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EXPRESSION OF RESISTANCE TO *PHYTOPHTHORA INFESTANS* IN CLIMATIC CHAMBER–, SCREENHOUSE– AND FIELD–GROWN WILD POTATO SPECIES IN A DETACHED LEAFLET ASSAY

ABSTRACT

A study on the expression of resistance to *Phytophthora infestans* of wild potato plants grown in a climatic chamber, in a screenhouse and in the field was performed in two experiments. In the first experiment 12 populations of *Solanum acaule* were tested. Detached leaves from field–grown plants appeared to be less resistant than detached leaves from chamber–grown plants.

In the second experiment resistance responses to inoculation with *P. infestans* of 24 *Solanum* species, grown in the field and in the screenhouse were compared. In 18 populations belonging to 11 species the predominance of resistant plants was found either when plants were grown in the field or when plants were grown in the screenhouse. Within 12 tested populations no difference in resis–tance was observed because of high susceptibility of plants, irrespective of grown conditions. Two populations showed the same level of resistance under both grown conditions.

Key words: detached leaflets, resistance, *Phytophthora infestans*, wild *Solanum* spp.

INTRODUCTION

Laboratory screening is a rapid and accurate method used to assess resistance of potato plants to *Phytophthora infestans*. Data obtained in numerous studies showed a significant positive correlation between the results of laboratory and field tests (Hodgson 1962, Knutson 1962, Bytchenkova 1968, Dorrance and Inglish 1997). In contrast, Stewart *et al*. (1983) did not find any satisfactory correlation between the levels of foliar resistance expressed in glasshouse and field tests.

The resistance expression is determined by many factors: plant age (Fry and Apple 1986, Stewart 1990), leaf position (Carnegie and Colhoun 1982, Visker *et al*. 2003), inoculum density (Kroll and Eide 1981, Stewart 1990), plant nutrition (Thurston 1971) and environmen–tal conditions (Umaerus 1969, Stewart *et al*. 1996). No differences were

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found in reaction to inoculation with *P. infestans* of field– and glass–house–planted tubers (Stewart *et al*. 1996). Nevertheless, the evaluation of foliage resistance of several *Solanum* species showed that individual species can respond in a different manner under different experimental conditions (Vleeshouwers *et al*. 1999).

MATERIAL AND METHODS

In total, 43 accessions representing 25 wild potato species from VIR (Vavilov Institute, St. Petersburg) collection were evaluated in two leaflet tests. First test was performed in 1999 on 12 populations of *S. acaule*. In this test one group of plants was planted in the field and other group was planted in a climatic chamber.

Seedlings were planted in the field in 30–plant rows with plant spacing 0.7 by 0.7 m.

In the climatic chamber seedlings were planted in plastic pots filled with potting soil. Potted plants were supplied with a 16 h photoperiod at light intensity of 8000 lux, day and night temperatures of 20˚C and 17˚C, respectively, RH ranging between 65% and 75%, and plant spacing 0.3 m. Plants were regularly watered.

The next trial comprised 32 accessions belonging to 24 wild potato species. The seedlings from each population were divided into two groups. Plants to be tested in the second test were comparatively grown in the field and in the screenhouse. Potted plants were maintained in the screenhouse covered by white wire–gauze at plant spacing 0.3 m.

Resistance to *P. infestans* was evaluated in laboratory screening using the detached leaflet assay. From each accession, 30 plants grown in the field and 20 plants grown in the climatic chamber and screenhouse each were inoculated. Inoculation of plants was done at the early stage of flowering at the beginning of July for plants grown in the field or screenhouse, and at the beginning of August for plants grown in the climatic chamber.

For inoculation, three apical leaflets from each plant were used in two replications. To inoculate the detached leaflets, a highly virulent and aggressive isolate MP 324 from the IHAR Młochów collection of *P. infestans* isolates was applied. The isolate MP 324 was of A1 mating type and expressed the presence of the following factors of virulence: 1.2.3.4.5.6.7.10.11. The concentration of inoculum was 50 sporangia/mm^3. The resistance ratings were estimated on the 6th day after inoculation with the use of a 1–9 scale, where 1 – the highest level of susceptibility, and 9 – the highest level of resistance. Three Polish cultivars: resistant (Bzura), moderately resistant (Sokół) and susceptible (Irys) were used as controls.

To compare the resistance expression the mean score grades for field– and climatic chamber–grown plants of each accession tested were calculated in the first experiment. In the second experiment the resistance

expression in field– and screenhouse–grown plants was separately esti–mated as a percentage of resistant (scored 7–9), moderately resistant (5–6) and susceptible (1–4) plants for each accession.

RESULTS

In the first test, the seedlings of 12 accessions of *S. acaule* partially grown in the field and in the climatic chamber were tested for resistance to *P. infestans* in the detached leaflet assay. All populations expressed a higher level of resistance following inoculation of the leaflets collected in the climatic chamber (Fig. 1). The average of mean grade scores for each accession fluctuated from 2.1 (k–4114) to 8.8 (k–10678) for the leaflets collected in the climatic chamber, and from 1.2 (k–18014) to 4.8 (k–10678) for the leaflets collected in the field. The mean grade scores for the controls grown in the field and climatic chamber were as follows: Irys 1.9 and 2.4, Sokół 3.4 and 4, Bzura 4 and 4.4, respectively. Test variability was evaluated at $LSD_{0.05}$ = 1.26. In the two tests, the differ–ences in the level of resistance between the controls were found not sig–nificant, in the contrary to those between the accessions.

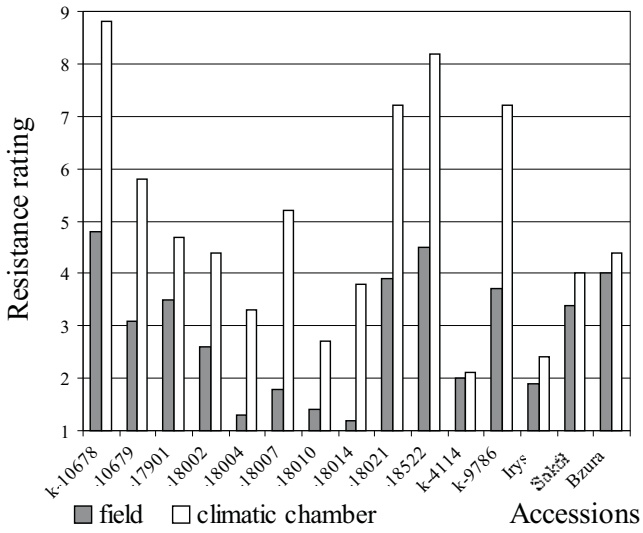

Fig. 1. Expression of resistance to *Phytophthora infestans* of *S. acaule* plants grown in the field and climatic chamber (scale 1–9, where 9 = most resistant)

In order to compare resistance expression to *P. infestans* of potato plants grown under different conditions, resistance ratings of 32 acces–sions belonging to 24 wild species, planted under the screenhouse and field conditions, were simultaneously assessed in the leaflet test. There was a significant effect both on the accessions grown in the screenhouse ($LSD_{0.05}$ = 1.83) and on those grown in the field ($LSD_{0.05}$ = 0.86).

Table 1

Expression of resistance to *Phytophthora infestans* of leaflets of potato accessions within wild species, collected in the field and screenhouse

Species	No. of VIR catalogue	Percentage of plants with resistance rating *							
		9	7–8	5–6	1–4	9	7–8	5–6	1–4
		leaflets from the screenhouse				leaflets from the field			
S. acaule	k–9747	30	–	–	70	–	–	–	100
S. acaule	k–9794	–	60	20	20	–	–	–	100
S. acaule	k–9795	–	–	20	80	–	–	–	100
S. albicans	k–9813	30	30	–	40	–	–	–	100
S. angustisectum	k–2733	–	–	–	100	–	–	–	100
S. arrac–papa	k–9742	–	–	40	60	–	–	–	100
S. berthaultii	k–7635	–	–	–	100	–	–	–	100
S. bukasovii	k–9708	–	–	–	100	–	–	–	100
S. demissum	k–2353	30	50	20	–	57	43	–	–
S. demissum	k–4445	50	50	–	–	90	10	–	–
S. famatinae	k–4304	–	–	–	100	–	–	–	100
S. fendleri	k–5747	–	–	–	100	–	–	–	100
S. gibberulosum	k–2739	20	–	–	80	4	–	–	96
S. gourlayi	k–11973	–	–	–	100	–	–	–	100
S. latisectum	k–2722	–	–	–	100	–	–	–	100
S. microdontum	k–9726	25	25	–	50	50	–	25	25
S. multidissectum	k–4289	–	–	20	80	–	–	–	100
S. papita	k–8816	40	20	–	40	38	16	–	46
S. papita	k–16888	66	–	–	34	59	24	–	17
S. papita	k–16889	–	40	40	20	57	29	–	14
S. papita	k–17455	–	20	–	80	66	17	–	17
S. parvicorollatum	k–9128	–	–	–	100	–	–	–	100
S. pinnatisectum	k–4330	–	–	–	100	23	31	–	46
S. polytrichon	k–7426	–	–	–	100	–	–	–	100
S. ruiz–ceballosii	k–7381	–	–	–	100	–	–	–	100
S. simplicifolium	k–5400	25	25	25	25	67	22	11	–
S. simplicifolium	k–5684	10	–	–	90	30	30	10	10
S. sparsipilum	k–10706	–	–	–	100	–	–	–	100
S. tarijense	k–7642	–	–	–	100	–	–	–	100
S. tarijense	k–10712	25	25	25	25	25	25	25	25
S. verrucosum	k–10556	28	14	–	57	28	28	17	17
S. virgultorum	k–3954	–	25	–	75	–	4	–	96

* scale 1–9, where 9 = most resistant

The proportions of resistant genotypes in the accessions of *S. demissum*, *S. microdontum*, *S. papita* (in three of four accessions), *S. pinnatisectum*, *S. simplicifolium* and *S. verrucosum* were higher in the field–grown plants than in the plants grown in the screenhouse (Table 1). The most pronounced differences in the resistance levels were found with *S. simplicifolium*. Extremely resistant genotypes (scored

with grade 9) within accession k–5400 were observed in the greater proportion in plants grown in the field. Resistant genotypes, scored 7–9, were in the prevalence in k–5684, a more susceptible accession of this species. Within accession k–9726 of *S. microdontum* the total percentages of resistant plants, scored 7–9, grown in the field and screenhouse were equal. The difference in the resistance levels within population of k–9726 consisted of the number of extremely resistant plants scored with grade 9, which predominated among the plants grown in the field. Within this accession the quarter of plants was found susceptible when the plants were grown in the field, whereas the number of susceptible plants was twice as high when the plants were grown in the screenhouse. Also within *S. demissum* populations the field–grown plants expressed a higher level of resistance. This was manifested by a greater number of extremely resistant genotypes in both tested accessions. Similarly, in three populations of *S. papita* more resistant genotypes predominated within the seedlings grown in the field. This predominance was highly significant (66% of genotypes scored 9) in accession k–17455. In other accession of *S. papita*, k–8816, the proportions of genotypes showing different resistance levels were almost equal. The field–grown seedlings of accession k–4330 of *S. pinnatisectum* expressed higher resistance than those grown in the screenhouse (54% of genotypes scored 7–9). Also in accession k–10556 of *S. verrucosum* the proportion of resistant plants was greater within the field–grown plants than within the screenhouse–grown ones.

On the other hand, the field–grown seedlings of *S. acaule*, *S. albicans*, *S. arrac–papa*, *S. gibberulosum* and *S. multidissectum* were characterized by the lower percentages of resistant genotypes, as compared with the screenhouse–grown plants. In the case of susceptible accessions: k–9795 of *S. acaule*, k–9742 of *S. arrac–papa* and k–4289 of *S. multidissectum,* the essential difference was shown in the number of moderately resistant genotypes, scored 5 or 6, which were in prevalence among screenhouse–grown plants. In more resistant accessions: k–9747 and k–9794 of *S. acaule*, k–2739 of *S. gibberulosum* and k–3954 of *S. virgultorum*, the predominance of genotypes scored 7–9 was also found when plants were grown in the screenhouse. The most significant predominance of resistant screenhouse–grown plants was found with accession k–9813 of *S. albicans*. The seedlings of moderately resistant accession k–10712 of *S. tarijense* did not differ in a level of resistance to *P. infestans*, whether they were grown in the field or in the screenhouse.

The infection conditions made impossible to differentiate between the accessions highly susceptible to *P. infestans* as the leaflets became entirely diseased in both tests. Thus, no differences in response to infection were found between the screenhouse– and field–grown plants in populations of the accessions: k–2733 of *S. angustisectum*, k–7635 of *S. berthaultii*, k–9708 of *S. bukasovii*, k–4304 of *S. famatinae*, k–5747 of *S. fendleri*, k–11973 of *S. gourlayi*, k–2722 of *S. latisectum*, k–9128 of

S. parvicorollatum, k–7426 of *S. polytrichon*, k–7381 of *S. ruiz–ceballosii*, k–10706 of *S. sparsipilum* and k–7642 of *S. tarijense*.

DISCUSSION

The effect of resistance to *P. infestans* of different species grown in different conditions was investigated in field, screenhouse and climatic chamber conditions in two experiments. The first experiment comprised 12 populations of the same species (*S. acaule*). Plants were grown in the field and in the climatic chamber. Inoculation was performed when the plants were at the early stage of flowering: in July for plants grown in the field and in August for plants grown in the climatic chamber. Differences in growing conditions (solar light vs. artificial light, different water supply) might have resulted in differences in physiological stage of plants. The plants grown in the climatic chamber looked physiologically younger than those grown in the field. On the other hand, the plants grown in the climatic chamber were older in the time of testing. Plant age is a significant factor influencing leaf resistance reaction. Carnegie and Colhoun (1982) reported that in several cases older plants were more resistant to late blight than younger plants. This could partly explain the higher resistance of older plants grown in the climatic chamber. Thus, time of testing appeared to be a more important factor than physiological age of plants.

In the second experiment the accessions of five species (*S. acaule*, *S. albicans*, *S. arrac–papa*, *S. gibberulosum* and *S. virgultorum*) expressed higher resistance when plants were grown in the screenhouse, and the accessions of six species (*S. demissum*, *S. microdontum*, *S. papita*, *S. pinnatisectum*, *S. simplicifolium* and *S. verrucosum*) expressed higher resistance when plants were grown in the field. Within one of the two tested populations of *S. tarijense* detached leaves from field–grown plants were as resistant as detached leaves from screenhouse–grown plants. The reaction of the other species was the same irrespective of growing conditions, as all plants became entirely diseased. In the second experiment higher resistance was expressed by *S. acaule* plants grown under covers, i.e. in the conditions characterized by lower insolation and regular watering. It seems that reaction to inoculation with *P. infestans* within *S. acaule* populations grown in different conditions may be caused rather by species reaction to environmental conditions than by plant stage.

J. Hawkes wrote: "….The physiological diversity of wild potato species from an ecological and phytogeographical viewpoint, wild potatoes exhibit a wide diversity of resistance to fungal and other diseases" (Hawkes 1990).

The wide geographical distribution of wild potatoes indicates a wide range of ecological diversity and thus a range of their adaptation to environmental conditions. Diverse ecological conditions in zones of tested

species origin could be the explanation for different results obtained following inoculation of leaves grown in different environmental conditions.

It may be concluded from the obtained results that resistance (susceptibility) of potato plants to *P. infestans* can greatly differ depending both on species and growing conditions.

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