab was designed. The genotypes ranked into scores 7 (high resistance) to 9 (very high resistance); on the new scale they could be considered perspective genetic resources in breeding for improvement of the level of this character. The evaluated set consisted of genotypes: Samantana, Karin, Monika, Impala, Santé, Annabelle, YP 94-067, YP 91-123, BEE J 85, Viola, and Granola.

Keywords: potato; common scab; potato genetic resources

Potato common scab significantly deteriorates potato tuber appearance causing pustules of different size and depth on the skin. Tubers with strong infection are difficult to use for fresh market and processing; sprouting capacity and emergence could be negatively affected in seed potatoes (Vokál et al. 2004). The pathogen is present in all agricultural lands; therefore the reduction of disease incidence is very difficult and particularly relies on a complex of indirect protective measures. Varieties are characterized by different levels of susceptibility to the disease and the choice of a variety suitable for specific soil conditions is a control measure. Susceptible varieties cannot be planted on plots with regular, higher occurrence of common scab. These are mostly the plots with light or stony soil, easily drying out, especially at the beginning stage of tuberization when suberin that defends the plant against initial infection with common scab is not present yet; it is produced after several weeks (1–2), and water stress supports the penetration of streptomycetes pathogens into young tubers. Tuber infection could be partly reduced by preservation of balanced microbiological soil activity using optimal cultural practices and balanced nutrition without direct liming. For potato growing, the range of soil reaction should be maintained between 5.5 and 6.5 pH. Irrigation at the stage of tuber set can support the development of antagonistic bacteria in the surroundings of lenticels that decrease the occurrence of common scab pathogens and can reduce tuber infection. Control measures recommended for a reduction of common scab occurrence, their principles, feasibility and practical efficacy were reviewed.

Resistance to common scab is a varietal characteristic that could be exceeded by a significant influence of environmental factors, especially weather progress during tuber initiation and early growth.

Many authors (Hawkes 1990, Goth et al. 1995, Hosaka et al. 2000) were engaged in breeding and selection of the sources of resistance to common scab, including the identification of sources in wild

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species. Krantz and Eide (1941) elaborated genetics of the resistance to common scab, distinguishing 5 genetic groups that differ in their response to common scab – quadruplex, triplex, duplex, simplex and nulliplex; for breeding minimally duplex is necessary. In the breeding for resistance to common scab Hindenburg, with presence of resistance genes in quadruplex constitution and Jubel with triplex constitution are the most used potato varieties (Krantz and Eide 1941, Zadina et al. 1976).

Zadina et al. (1975) performed field tests of resistance on a plot with strong natural infestation that was artificially inoculated every year. They evaluated 684 varieties of world potato assortment and found that only a few varieties (1.3 %) exhibited a high relative resistance to common scab, expressed with the rating score 8 (Ackersegen, Akebia, Arnika, Carnea, Hindenburg, Kotnov, Patrones, Reichskanzler, Šárka). In addition to these varieties they recommended varieties included in the rating score 7 for breeding purposes, e.g. Blaník, Čajka, Daria, Jubel, Kardinál, Keřkovské rohlíčky, Maritta etc. Also Hougas and Ross (1956) evidenced a possibility of breeding varieties resistant to common scab using varieties Antigo, Cayuga, Cherokee, Menominee, Ontario, Osage, Pungo, Redkote, Seneca, Tawa, Yampa, which were derived from Jubel or Hindenburg. Mishra et al. (2001) evaluated resistance of twenty-seven varieties, none was shown resistant, and only eight of them were found less susceptible.

A number of provocation tests are used for the evaluation of potato resistance level to common scab, namely field tests with higher natural infestation of trial plot, laboratory and field tests including an artificial infestation of a suitable plot with agar-grown common scab pathogens, and the most frequent greenhouse tests with soil naturally or artificially infested with common scab pathogens (Zadina et al. 1975).

The aim of the study was the verification of suitability of the greenhouse test for the determination of resistance level to common scab and the assessment of its usefulness for evaluation of the collection of genetic resources and hybrid materials from potato clonal selection.

MATERIAL AND METHODS

Tuber resistance to common scab was evaluated in the greenhouse provocation tests with planting in naturally infested soil. The greenhouse tests were performed in the department of the Potato Research Institute Havlíčkův Brod in Kunratice near Šluknov, Czech Republic. The test evaluated the tubers of 26 varieties and *Solanum tuberosum* hybrids (hereafter referred to as genotypes) derived from a potato genetic resource collection. Ten tubers of each sample were individually planted in three-liter pots containing infested soil in 2002–2004. At the beginning of vegetation, the pots were overhead watered; later (from the beginning of tuber formation of the size of about 5 mm) till the vegetation ending they were underwatered to induce conditions suitable for the disease development (McIntosh 1970). After the end of the vegetation tubers from pots were harvested. Tubers with more than 20 mm diameter were selected for the evaluation of common scab occurrence. Each tuber was individually tested for infection; the level of tuber surface infection was evaluated on a nine-score rating scale (Table 1).

For comparison of individual varieties the extent of tuber surface infection was expressed as a coefficient. For the coefficient calculation, percentage distribution of number of infected tubers in individual rating scores was determined at first and subsequently transformed in the way that percentage occurrence was multiplied by the factor for a given rating score (Table 1). A nine-score rating scale of resistance to common scab was designed according to the mean coefficient and evaluated varieties and hybrids were rated on this scale.

Utilization of the factor for calculation of a resistance coefficient allows more consistent distinguishing of material with higher incidence of common scab than the estimated extent for marketable raw staff. It is presupposed that the material selected

Table 1. Rating scale of common scab tuber infection

Rating score	Infection of tuber surface (%)	Factor for calculation of coefficient of resistance
9	0	0.0
8	< 0.8	0.1
7	0.9–2.8	0.2
6	2.9–7.9	0.3
5	8.0–18.0	0.4
4	19.0–34.0	4.0
3	35.0–55.0	5.0
2	56.0–77.0	6.0
1	> 77.0	7.0

in this way will have parameters on the level of binding regulations for occurrence of common scab on tubers.

Further, the calculation of basic statistic quantities, correlation coefficient and heritability coefficient were used for assessment of the results.

RESULTS AND DISCUSSION

Resistance to common scab in genotypes evaluated during 2002–2004 was expressed as a mean rating score and also as a mean coefficient of resistance to common scab. Both characteristics given

Table 2. Mean resistance of selected genotypes to common scab in 2002–2004

Genotype	Mean rating score			Mean coefficient of resistance		
	mean	standard deviation	standard error	mean	standard deviation	standard error
Samantana	7.16	0.21	0.12	24.81	13.18	7.61
Karin	7.05	0.27	0.16	27.16	11.83	6.83
Monika	6.74	0.71	0.41	30.40	16.21	9.36
Impala	6.73	0.31	0.18	31.20	15.74	9.09
Santé	6.33	0.51	0.29	38.78	15.90	9.18
Annabelle	6.65	0.52	0.30	38.81	17.08	9.86
YP 94-067	6.73	0.88	0.51	40.30	32.74	18.90
YP 91-123	6.15	0.34	0.20	46.88	25.99	15.00
BEE J 85 1135	6.49	0.62	0.36	55.58	36.33	20.98
Viola	6.43	0.94	0.54	57.25	50.61	29.22
Granola	6.66	0.63	0.36	57.30	38.11	22.00
Westamyl	6.13	0.84	0.48	65.64	47.59	27.48
Kornelie	6.36	0.76	0.44	66.06	42.18	24.35
Santana	6.47	0.73	0.42	70.93	86.04	49.68
Ornella	6.38	1.03	0.59	81.19	58.18	33.59
Tomensa	5.87	0.59	0.34	83.22	52.07	30.06
Kréta	6.07	0.97	0.56	91.40	71.08	41.04
VDW 94-76	5.70	0.63	0.36	92.63	57.83	33.39
Adora	5.68	0.74	0.42	111.51	110.40	63.74
YP 89-070	5.76	1.18	0.68	125.84	105.93	61.16
Inova	5.58	0.82	0.47	127.83	139.68	80.64
Ramos	5.56	0.80	0.46	130.41	81.26	46.91
Carmona	5.40	0.47	0.27	133.18	91.45	52.80
Futura	5.48	1.40	0.81	155.97	120.04	69.30
Jan A 87 1933	4.80	0.47	0.27	206.78	72.76	42.01
Agria	4.33	0.74	0.43	272.98	137.35	79.30
Mean	6.10			87.08		
Standard deviation	0.67			59.23		
Coefficient of variation	10.98			68.02		
Analysis of variance *F*-test: varieties	4.288**			3.138**		
Analysis of variance *F*-test: years	20.902**			14.013**		
Minimal significant difference for varieties: α = 0.01	1.951			201.281		
Minimal significant difference for varieties: α = 0.05	1.698			175.201		
Minimal significant difference for years: α = 0.01	0.471			48.61		
Minimal significant difference for years: α = 0.05	0.374			38.615		

in Table 2 are supplied with the calculations of standard deviation, standard error and variation coefficient.

It is apparent in Table 2 that the transformation of results using the coefficient of resistance was well founded, as the data better correspond to the differences among varieties. A coefficient of variation identified for the value of mean coefficient of resistance is 68.02% showing a very high rate of variability in the evaluated set. The fact that the coefficient of resistance to common scab takes into account particularly the presence of tubers with higher damage is also proven by the results of testing in individual years, as shown in Tables 3–5.

Analysis of variance for recorded values shows the presence of significant differences among individual genotypes as well as among years. Genotype and year effects, and year-genotype interaction contribute to the expression of this character.

Table 3. Resistance of selected potato genotypes to common scab in 2002

Genotype	Mean rating score	Standard error	Tuber distribution (%) in individual rating scores									Resistance coefficient
			1	2	3	4	5	6	7	8	9	
Impala	7.07	0.16					7.41	7.41	55.56	29.62		19.26
Adora	6.16	0.21				5.26	15.79	36.84	42.11			46.3
Annabelle	6.24	0.21				7.89	10.53	34.21	44.74	2.63		55.25
Inova	6.32	0.30				10.71	7.14	25.00	35.72	21.43		62.48
Karin	7.14	0.12						17.65	50.00	32.35		18.53
Kréta	7.16	0.11						12.90	58.06	29.03		18.39
Tomensa	6.50	0.13					10.00	33.33	53.34	3.33		25.00
Kornelie	7.22	0.10						6.25	65.63	28.12		17.81
Carmona	5.65	0.16				11.76	29.41	41.18	17.65			74.69
Ramos	6.48	0.17				3.70	7.41	33.33	48.15	7.41		38.13
Santana	6.87	0.19					8.00	28.00	36.00	28.00		21.60
Jan A 87 1933	5.26	0.22			9.68	12.90	35.48	29.03	9.68	3.23		125.16
Viola	6.63	0.19					14.81	25.93	40.74	18.52		23.70
Santé	6.33	0.17					14.29	42.86	38.09	4.76		26.67
Agria	4.81	0.17			7.41	25.93	44.44	22.22				165.21
Granola	6.63	0.23				10.53		10.53	73.68	5.26		60.54
VDW 94-76	6.42	0.17					11.76	35.29	52.94			25.88
YP 91-123	6.53	0.23					20.00	13.33	60.00	6.67		24.67
Ornella	7.56	0.16						5.56	3.33	61.11		14.45
Samantana	7.23	0.14						15.38	46.15	38.46		17.69
Monika	7.50	0.13						4.55	40.91	54.54		15.00
Westamyl	6.85	0.15						38.46	38.46	23.08		21.54
BEE J 85 1135	7.05	0.13						14.29	66.67	19.04		19.53
Futura	7.09	0.21						18.18	54.55	27.27		19.09
YP 89-070	6.52	0.18					14.29	23.81	57.14	4.76		29.05
YP 94-067	7.21	0.16					4.17	8.33	50.00	37.50		17.92
Mean	6.631											38.62
Standard deviation	0.654											35.87
Coefficient of variation	9.862											92.88

The relationship between years characterized by the correlation coefficient is expressed as 0.557** for the years 2002 and 2003, 0.518* for the years 2002 and 2004, and 0.548** for the years 2003 and 2004.

From the correlation coefficients characterizing the relationship between years, a coefficient of heritability, that was estimated to express the proportion of genetic variance and total variance, was 0.54 on average (the limit of high heritability is 0.60).

Based on the derived results, a rating score was designed for the evaluation of resistance to common scab in potato genotypes (Table 6). Genotypes included in the rating scores 7 (high resistance) to 9 (very high resistance) of the new designed scale could be considered as perspective genetic resources in breeding for improvement of the level of this character. The evaluated set consisted of genotypes: Samantana, Karin, Monika, Impala, Santé, Annabelle, YP 94-067, YP 91-123,

Table 4. Resistance of selected potato genotypes to common scab in 2003

Genotype	Mean rating score	Standard error	Tuber distribution (%) in individual rating scores									Resistance coefficient
			1	2	3	4	5	6	7	8	9	
Impala	6.47	0.11					8.82	35.30	55.88			25.29
Adora	6.04	0.22			4.35		26.09	26.09	43.47			48.71
Annabelle	6.48	0.11					6.06	39.39	54.55			21.15
Inova	5.72	0.15					44.00	40.00	16.00			32.80
Karin	6.75	0.10					3.57	17.86	78.57			22.30
Kréta	5.29	0.18				16.67	45.83	29.17	8.33			95.43
Tomensa	5.32	0.17				17.86	42.86	28.57	10.71			99.30
Kornelie	5.77	0.25				18.18	27.27	13.64	40.91			95.90
Carmona	5.68	0.19		2.63	2.63	7.89	21.05	42.12	23.68			86.28
Ramos	5.03	0.16			2.63	31.58	31.58	28.94	5,27			161.84
Santana	6.91	0.17					9.09	9.09	63.64	18.18		20.91
Jan A 87 1933	4.32	0.21		9.68	9.68	35.48	29.03	16.13				264.85
Viola	5.41	0.23				22.73	36.36	1818	22.73			115.46
Santé	5.82	0.16				7.14	25.00	46.43	21.43			56.78
Agria	3.47	0.15			61.90	28.58	9.52					427.63
Granola	6.11	0.32		5.26		10.53	5.26	21.06	57.89			93.68
VDW 94-76	5.31	0.24			9.09	13.64	22.73	45.45	9.09			124.56
YP 91-123	5.87	0.13				2.63	31.58	42.11	23.68			40.50
Ornella	5.65	0.35			5.88	17.65	23.53	23.53	17.65	11.76		121.18
Samantana	6.93	0.17			2.44	2.44	4.87	9.76	51.22	29.27		40.01
Monika	6.11	0.14					27.78	33.33	38.89			28.89
Westamyl	5.21	0.19			3.57	17.86	42.86	25.00	10.71			116.08
BEE J85 1135	5.83	0.16				6.67	26.67	43.33	23.33			55.01
Futura	4.75	0.39		15.00	15.00	5.00	30.00	15.00	20.00			205.50
YP 89-070	4.4	0.21			20.00	30.00	40.00	10.00				239.00
YP 94-067	5.72	0.18			3.03	9.09	21.21	45.45	21.21			77.87
Mean	5.629											104.50
Standard deviation	0.809											93.36
Coefficient of variation	14.372											89.34

BEE J 85, Viola, and Granola. A very good level of resistance to common scab was recorded in varieties Samantana and Karin, associated with a relatively low variability of expression – modification variability (Table 3). These varieties also showed a statistically significant difference of mean rating scores and mean coefficients with two most susceptible varieties (Table 7).

The above-mentioned results indicate that the chosen test (McIntosh 1970) created nearly optimal conditions for tuber infection and the effect of underwatering on infection progress was probably negligible. In a more comprehensive set of varieties Zadina (1975) included 74.7% of varieties into rating scores 4–6. In the studied set 53.85% of varieties were included in these scores, 42.30% were ranked into scores 7 and 8 and 3.85% of varieties were included in the rating score 3. From this finding a certain shift towards a higher resistance to common scab in modern varieties could be concluded. It is also

Table 5. Resistance of selected potato genotypes to common scab in 2004

Genotype	Mean rating score	Standard error	Tuber distribution (%) in individual rating scores									Resistance coefficient
			1	2	3	4	5	6	7	8	9	
Impala	6.66	0.17				7.32	4.87	19.52	51.22	17.07		49.04
Adora	4.83	0.35		13.79	17.25	13.79	13.79	13.79	24.14	3.45		238.98
Annabelle	7.24	0.16			3.64	1.82	3.64		40.00	50.90		40.03
Inova	4.70	0.34		9.10	30.30	18.18	3.02	9.10	24.24	6.06		288.21
Karin	7.27	0.21				6.66	3.34	6.66	23.34	60.00		40.64
Kréta	5.77	0.31		3.85		30.76		11.54	53.85			160.37
Tomensa	5.80	0.25				26.67	16.67	13.33	36.67	6.66		125.35
Kornelie	6.08	0.18				15.79	7.89	28.95	47.37			84.48
Carmona	4.86	0.26			10.71	42.86	17.86	7.15	21.42			238.56
Ramos	5.16	0.27			19.35	19.35	12.90	22.59	25.81			191.25
Santana	5.62	0.36		10.34	10.34	10.34	3.45	17.25	37.94	10.34		170.28
Jan A 87 1933	4.81	0.26			22.22	25.92	7.41	37.03	7.42			230.34
Viola	7.26	0.21				4.34		13.04	3.44	52.18		32.58
Santé	6.84	0.20				3.22	9.67	22.58	29.04	35.49		32.88
Agria	4.70	0.26		4.35	8.69	34.79	26.09	17.39	8.69			226.10
Granola	7.23	0.15					3.33	13.33	40.00	43.34		17.67
VDW 94-76	5.36	0.25		3.57	10.71	7.14	17.86	46.43	14.29			127.46
YP 91-123	6.05	0.18			4.76	7.14	11.90	30.96	45.24			75.46
Ornella	5.94	0.23			5.88	14.71	11.76	14.71	52.94			107.95
Samantana	7.33	0.09					1.56	7.81	46.87	43.76		16.72
Monika	6.60	0.22				6.66	16.66	10.00	43.34	23.34		47.31
Westamyl	6.33	0.15				9.30	6.97	25.59	58.14			59.29
BEE J 85 1135	6.60	0.24			6.66	11.11	2.22	11.11	33.34	35.56		92.19
Futura	4.60	0.41			40.00	6.66	26.67	6.67	20.00			243.31
YP 89-070	6.36	0.40		4.54	4.54	9.09	18.18	36.37	22.73	4.55		109.48
YP 94-067	7.27	0.13				2.22	2.22	6.66	44.45	44.45		25.10
Mean	6.048											118.12
Standard deviation	0.947											85.02
Coefficient of variation	14.61											71.98

Table 6. The nine-score rating scale for evaluation of resistance to common scab in potato genetic resources enlarged with classification of tested varieties and hybrids

Rating scale			Genotype(value of mean coefficient)
Rating score	word expression of resistance	value of mean coefficient	
9	very high	0	
8	high to very high	0.01–30.00	Samantana (24.81) Karin (27.16)
7	high	30.01–60.00	Monika (30.40) Impala (31.20) Santé (38.78) Annabelle (38.81) YP 94-067 (40.30) YP 91-123 (46.88) BEE J 85 1135 (55.58) Viola (57.25) Granola (57.30)
6	medium to high	60.01–90.00	Westamyl (65.64) Kornelie (66.06) Santana (70.93) Ornella (81.19) Tomensa (83.22)
5	medium	90.01–120.00	Kréta (91.40) VDW 94-76 (92.63) Adora (111.51)
4	low to medium	120.01–240.00	YP 89-070 (125.84) Inova (127.83) Ramos (130.41) Carmona (133.18) Futura (155.97) JAN A 87 1933 (206.78)
3	low	240.01–360.00	Agria (272.98)
2	very low to low	360.01–480.00	
1	very low	> 480.01	

proven by the findings of Mishra et al. (2001), who identified 29% of varieties as least susceptible and 71% as medium susceptible to very susceptible in a comparable set of varieties.

The abovementioned method of evaluation can be recommended as a method suitable for characterization of resistance to common scab, based on the assumption that resistance and/or susceptibility of tested material can be classified. The method can be used for evaluation of varieties and other potato genetic resources and for elimination of susceptible and recognition of relatively resistant material during clonal selection. The method is not demanding as to equipment and amount of tested material and can be used even for a more extensive testing.

Table 7. Statistically significant differences among varieties and hybrids

According to the mean coefficient

Genotype	Samantana	Karin	Monika	Impala	Santé	Annabelle	YP 94-067	YP 91-123	BEE J 85 1135	Viola	Granola	Westamyl	Kornelie	Santana	Jan A 87 1933	Agria
Samantana															*	**
Karin															*	**
Monika															*	**
Impala															*	**
Santé																**
Annabelle																**
YP 94-067																**
YP 91-123																**
BEE J 85 1135																**
Viola																**
Granola																**
Westamyl																**
Kornelie																**
Santana																**
Jan A 87 1933		*	*	*												
Agria	*	**	**	**	**	**	**	**	**	**	**	**	**	**		

According to the mean rating score

Genotype	Samantana	Karin	Monika	Impala	YP 94-067	Granola	Annabelle	BEE J 85 1135	Santana	Viola	Ornella	Kornelie	Santé	YP 91-123	Westamyl	Kréta	Carmona	Jan A 87 1933	Agria
Samantana																	*	**	**
Karin																		**	**
Monika																		*	**
Impala																		*	**
YP 94-067																		*	**
Granola																		*	**
Annabelle																		*	**
BEE J 85 1135																		*	**
Santana																			**
Viola																			**
Ornella																			**
Kornelie																			**
Santé																			**
YP 91-123																			*
Westamyl																			*
Kréta																			*
Carmona	*																		
Jan A 87 1933	**	**	*	*	*	*	*	*											
Agria	**	**	**	**	**	**	**	**	**	**	**	**	**	*	*	*			

**α = 0.01, *α = 0.05

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