Late blight-resistant tuber-bearing *Solanum* species in field and laboratory trials

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Introduction

The collection of wild potato species at the N.I. Vavilov Institute of Plant Industry (VIR) is a valuable source of economic features of potato, such as the resistance to pests and diseases. To describe the breeding potential of wild potato species, the germplasm, stored at the VIR vollection, has been assessed by many authors (1, 2, 3). Since the most of data on the wild potato assessment are provided by the screening of populations, this information can be used only as a general guide for the selection of promising germplasm (4). Besides, the published data on the germplasm response to *Phythophtora infestans* must be verified against the particular changes in *P. infestans* populations in Russia (5).

Mexican wild potato species are recognized as an outstanding source of the late blight resistance. We examined a number of accessions of Mexican tuber-bearing *Solanum* species in order to check their resistance to the current *P. infestans* population and the complex race of *P. infestans* under field and laboratory conditions, respectively. This study reports on the well-characterized *Solanum* genotypes with a broad range of resistances, which are prospective for further molecular-genetic studies and breeding programs.

Material and Methods

Plant genotypes belong to 77 accessions of 19 *Solanum* species representing eight series as listed in Table 1.
- **Each accession grown from greenhouse seedlings is presented by one genotype selected on the basis of abundant tuber numbers and lack of virus symptoms.**
- **The tubers of each individual genotype were harvested in a greenhouse.**
- **The clones were propagated in a greenhouse annually and used for field and laboratory tests (Figs. 1, 2).**

Table 1. *Solanum* tuber-bearing species tested for late blight resistance

Series name	Species name	Number of accessions
Demissa	*S. brachycarpum*	1
	S. demissum	2
	S. hougasii	1
Longipedicellata	*S. fendleri*	6
	S. hjertingii	5
	S. papita	2
	S. polytrichon	10
	S. stoloniferum	7
Borealia	*S. wightianum*	1
Polyadenia	*S. polyadenium*	1
Pinnatisecta	*S. brachystotrichum*	3
	S. jamesii	6
	S. pinnatisectum	4
	S. stenophyllidium	2
	S. tarnii	1
Cardiophylla	*S. cardiophyllum*	12
	S. ehrenbergii	10
Bulbocastana	*S. bulbocastanum*	2
Tuberosa	Control- *S. chilotanum*	1
	Total species 19	Total accessions 77

Fig.1. Plants in an ARRIP greenhouse, kindly provided by A.A. Pankin: (a) *Solanum stoloniferum* (k-19196), (b) *S. polytrichon* (k-24298), (c) *S. demissum* (k-18521), (d) *S. verrucosum* (k-23015), (e) *S. pinnatisectum* (k-24239), (f) *S. bulbocastanum* (k-21274)

Fig. 2. Plants of Mexican *Solanum* species in a VIR greenhouse

The field test was carried out in 2008-2009 at the Pushkin Experimental station of VIR (20 km to the south of St-Petersburg, North-Western part of Russia).
- **Each year 2-5 plants per accessions were grown on the experimental plots, located between adjacent border rows of cultivated potato species.**
- **Foliar late blight assessment was carried out on a weekly basis 4 times in 2009 and 5 times in 2008 using the 9-score rating scale, where 1 means a 100% necrotic tissues and 9 means the absence of any visible lesions.**
- **The scores were converted to the mean defoliation (in %) of the corresponding range (i.e., 1=0%, 5=50%, and 9=100%) and used to calculate the area under the disease progress curve (AUDPC) for each individual accession (6).**

Detached leaf tests were conducted independently in ARRIP and VIZR.
- **Leaves were collected from 30-55-day greenhouse plants.**
- **Two single *P. infestans* isolates from the Leningrad and Moscow regions both containing the race 1,2,3,4,5,6,7,8,9,10,11 were used.**
- **For each accession we inoculated 3-5 leaves with the suspension of zoospores (30-40 × 1000 zoospores/ml) according to the standard protocol.**
- **As a control, we used the leaves of potato cvs. Alpha, Bintje, Eesterling, Escort, Robin, Gloria, Sapro, Mira and Sante (Eucablight standard set) in ARRIP tests and those of cvs. Latona and Elizaveta in the VIZR tests.**
- **The disease assessment was carried out 6 days after the spot inoculation. Both the leaf area affected by the pathogen and the sporulation intensity were scored (Figs. 3, 4)**

Fig. 3 Reaction of various *Solanum* species to the *P. infestans* infection in the ARRIP detached leaf test

Fig. 4 Reaction of various *Solanum* species to the *P. infestans* infection in the VIZR detached leaf test

Statistical analysis
- **The ANOVA software was used to compare the accessions of wild potato species across the two-year field test.**
- **The relation between AUDPC and the resistance of wild potato plants, infected under laboratory conditions, was evaluated using the Spearman's and Kendall's correlation coefficients.**
- **The analyses were performed using a Statistics 6.1 package.**

Results

Field trials were performed in both epidemic years.
- *P. infestans isolates* from these fields were very complex and virulent to all 11 R-genes tested, excepting R9 gene.
- During both years the disease emergence was observed in the same period (55-60 days after the planting), though the time-course of the disease development significantly varied.

Fig.5 Graphic for ANOVA: Two-Factor with Replication.

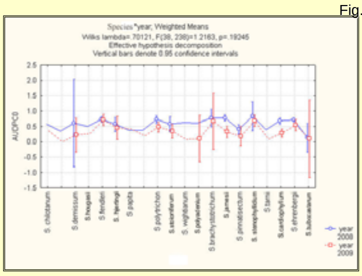


Fig.6. Plants of *Solanum* species in the field (2009).

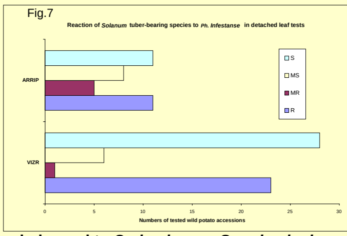
The *P. infestans* infection varied both between and within *Solanum* species

Figure 5 presents the AUDPC means for *Solanum* species, calculated for two years.
Factorial ANOVA indicates that the plant species and the year of testing had considerably affected the final defoliation of tested accessions, whereas an interaction of these two factors was not significant.

The rate of infected leaf area increase in the field tests was greater in 2008, than in 2009.
- The average AUDPC value for plants of *Solanum* species was 0.64 (ranging from 0,10 to 1,00) in 2008 and 0.41 (from 0 to 1.00) in 2009.
- In both years we registered the following significant species-specific effects:
- *S. bulbocastanum* is resistant (final defoliation did not exceed 20%),
- *S. pinnatisectum* is moderately resistant (final defoliation under 50%),
- *S. hjertingii* is moderately susceptible (final defoliation of 35-80%)
- *S. fendleri, S. brachystotrichum,* and *S. stenophyllidium* are the most susceptible (final defoliation up to 100%).

Detached leaf tests showed a similar pattern (Fig. 7).
- The relative number of resistant and susceptible accessions was about equal (31-40% and 31-50%, respectively).
- All genotypes of *S. demissum* and *S. polyadenium* species, as well as the single tested genotype *S. brachycarpum, we*re highly resistant to infection.
- All genotypes of *S. brachystotrichum, S. stenophyllidium*, *S. papita, S. polytrichon,* and *S. ehrenbergii* were as susceptible as the control plants.

Fig.7



- **9 genotypes, resistant to both *P. infestance* isolates, belonged to *S. demissum*, *S. polyadenium* , *S. pinnatisectum*, *S. cardiophyllum,* and *S. bulbocastanum* species.**
- **3 genotypes, resistant in the field tests, became infected in the detached leaf test.**
- **In contrast, 7 genotypes were susceptible to the natural infection and resistant in the detached-leaf test.**

Table 2. Final distribution of *Solanum* accessions concerning their late blight resistance

Field / Laboratory	Resistant	Moderately resistant	Moderately susceptible	Susceptible
Resistant	***S. brachycarpum* 2830*** ***S. demissum* 15173** ***S. hjertingii* 24223** ***S. cardiophyllum* 24207** ***S. bulbocastanum* 19981, 21266,**	***S. stoloniferum* 21618** ***S. polyadenium* 23553** ***S. cardiophyllum* 16828, 18086, 24206, 24375**	***S. demissum* 18521** ***S. jamesii* 24397**	
Moderately resistant	***S. pinnatisectum* 24239**	***S.hougasii* 8818**	***S. pinnatisectum* 24243**	***S. fendleri* 23841**
Moderately susceptible	***S. papita* 24417** ***S. stoloniferum* 21547**	***S. jamesii* 22619**	***S. stoloniferum* 23652** ***S.jamesii* 15203**	***S. jamesii* 23398**
Susceptible	***S. polytrichon* 24463** ***S. pinnatisectum* 21955**	***S. hjertingii* 24387** ***S. papita* 16889** ***S. brachystotrichum* 24197** ***S. ehrenbergii* 24373**	***S. chilotanum* 1671** ***S. polytrichon* 23561, 24298, 24462** ***S. stoloniferum* 19196** ***S. cardiophyllum* 4464** ***S. ehrenbergii* 23279**	***S. fendleri* 24221** ***S. polytrichon* 16905** ***S. stoloniferum* 24420** ***S. stenophyllidium* 20105, 24255** ***S. ehrenbergii* 18225**

* Here and further on, the accession numbers at the VIR collection

Conclusions

- **The response of *Solanum* species to the late blight significantly varied depending on the test used.**
- **A high level of the late blight resistance was registered only for individual plants of such *Solanum* species as *S. brachicarpum, S. demissum, S. hjertingii, S. cardiophyllum,* and *S. bulbocastanum.***

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