Short communication. Resistance to *Phytophthora infestans* in populations of wild potato species in the Sorata microcentre of genetic diversity, La Paz, Bolivia

M. Coca Morante* and N. Montealegre Villanueva

Estación Experimental Belén. Facultad de Agronomía. Universidad Mayor de San Andrés. La Paz. Bolivia

Abstract

Endemic wild potato species can be found in the Sorata microcentre of potato genetic diversity (Bolivia). This area, which lies at some 2640 m above sea level, is also a region of intensive *phurejas* potato cultivation. Pressure from the fungus *Phytophthora infestans* is high. *In vitro* experiments were performed to assess the resistance of the following potatoes to *P. infestans*: i) populations of the wild species *Solanum acaule* (*S. acl*), *S. circaeifolium* (*S. crc*-LA, *S. crc*-LB and *S. crc*-CO) and *S. achacachense* (*S. ach*), maintained at the Belén Research Station ex situ bank, ii) the reference species *S. capsicibaccatum* (*S. cap*), *S. berthaultii* (*S. ber*), *S. toralapanum* (*S. tor*) and *S. sparsipilum* (*S. spl*), and iii) susceptible cultivated varieties of *S. phureja* (*S. phu*) and *S. tuberosum* subsp. *andigena* (*S. adg*). The populations of *S. acl*, *S. crc*-LA, *S. crc*-LB and *S. crc*-CO showed high levels of resistance to *P. infestans*, while *S. ach* was very susceptible, in fact even more so than *S. phu*. *S. tor* was very resistant, while *S. cap*, *S. ber* and *S. spl* showed susceptibility similar to that of *S. phu*. The susceptible control *S. adg* showed the expected response to *P. infestans*, while that of *S. phu* was in agreement with its non-specific resistance to this pathogen.

Additional key words: late blight, non-specific resistance.

Resumen

Resistencia a *Phytophthora infestans* de poblaciones de especies silvestres de papa del microcentro de diversidad genética Sorata, La Paz, Bolivia

En el microcentro de diversidad de papas Sorata, Bolivia, situado a 2640 metros sobre el nivel del mar, algunas especies silvestres tienen distribución endémica, el cultivo de papas phurejas es intensivo y hay alta presión de *Phytophthora infestans*. Por su resistencia a este hongo, se evaluaron *in vitro*: i) poblaciones de especies silvestres de *Solanum acaule* (*S. acl*), *S. circaeifolium* (*S. crc*-LA, *S. crc*-LB y *S. crc*-CO) y *S. achacachense* (*S. ach*), conservadas en el Banco ex situ de la Estación Experimental Belén; ii) *S. capsicibaccatum* (*S. cap*), *S. berthaultii* (*S. ber*), *S. toralapanum* (*S. tor*) y *S. sparsipilum* (*S. spl*), especies de referencia, y iii) variedades cultivadas susceptibles de *S. phureja* (*S. phu*) y *S. tuberosum* subsp. *andigena* (*S. adg*). Las poblaciones de *S. acl*, *S. crc*-LA, *S. crc*-LB y *S. crc*-CO mostraron alto grado de resistencia a *P. infestans*. En cambio, *S. ach* mostró un alto grado de susceptibilidad, incluso superior a *S. phu*. Las poblaciones de *S. tor* mostraron alto grado de resistencia, y *S. cap*, *S. ber* y *S. spl* niveles similares de susceptibilidad a *S. phu*. El testigo susceptible *S. adg* mostró la esperada susceptibilidad a *P. infestans*, y *S. phu* fue concordante con su resistencia no específica al patógeno.

Palabras clave adicionales: resistencia no específica, tizón tardío.

In the Department of La Paz, in eastern Bolivia, potato (*Solanum tuberosum* L.) cultivation is concentrated on the Altiplano (the High Plain) and in mountainous areas between altitudes of 3820 and 4500 m. The Prepuna (a High Andes ecosystem) and valley areas under 3200 m form another, traditional, and relatively important, growing area. These microregions fall within the Larecaja, Camacho, Muñecas, Bautista Saavedra, Nor Yungas and Sur Yungas provinces. Given the climate of these areas, cultivation is seriously
Phytophthora infestans resistance in wild potato species in Bolivia

Affected by late blight caused by Phytophthora infestans Mont de Bary. The disease it causes is known to growers as Llejte (an Aymara word meaning ‘burnt’). It is mainly controlled with fungicides, and in some regions by sowing at specific times. The Department of La Paz is the main centre of diversity for wild potato species in Bolivia (Ochoa, 1990). The great majority of wild species reported for the region are found in wet and temperate areas where the incidence of P. infestans is high. In some microcentres of diversity, such as Sorata (Province of Larecaja), some species such as S. circaeifolium, S. achacachense and S. candolleanum are widely distributed and late blight (P. infestans) is a limiting factor in potato production. Recently, P. infestans has been reported affecting certain wild species in in situ conditions (Coca-Morante, 2003). Attempts to improve potato r genes have led to the study of wild and other cultivated species, and several important advances in achieving resistance to P. infestans have been made (Hawkes and Hjerting, 1989; Ruiz de Galarreta et al., 1998). Currently, r genes from S. tuberosum subsp. andigena, S. phureja, as well as certain wild species, are helping to improve this resistance. In Bolivia, P. infestans is endemic over the distribution ranges of wild potato species. The survival of the latter suggests they possess resistance mechanisms, or that a process of gradual genetic erosion is underway. Being a primary centre of potato genetic diversity, the variability of P. infestans may ample, and different resistance mechanisms may have evolved.

The aim of the present work was to determine the in vitro resistance to isolates of P. infestans of populations of wild potato species from the Sorata microcentre of diversity.

Different populations of wild potato species were selected (Fig. 1, Table 1) from the Belén Research Station ex situ bank (Faculty of Agriculture, Universidad Mayor de San Andrés) (see Coca-Morante, 2003). Small tubers belonging to the chosen species were sown under glass, along with locally cultivated susceptible controls (Table 1). All tubers were sown in plastic pots (15 × 10 cm) containing a mixture of sterilised substrate, black soil and fine sand (1:2:1). All treatments were replicated five times.

P. infestans isolates were collected from leaflets of the phurejas potato variety S. phureja Juxepczuk et Bukasov growing in the Sorata area. These isolates were maintained on potato (Solanum tuberosum subsp. andigena var. Waych’a Paceña) slices at 18°C until inoculating the leaflets of the test plants (three replicates per treatment) using the method described by the International Potato Center (CIP, 2001). These leaflets (all taken from the middle part of the plant before flowering) were moistened with sterile water and placed in Petri dishes containing 2% agar water. All inoculations were made using isolate CH-001. Twenty microlitres of a suspension containing $8 \times 10^3$ sporangia filtered through 20 and 10 µm sieves were placed on the lower side of each leaflet. The inoculated leaflets were then maintained in the Petri dishes at 18°C. The affected area (disease severity) and sporulation were recorded from 48 h to 120 h using a binocular microscope. The mean disease severity values were used to determine the area under the disease progress curve (AUDPC) according to the method of Campbell and Madden (1990):

$$AUDPC = \sum_{i=1}^{n-1} 4 (y_i + y_{i+1}) / 2 (t_{i+1} - t_i),$$

where n is the number of determinations (i.e., the number of disease severity readings), y is disease severity, and t is the time (in days) elapsed since inoculation. The mean AUDPC values at 120 h were analysed using a random block design.

Figure 2 shows that the populations of the wild species differ in their resistance to P. infestans. Those of the Megistacroloba (S. tor), Acaulia (S. acl) and Circaefolia (S. crc and S. cap) series showed the lowest AUDPC values, the very lowest being those for the S. tor and S. acl populations. Although the S. crc-LA, S. crc-CO and S. crc-LB populations showed significant differences in their resistance to P. infestans, all had low AUDPC values. The S. cap population showed the highest AUDPC values of the Circaefolia series, similar to other populations susceptible to P. infestans. The S. ach population showed AUDPC values higher than those of the S. crc populations, and similar to those of the S. phu control variety. The susceptible phureja (local) and Waych’a Paceña varieties also showed significantly different behaviour with respect to P. infestans.

The S. acl population from the high area of the Sorata microcentre (Chojchoni, 3500 m), showed the greatest resistance to P. infestans. Hawkes and Hjerting (1989) report this species to show characteristics of field resistance to P. infestans.
Figure 1. Distribution of wild potato species in the Sorata genetic diversity microcentre, La Paz (circle). Blue line: lake Titicaca border.
The populations *S. crc*-LA, *S. crc*-LB and *S. crc*-CO also showed resistance, but with differences, even though they came from neighbouring areas. These results agree with other reports indicating that *S. crc* shows partial (and promising) resistance to *P. infestans* (Hawkes and Hjerting, 1989; Ruiz de Galarreta et al., 1998). This is in line with the current situation in the Sorata microcentre where, even though potato cultivation is intensive, and despite negative human activities, populations of *S. crc* survive in marginal sites through their resistance to the effects of *P. infestans*.

The population *S. ach* was very susceptible to *P. infestans*. This population, from the type locality of «La Apacheta» (3200-3500 m), between Achacachi (Omasuyos Province) and Sorata (Larecaja Province), is now found in an area of intensive *phurejas*

---

**Table 1.** Populations of wild potato in the Sorata diversity microcentre, La Paz, and control and cultivated species

<table>
<thead>
<tr>
<th>Species of Solanum</th>
<th>Code</th>
<th>Type</th>
<th>Series</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S. megistacrolobum</em> var. <em>toralapnaum</em> (Card. y Hawkes) Ochoa</td>
<td>tor</td>
<td>Control</td>
<td>Megistacroloba</td>
<td>Sayari, Cochabamba, 4250</td>
</tr>
<tr>
<td><em>S. acaule</em> Bitter</td>
<td>acl</td>
<td>Wild</td>
<td>Acaulia</td>
<td>La Apacheta, La Paz, 4150</td>
</tr>
<tr>
<td><em>S. circaeifolium</em> Bitter</td>
<td>crc - LA</td>
<td>Wild</td>
<td>Circaeifolia</td>
<td>Laripata Alto, La Paz, 2650</td>
</tr>
<tr>
<td><em>S. circaeifolium</em> Bitter</td>
<td>crc - CO</td>
<td>Wild</td>
<td>Circaeifolia</td>
<td>Cotaña, La Paz, 2620</td>
</tr>
<tr>
<td><em>S. circaeifolium</em> Bitter</td>
<td>crc - LB</td>
<td>Wild</td>
<td>Circaeifolia</td>
<td>Laripata Bajo, La Paz, 2620</td>
</tr>
<tr>
<td><em>S. circaeifolium</em> var. <em>capsicibaccatum</em> Ochoa</td>
<td>cap</td>
<td>Control</td>
<td>Circaeifolia</td>
<td>Tunari, Cochabamba, 2750</td>
</tr>
<tr>
<td><em>S. sparsipilum</em> (Bitter) Juz. et Bukasov</td>
<td>spl</td>
<td>Control</td>
<td>Tuberosa</td>
<td>Ajillata, La Paz, 3810</td>
</tr>
<tr>
<td><em>S. achacachense</em> Cárdenas</td>
<td>ach</td>
<td>Wild</td>
<td>Tuberosa</td>
<td>La Apacheta, La Paz, 4150</td>
</tr>
<tr>
<td><em>S. berthaultii</em> Hawkes</td>
<td>ber</td>
<td>Wild</td>
<td>Commersoniana</td>
<td>San Pedro, Cochabamba, 2650</td>
</tr>
<tr>
<td><em>S. phureja</em> Juz et Bukasov var. <em>negra</em></td>
<td>phu</td>
<td>Cultivated</td>
<td>Tuberosa</td>
<td>Umanata, La Paz, 3150</td>
</tr>
<tr>
<td><em>S. tuberosum</em> subsp. <em>andigena</em> var. <em>Waych’a</em> Paceña</td>
<td>adg</td>
<td>Cultivated</td>
<td>Tuberosa</td>
<td>Belén, La Paz, 3810</td>
</tr>
</tbody>
</table>

1 Locality, Department and altitude (m). 2 LA, CO and LB, populations of *S. circaeifolium* from different localities.

**Figure 2.** AUDPC for wild species and populations with respect to resistance to *P. infestans*. Me = Megistacroloba series; Ac = Acaulia series; Com = Commersoniana series. Significance set at F.01.
cultivation where *P. infestans* is endemic and has serious effects. In 2003 it was reported that *P. infestans* affected *S. ach* in *in situ* conditions (Coca Morante, 2003). Apparently, *P. infestans* may be acting as a negative selection factor, and appears to be having a certain impact on existing populations.

Differences in resistance to *P. infestans* were also seen in the populations of control wild species, with *S. tor* showing the highest levels. This population, which comes from high altitude areas (4250 m), was reported by Hawkes and Hjerting (1989) to show non-specific field resistance to *P. infestans*, while Ruiz de Galarreta et al. (1998) recorded it as susceptible. The *S. cap* population was highly susceptible compared to those of *S. crc* of the Sorata microdiversity centre. The *S. cap* population comes from the Cochabamba Valley (2750 m). Alandia (1951) reported *S. cap* to be resistant to the «D» race of *P. infestans* from this area. Later, Hawkes and Hjerting (1989) reported its high field resistance to *P. infestans*, and 11 years later its partial resistance to the same fungus was reported (Ruiz de Galarreta et al., 1998). Apparently, *S. cap* is experiencing a process of erosion of its resistance to *P. infestans*, although it should also be remembered that different population of the pathogen may also vary.

The population *S. spl* is more resistant to *P. infestans* than *S. cap*. *S. spl* comes from the Lake Titicaca area (3820 m) (in the basin of which *P. infestans* has recently been detected in potatoes [Coca-Morante, 2003]) and has been reported to show non-specific resistance to *P. infestans* (Hawkes and Hjerting, 1989; Ruiz de Galarreta et al., 1998).

The *S. ber* populations from the Cochabamba Valley showed a level of susceptibility similar to that of *S. spl*. Contradictory reports exist, however, regarding its response to *P. infestans*. Hawkes and Hjerting (1989) report it to show good field resistance, Ochoa (1990) indicate it to be very susceptible, Ruiz de Galarreta et al. (1998) indicate that it is partially resistant, and Trognitz et al. (1999) that it is highly resistant with respect to a specific race of *P. infestans*. The control varieties of red *phureja* (*S. phu*) and Waych’a Paceña (*S. adg*) showed susceptibility to *P. infestans*, although to a significantly different degree. The lower susceptibility of some *phurejas* varieties, attributed to the presence of additive genes, is reported by Trognitz et al. (1999) as high resistance (non-specific reaction). These varieties have been traditionally cultivated by farmers despite the severity of *P. infestans* infestations, both in the Sorata microcentre and in other areas of Bolivia.

The difference in the responses of the wild populations in this work compared to those reported by other authors may be explained by variations in the different *P. infestans* populations. In Bolivia, A2 mating and clonal reproduction has been reported for *P. infestans* (Forbes et al., 1998). However, the different *P. infestans* isolates affecting wild potato species have not yet been studied.

**Acknowledgements**

The authors thank the Director of the Laboratorio de la Oficina Regional de Semillas - Jesmy Laredo Espinoza - for the kind cooperation shown during laboratory work. Thanks are also owed to Dr. Robert Hijmans of the International Potato Centre for his help in producing the wild potato distribution map.

**References**


