

Wild potato species threatened by extinction in the Department of La Paz, Bolivia

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Abstract

The Department of La Paz has the largest number of wild potato species (*Solanum* Section *Petota Solanaceae*) in Bolivia, some of which are rare and threatened by extinction. *Solanum achacachense*, *S. candolleanum*, *S. circaeifolium*, *S. okadae*, *S. soestii* and *S. virgultorum* were all searched for in their type localities and new areas. Isolated specimens of *S. achacachense* were found in its type localities, while *S. candolleanum* was found in low density populations. *Solanum circaeifolium* was also found as isolated specimens or in low density populations in its type localities, but also in new areas. *Solanum soestii* and *S. okadae* were found in small, isolated populations. No specimen of *S. virgultorum* was found at all. The majority of the wild species searched for suffered the attack of pathogenic fungi. Interviews with local farmers revealed the main factors negatively affecting these species to be loss of habitat through urbanization and the use of the land for agriculture and forestry. Some 37.8% of those interviewed knew the local uses of the wild potatoes studied.

Additional key words: genetic erosion, locality type, rare species, *Solanum* sp., threatened species.

Resumen

Especies silvestres de papa amenazadas de extinción en el Departamento de La Paz, Bolivia

El Departamento de La Paz posee el mayor número de especies silvestres de papa (*Solanum* Section *Petota Solanaceae*) reportadas para Bolivia. Algunas de estas especies son «raras» y se encuentran amenazadas de extinción. Se realizaron prospecciones y evaluaciones *in situ* de *Solanum achacachense*, *S. candolleanum*, *S. circaeifolium*, *S. okadae*, *S. soestii* y *S. virgultorum*, tanto en sus localidades tipo como en nuevas áreas. En sus localidades «tipo», se registraron individuos aislados de *S. achacachense*; *S. candolleanum* se encuentra en poblaciones de baja densidad; *S. circaeifolium* se registró aisladamente y en poblaciones bajas, pero se registró en nuevas áreas hasta ahora no reportadas; *S. okadae* y *S. soestii* se encuentran en poblaciones bajas y aisladas; y no se encontró ningún espécimen de *S. virgultorum*. La mayoría de las especies silvestres evaluadas se encuentran asociadas con hongos patógenos. Según entrevistas realizadas a los agricultores de la zona, los principales factores que están afectando a las especies silvestres estudiadas son la urbanización rural, la habilitación de tierras para agricultura y plantaciones forestales. El 37,8% de los encuestados conocen los usos locales de las papas silvestres.

Palabras clave adicionales: erosión genética, especies amenazadas, especies raras, localidad tipo, *Solanum* sp.

Introduction

Of the 34 wild species of potato (*Solanum* Section *Petota Solanaceae*) described for Bolivia, between 17 (Hawkes and Hjerting, 1989) and 19 (Ochoa, 1990) are distributed among the different Andean and Interandean microregions (altitude 2,500-4,200 m) of the Dept. of

La Paz. Within this Dept., in the Larecaja Province, *Solanum acaule*, *S. achacachense* Cárdenas, *S. candolleanum* Berthault, *S. circaeifolium* Bitter, *S. flavoviridens*, *S. megistacrolobum*, *S. virgultorum* (Bitter) Cárdenas and Hawkes and *S. yungasense* can all be found, while the Province of Inquisivi is home to *S. acaule*, *S. capsicibaccatum*, *S. circaeifolium*, *S. megistacrolobum* var. *metriophyllum*, *S. okadae* Hawkes and Hjerting and *S. soestii* Hawkes and Hjerting (Ochoa, 1990). *Solanum violaceimarmoratum*

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Bitter can be found in the Province of Nor Yungas, *S. leptophyes* and *S. sparsipilum* Bitter in the Province of Murillo, and *S. bombycinum* Ochoa and *S. neovavilovii* Ochoa in the Province of Franz Tamayo.

In 1946, Martín Cárdenas travelled to Sorata (Prov. Larecaja) with the aim of collecting wild potato species. He described *S. circaeifolium* Bitter and *S. virgultorum* Bitter as rare species since they were very poorly represented in European herbaria (Cárdenas, 1973). Later Ochoa (1990) made several collecting trips to the area of Sorata (1978-1979 and 1983-1984) and concluded it «impossible to find *S. virgultorum* at its original collection site». It may still exist, but it has suffered at the hands of Man who has used it as a food, and it may be threatened with extinction, at least in this area. Hawkes (1994) indicated several wild Bolivian potato species —*S. achacachense*, *S. bombycinum*, *S. circaeifolium*, *S. flavoviridens*, *S. okadae*, *S. soestii* and *S. violaceimarmoratum*— to be rare, while Huamán (1994) reported that, given the genetic erosion suffered by some wild species, the slopes of Inquisivi (home to *S. circaeifolium*, *S. okadae*) should be protected, along with the foothills of the Nevado Illampu (home to *S. candolleianum*) and the Monte de Vallegrande (home to *S. alandiae*, *S. microdontum* and *S. virgultorum*), as natural, *in situ* conservation reserves.

Different authors term wild potato species as «rare» mainly because their geographical distributions are restricted. The distributions of several of these species

are restricted to their original collection site (type locality), or this plus an additional area. Rabinowitz (1981) indicates that a species can become «rare» in several ways, according to its geographical range, the specificity of its habitat, or the size of its local populations. The reported geographical distributions of the known wild species of potatoes have never been extended, and some now appear to be in danger of extinction in their type localities. Such is the case of *S. virgultorum*, reported by Cárdenas (1973) and Ochoa (1990). Coca-Morante *et al.* (2007) indicate that, in the Dept. of La Paz, different factors are drastically modifying the habitats where a number of rare potato species are known to grow, threatening their survival.

The aim of the present work was to determine the degree of genetic erosion of the rare, wild potato species of the Dept. of La Paz, and to identify the main factors associated with this erosion.

Material and Methods

Surveying and collecting

Surveying and collecting was performed between December and April of 2004 and 2005 at sites in the Provinces of Larecaja, Inquisivi, Manco Kápac and Camacho, all of which belong to the Dept. of La Paz (Fig. 1) and potentially offer homes to some of the six,

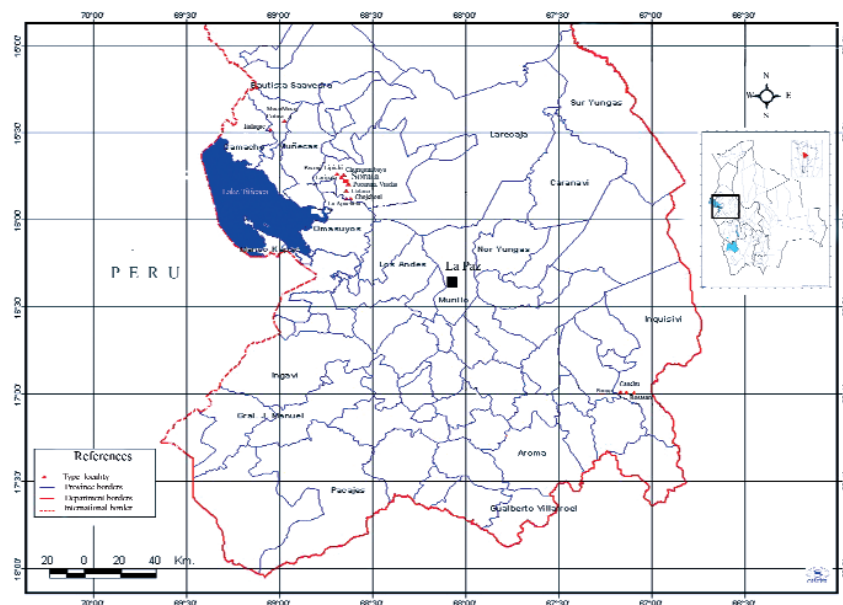


Figure 1. Type localities of rare potato species in the Dept. of LaPaz, and the newly surveyed areas.

rare, wild species of potato in danger of extinction: *S. achacachense*, *S. candolleanum*, *S. circaeifolium*, *S. okadae*, *S. soestii* and *S. virgultorum*. The criteria for geographical range and local population size were those of Rabinowitz (1981). To determine the former, the type localities of the species (as reported by Cárdenas, 1973; Ochoa, 1990; Hawkes, 1994; Huamán, 1994; Table 1) were examined, as well as new sites in the area of influence of these type localities plus ecologically similar areas not surveyed in earlier collecting expeditions (Table 2). At each site the latitude, longitude and altitude was recorded using a Global Positioning System device (GPS 12, GARMIN).

For their inclusion in herbaria, fully developed or developing plants were collected. All samples were identified and preserved in the laboratory. The morphological characteristics were determined using the descriptors provided by Cárdenas (1956) and Ochoa (1990).

In situ assessment of populations

To determine the size of local populations *in situ*, transects of different lengths (metres to kilometres)

were used depending on the topology of the area in question. When a species was found, its location was taken as the «focus» of distribution for the corresponding population assessment. A 100 m² (10 × 10 m) area was outlined around this point and a zigzag path inside the area covered, counting the number of specimens found. Between one and three assessments were made, depending upon the characteristics of the terrain.

An arbitrary scale was adopted for describing the population density of the species (per 100 m²): 0 plants = absent; 1–6 plants = low density; 7–15 plants = intermediate; 16 plants = high density. The type of distribution shown was described as aggregate (when two or more wild potato species were found), random, uniform, or grouped (i.e., groups of the same wild species).

Identification of the biotic and abiotic factors affecting the wild species, and ethnobotany

The most important anthropic activities related to the changes observed in the ecosystems of the type localities, and local knowledge regarding the studied species, were identified in informal interviews of

Table 1. Type localities of the studied rare species in the Dept. of La Paz

| Species | Series | Source ¹ | Type locality ² |
|-------------------------|--------------|-------------------------------|---|
| <i>S. achacachense</i> | Tuberosa | Hawkes (1994) | Prov. Omasuyos, La Apacheta, between Achacachi and Sorata |
| <i>S. candolleanum</i> | Tuberosa | Huamán (1994) | Prov. Larecaja, rocky mountain ranges of Illampu, Lancha de Cochipata, Sorata |
| <i>S. circaeifolium</i> | Circaeifolia | Cárdenas (1973); Ochoa (1990) | Prov. Larecaja, Villa Rosa (Munaypata), Sorata 2,650 m |
| <i>S. okadae</i> | Tuberosa | Hawkes (1994) | Prov. Inquisivi, 0.5 km along the Quime-Inquisivi route (outside Quime) |
| <i>S. soestii</i> | Circaeifolia | Hawkes (1994) | Prov. Inquisivi, 4.5 km along the Quime to Inquisivi route. Rosasani, between Quime and Inquisivi |
| <i>S. virgultorum</i> | Tuberosa | Cárdenas (1973); Ochoa (1990) | Prov. Larecaja, Villa Rosa (Munaypata) Sorata 2,650 m |

¹ Authors indicating that these species are rare or threatened by extinction. ² According to Ochoa (1990).

Table 2. New areas surveyed for the rare wild potato species of the Dept. of La Paz

| Species | Area of influence of type locality | | Potential new areas | |
|-------------------------|------------------------------------|-------------------------------|---------------------|----------------------------------|
| | Province | Site(s) | Province | Site(s) |
| <i>S. achacachense</i> | Larecaja | Umanata, Millipaya | Camacho | Italaque |
| <i>S. candolleanum</i> | Larecaja | Llust'a | Manco Kapac | Copacabana, San Pedro de Tiquina |
| <i>S. circaeifolium</i> | Larecaja | Cotaña, Condorpata, San Pedro | Larecaja | Paconi, Lip'ichi |
| <i>S. okadae</i> | Inquisivi | Pongo | Camacho | Italaque, Moco Moco |
| <i>S. soestii</i> | Inquisivi | Pongo, Ruta Quime-Inquisivi | Camacho | Italaque |
| <i>S. virgultorum</i> | Larecaja | Cotaña, Condorpata, San Pedro | Camacho | Italaque, Moco Moco |

74 farmers seen working during the survey period. The questions asked related to their knowledge of wild potatoes, their local names, and the factors that might be affecting their distribution. For the identification of the biotic factors associated with pathogen-caused leaf damage, leaf samples were taken for the examination of their symptoms and for the cultivation of the pathogen (samples were placed in plastic bags in a damp chamber at 24°C). Using these samples, semi-permanent mounts were made in lactophenol solution, and further cultures of pycnidia-producing pathogens raised on potato dextrose agar (PDA). The latter and *Phytophthora infestans* were identified using the criteria of Sutton and Waterson (1966) and Erwin and Ribeiro (1996) respectively.

Results

Location, density and spatial distribution of the studied species in their type localities and new areas

Table 3 shows the geographical location of the different type localities and the new areas of distribution for the studied species.

— *S. achacachense* was found in its type locality (La Apacheta, Prov. Larecaja), but not in any of the new areas surveyed.

— *S. candolleanum* was found in its type locality (Cochipata) as well as in other areas neighbouring Sorata, but at higher altitudes, e.g., Churiquimbaya (3,456m) and Paconi (3489 m), and at Llust'a (3,950 m) in the foothills of the Nevado Illampu.

— *S. circaeifolium* was found in its type locality (Cerro Iminapi) as well as in other areas neighbouring Sorata (Prov. Larecaja), e.g., San Pedro, Cordorpata and Cotaña (Fig. 2). It was also found in areas away from Sorata, such as Cotusi (Moco Moco, Prov. Camacho), Italaque-río Uyo Uyo (Prov. Camacho), and Canchu-Quime (Prov. Inquisivi).

— *S. okadae* and *S. soestii* were found close to their shared type locality, at Rosasani (Prov. Inquisivi), but not in any of the new areas surveyed.

— *S. virgultorum* was not found at all in its type locality (Munaypata, today's Villa Rosa, Sorata, Prov. Larecaja) (Fig. 3), nor at any other of the sites for which it was surveyed (Exit of the Hotel Prefectural of Sorata, San Pedro, Condorpata and Cotaña).

Differences were seen in the mean densities of the species in their type localities (Fig. 4). *Solanum virgul-*

Table 3. Geographical references for the species studied in their type localities and new areas

| Site | Province | Altitude (m) | Latitude S | Longitude W | Species |
|---------------------------------|-----------|--------------|---------------|---------------|--|
| Chojchoni Alto (Apacheta) | Larecaja | 4,186 | 15° 52' 32.2" | 68° 38' 25.0" | <i>S. achacachense</i> |
| Sorata - Pueblo | Larecaja | 2,664 | 15° 46' 30.4" | 68° 38' 46.3" | <i>S. circaeifolium</i> |
| Sorata - Villa Rosa - Munaypata | Larecaja | 2,664 | 15° 46' 30" | 68° 38' 46" | (<i>S. virgultorum</i>) ¹ |
| Laripata (Cerro Iminapi) | Larecaja | 2,930 | 15° 45' 02.7" | 68° 40' 04.0" | <i>S. circaeifolium</i> |
| Laripata - San Pedro - Sorata | Larecaja | 3,090 | 15° 45' 02.7" | 68° 40' 04.0" | <i>S. circaeifolium</i> |
| Churiquimbaya alto - Sorata | Larecaja | 2,653 | 15° 43' 58.3" | 68° 41' 27.2" | <i>S. candolleanum</i> |
| Cochipata - Sorata | Larecaja | 3,214 | 15° 49' 10.1" | 68° 37' 31.5" | <i>S. circaeifolium</i> |
| Paconi - Lip'ichi - Sorata | Larecaja | 3,489 | 15° 52' 30.7" | 68° 37' 04.5" | <i>S. candolleanum</i> |
| Pucarani - Sorata | Larecaja | 3,456 | 15° 44' 27.3" | 68° 39' 07.9" | <i>S. circaeifolium</i> |
| Viacha - Sorata | Larecaja | 3,040 | 15° 47' 37.3" | 68° 38' 00.6" | <i>S. circaeifolium</i> |
| Cotaña (cerro) - Sorata | Larecaja | 3,168 | 15° 47' 35.8" | 68° 37' 44.3" | <i>S. circaeifolium</i> |
| Condorpata - Sorata | Larecaja | 3,266 | 15° 49' 41.1" | 68° 38' 27.1" | <i>S. circaeifolium</i> |
| Italaque - Río Uyo Uyo | Camacho | 2,750 | 15° 28' 48.5" | 69° 02' 54.4" | <i>S. circaeifolium</i> |
| Mocomoco - Cotusi | Camacho | 2,563 | 15° 25' 52.5" | 68° 58' 27.7" | <i>S. circaeifolium</i> |
| Pongo - Quime | Inquisivi | 2,780 | 16° 59' | 67° 16' | <i>S. okadae</i> |
| Quime (Pueblo) | Inquisivi | 2,750 | 16° 59' | 67° 16' | <i>S. okadae</i> |
| Rosasani - Quime | Inquisivi | 2,720 | 16° 57' | 67° 44' | <i>S. okadae</i> |
| Rosasani - Quime | Inquisivi | 2,720 | 16° 57' | 67° 44' | <i>S. soestii</i> |
| Canchu - Quime | Inquisivi | 2,710 | 16° 57' | 67° 44' | <i>S. circaeifolium</i> |
| Inquisivi (camino a Quime) | Inquisivi | 2,680 | 16° 59' | 67° 10' | <i>S. okadae</i> |
| Inquisivi (camino a Quime) | Inquisivi | 2,680 | 16° 59' | 67° 10' | <i>S. soestii</i> |

¹ Species not found.



Figure 2. Cotaña, near Sorata (Prov. Larecaja), a new area of distribution for *S. circaeifolium*.

virgultorum was absent, the populations of *S. achacachense*, *S. candolleanum* and *S. soestii* were of low density, and those of *S. circaeifolium* and *S. okadae* intermediate (10-12 specimens/100 m²).

In the newly surveyed areas, *S. circaeifolium* had the widest distribution (Fig. 5). Its population densities ranged from low (Canchu-Quime = 1.6) to intermediate (Cotaña-Sorata and Italaque-Uyo Uyo = 8.4).

In its type locality the spatial distribution of *S. achacachense* was completely random; specimens were found isolated in inaccessible places, sometimes next to *S. acaule*.

In its type locality [the foothills of the Nevado Illampu (Llust'a), in the community of Cochipata], the distribution of *S. candolleanum* was random and isolated. It was also found in the area of Sorata, but at damp altitudes of over 3,000 m, where it was found isolated and its distribution random; it grew alongside no other wild potato species.



Figure 3. Sorata (Prov. Larecaja, La Paz), the type locality of *S. virgultorum*. Yellow line: Munaypata (Villa Rosa). White circle: exit to the Hotel Prefectural.

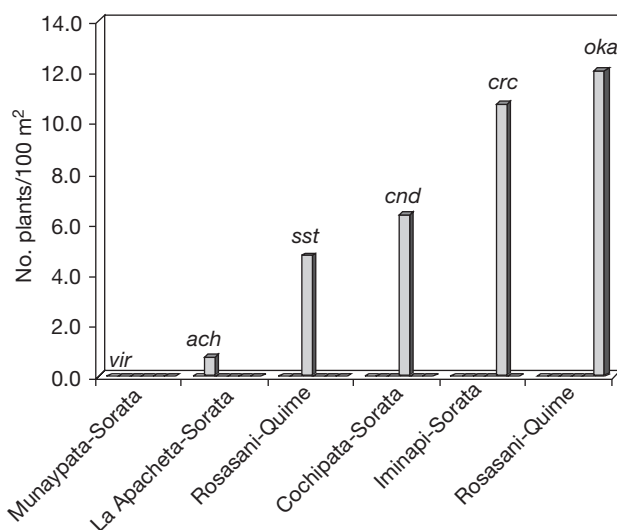


Figure 4. Population densities of the studied species in their type localities: *S. achacachense* (ach), *S. candolleanum* (cnd), *S. circaeifolium* (crc), *S. okadae* (oka), *S. soestii* (sst) and *S. virgultorum* (vir).

In its type locality (Cerro Iminapi), *S. circaeifolium* showed a grouped distribution. It was found growing only amongst the vegetation making up the divisions between lots of cultivated land. In the new areas surveyed its distribution was completely random; it was never found growing alongside any other wild potato species. In the Quime-Inquisivi type locality for

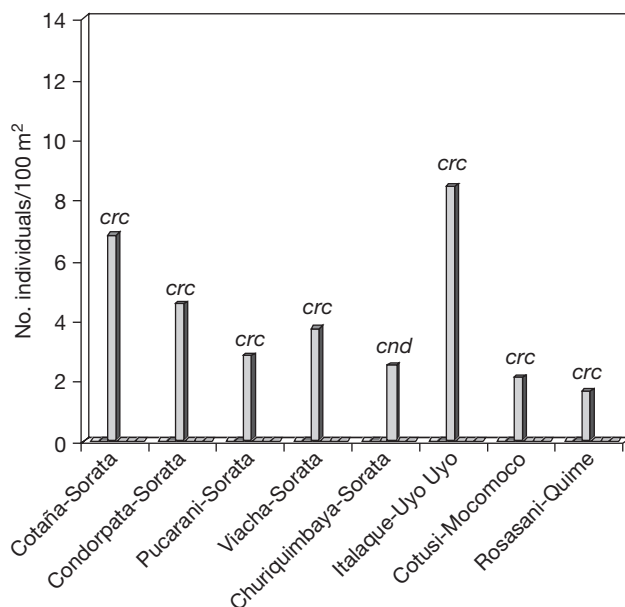


Figure 5. Population densities of the studied species in the newly surveyed areas in the Dept. of La Paz, Bolivia: *S. candolleanum* (cnd) and *S. circaeifolium* (crc).

S. okadae and *S. soestii*, *S. circaefolium*, *S. okadae* and *S. soestii* showed completely random distributions but did not grow alongside one another. *Solanum soestii* was sometimes associated with *S. brevicaulis*.

Taxonomic and morphological descriptions

A variable number of specimens of each species (from their type localities and newly surveyed areas) were collected for inclusion in herbaria: two specimens of *S. achacachense* and *S. candolleanum*, six of *S. circaefolium*, *S. okadae* and *S. soestii*, and none for *S. virgultorum*.

— *S. circaefolium* and *S. soestii* are members of the series *Circaeifolia*, and to date are only known in Bolivia (Ochoa, 1990).

- Ochoa (1990) used the dissection and the glabrescence of the leaf as key points in the characterization of *S. circaefolium*; the same criteria were used to identify the present samples. In general, foliolar pubescence was seen in the samples from Sorata (Prov. Larecaja), while no pubescence was seen in the samples from Italaque (Prov. Camacho). The size of the plants was variable; those from Sorata were generally much bigger (45-65 cm) than those from Italaque (15-35 cm) and Canchu-Quime (15-25 cm).

- *S. soestii* showed imparipinnate leaflets that were glabrescent and narrowly lanceolate. Its flowers were creamy white and star-shaped. It was found in disturbed habitats, growing to a height of 15-35 cm.

— *S. achacachense*, *S. candolleanum* and *S. okadae*. These species belong to the series *Tuberosa* (Ochoa, 1990) but show clearly distinguishable morphological characteristics.

- *S. achacachense*, in its natural habitat, is small (10-15 cm) and subrosetted with an erect, visible stem with sparse hairs. However, in modified habitats (generally prepared for crops), it becomes much taller, the leaves are more developed, and the tubers and stolons larger (in fact they resemble those of cultivated plants). During initial development, the underside of the basal leaflets is normally pigmented lilac or diffuse lilac.

- *S. candolleanum*, in its natural habitat, is an erect, robust plant that normally reaches the size of cultivated plants (50-60 cm). Its stems are simple, thick, and widely winged.

- *S. okadae*, in its natural habitat, is small (10-25 cm), has sparse hairs on the leaflets narrow wings, and short, wide imparipinnate leaves (also with sparse hairs). The terminal leaflet is bigger and wider (elliptic, lanceolate). Its flowers are white.

Factors affecting the distribution of the wild populations in their type localities, and ethnobotany

According to the local farmers, three important factors affect the distribution of the populations of the studied species in their type localities: the urbanisation of agricultural areas, the preparation of new land for agriculture, and the planting of forests (especially of *Eucalyptus* sp.) (Fig. 6). In the type locality of *S. virgultorum* (Fig. 3), the agricultural land has become both strongly urbanised and forested. In the types area of *S. achacachense* the land has been largely turned over to agricultural use, mainly the cultivation of the local phurejas potatoes¹. In the type locality of *S. circaefolium*, the land has been completely given over to agricultural use, housing and plantations of *Eucalyptus* sp. *Solanum candolleanum* is mainly affected by land being turned over to agriculture, and is becoming reduced to ever more inaccessible areas. With respect to *S. soestii* and *S. okadae*, the main problem is the use of the land for forestry (*Eucalyptus* sp.).

Some 98.6% of the farmers from the different type localities and newly surveyed areas knew the names of the different wild potatoes and were able to distinguish them. These potatoes receive a number of common names, mainly in the Aymara language, such as *achachil*

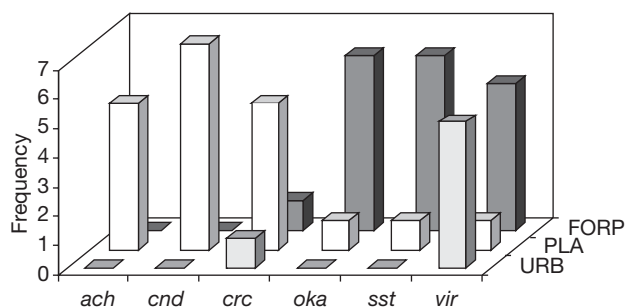


Figure 6. Main factors affecting the distribution of the studied species in their type localities: *S. achacachense* (*ach*), *S. candolleanum* (*cnd*), *S. circaefolium* (*crc*), *S. okadae* (*oka*), *S. soestii* (*sst*) and *S. virgultorum* (*vir*). URB: urbanisation. PLA: preparation of land for agriculture. FORP: forest plantations.

¹ Native varieties of *Solanum phureja*.

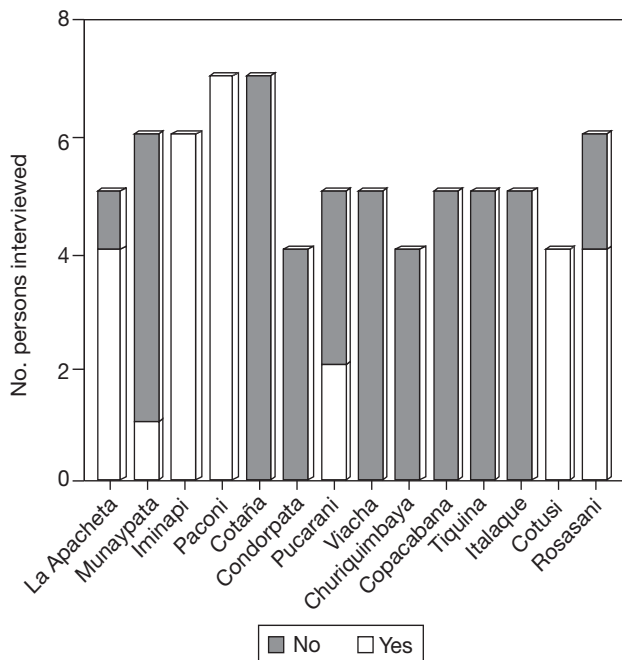


Figure 7. Knowledge of local use of wild potato species in their type localities and new areas.

ch'ogue (old potato), *monte ch'ogue* (mountain woodland potato), *monte phureja* (mountain woodland phureja potato) or *apharu ch'ogue* (non-edible potato). The first three of these common names are the most used in the area of influence of Sorata (Prov. Larecaja): *achachil ch'ogue* for *S. achacachense*, *monte ch'ogue* for *S. circaefolium* and *monte phureja* for *S. candolleanum*. For *S. circaefolium*, *monte ch'ogue* is the most used in the area of influence of Quime (Prov. Inquisivi). *Apharu ch'ogue* is used for *S. acaule* in the area of influence of Copacabana and on the Altiplano in general. Wild potatoes are generally used for their leaves, which are fed to different types of livestock (Fig. 7). Some 37.8% of the farmers indicated they knew of local uses for wild potatoes.



Figure 8. Leaflets of *S. soestii* affected by *Septoria lycopersici*.

Pathogenic fungi affecting the studied species

In situ, the leaves of five of the studied species were affected by fungal pathogens, *S. circaefolium* by the greatest number (*P. infestans*, *Erysiphe* sp. and *Globodera* sp.), and *S. achacachense* only by *P. infestans*. The latter pathogen also affected *S. achacachense*, *S. circaefolium*, *S. candolleanum* and *S. okadae*. The disease known as leaf powdery mildew caused by *Erysiphe* sp. strongly affected *S. circaefolium*, *S. okadae* and *S. soestii*. In agreement with its morphological and morphometric characteristics, the leaf staining seen in *S. soestii* specimens (Fig. 8) was caused by *Septoria lycopersici* Speg (Table 4).

Discussion

Solanum achacachense

In its type locality, La Apacheta (Prov. Larecaja), this species was found in low density populations

Table 4. Morphological and morphometric characteristics of fungus structure on leaves of *Solanum soestii*. Rosasani - Quime - Inquisivi, Dept. of La Paz

| Morph. characteristic | Sutton and Waterson (1966) | | Observed (2005) | |
|-----------------------|----------------------------|-----------|----------------------|----------|
| | Pycnidium | Conidium | Pycnidium | Conidium |
| Colour | Yellow to coffee | Hyaline | Clear coffee | Hyaline |
| Size (µm) | 75-200 | 2 × 52-95 | 150.65 | 73.08 |
| Shape | Globose ¹ | Filiform | Globose ¹ | Filiform |
| Septa | — | 2-6 | — | 12.8 |

¹ According to Barnett and Hunter (1998).

randomly distributed in areas of difficult access. Cárdenas (1956) mentions the collection of this species in February of 1946 along the highest part (recorded as 4,000 m) of the route between Achacachi and Sorata (Prov. Omasuyos). According to Ochoa (1990), this route, also said to be known as La Apacheta (recorded as 4,050 m), has several kilometres of grassy fields, and lies on the western side of the Nevado Illampu (6,424 m). The present work confirms that La Apacheta (here recorded at 4,186 m) covers an area of several square kilometres after the high area known as Las Antenas, which forms the boundary between the Provinces of Omasuyos and Larecaja. Here the native vegetation, such as *Stipa ichu*, is little developed for a distance of some 10 km until the area known as Humanata (3,350 m) is reached. According to the current political map of Bolivia, La Apacheta belongs to the community of Chojchoni in the Millipaya Canton. Ochoa (1990) found no other tuberiferous species in this area. However, the present results show that *S. achacachense* in some places grows alongside and shares the distribution of *S. acaule*. Similarly *S. achacachense* can sometimes be found in low density populations in cultivated land used to raise *S. phureja* and *S. tuberosum* subsp. *andigena*, and oca (*Oxalis tuberosa*), etc., although it is usually eliminated as a weed. Its leaves are also fed to grazing livestock.

Cárdenas (1956) described the underside of the young leaves of *S. achacachense* to be dark lilac in colour; a feature confirmed in the present work. However, this is mentioned neither by Hawkes and Hjerting (1989) nor Ochoa (1990). The species is known to farmers as *achachil ch'ogue*. It is confirmed that it suffers problems with *P. infestans*.

According to Ochoa (1990) and Hawkes (1994), the distribution of *S. achacachense* is limited to its type locality – this is confirmed by the present results. No specimens were seen in the neighbouring and newly surveyed areas of Umanata and Millipaya, nor at the new latitudes surveyed. Where it does grow wild it is rare and at extreme risk of extinction. This is probably a consequence of turning land over to agriculture.

Solanum candolleianum

Mandon (1858) made the first collection of this species at Lancha de Cochipata, which is considered to be its

type locality (Hawkes and Hjerting, 1989; Ochoa, 1990). At Cochipata, in the high area of Sorata, isolated specimens were found, although they were in poor condition for adding to herbaria [a problem of the time of the year and late blight infection² (*P. infestans*)]. The species was also found in other places such as Llust'a (3,850 m), Paconi (3,459 m) and Churiquimbaya (2,653 m), in the foothills of the Nevado Illampu (6,424 m); it therefore has a wider distribution than originally believed. In these new areas its distribution was random and isolated, or it was found growing on steep mountains of difficult access. It is under threat from the constant turning over of land to agriculture. In areas of difficult access the foliage is used to feed livestock such as sheep. In some places, e.g., Paconi, the populations of this species are strongly affected by late blight (*P. infestans*) and known to local farmers as *monte ch'ogue*.

Solanum circaeifolium

This species is currently found in its type locality (Cerro Iminapi), although its populations are of low density. It is randomly distributed along field borders and under shrubs. In 1946, Cárdenas (1973) reported *S. circaeifolium* in the type locality of Monte Iminapi. «Monte» refers to the then mountain woodland character of the area, but this description does not match that of the current «Cerro» Iminapi. Rather than mountain woodland, the area is a slope practically naked of all its original vegetation, which has been divided up for agricultural use. It is now also the site of a village. The natural vegetation is reduced to shrubby remnants at the borders between fields, where this species can still be found. However, the present study shows *S. circaeifolium* to have a wider range within the Dept. of La Paz, including areas not cited by Cárdenas (1973), Hawkes and Hjerting (1989), Ochoa, (1990) or Spooner *et al.* (1994). The area of influence of Sorata, includes villages on the western side of the Nevado Illampu such as Condorpata, Viacha and Cotaña, where this species can be found. This suggests that the original plants were endemic to Sorata. Ochoa (1990) indicates that thirty years ago the Cerro Iminapi was almost completely covered by natural, bushy and tree vegetation (the name *monte ch'ogue* reflects this condition); but today this can only be seen towards the

² Known to farmers as Llejte, an Aymaran word meaning «burnt».

summit of the slope. A few remains of the natural vegetation are also to be found in the borders between lots completely given over to agriculture. The slope is now also home to planted *Eucalyptus* and is undergoing urbanisation. The finding of the species in other areas such as Italaque-Uyo Uyo and Cotusi-Moco Moco (Prov. Camacho) (the northwest of Sorata), and in the area of influence of Canchu-Quime (Prov. Inquisivi), shows how wide its distribution may be. According to Ochoa (1990), in the Inquisivi province this species was collected in the village of Circuata (3,820 m). It was not found there in the present work, but was recorded at the new site of Canchu-Quime, which lies about 2 km from Quime. In general, the populations of this species in these new areas are low in density. Slight differences were seen in the specimens collected from the type localities and the new areas, such as pubescence on the leaflet surface at the former sites. Ochoa (1990) also indicated samples from the type locality to have somewhat pubescent leaf surfaces. The samples from Italaque, however, were completely glabrescent, which agrees with the observations of Spooner *et al.* (1994). The latter authors indicated variations in the degree of pubescence. This species was found suffering from several fungal pathogens, including *P. infestans* and *Erysiphe* sp. It is also known as *monte ch'ogue* by local farmers.

Solanum okadae and *Solanum soestii*

These two species are found between Quime and Inquisivi (Hawkes and Hjerting, 1989; Ochoa, 1990). In 1981 they were collected by Hawkes, Aviles and Hoopes some 0.5 km along the Quime-Inquisivi road (Ochoa, 1990). Similarly, Hawkes and Hjerting (1989) collected them between 0.5 km and 14 km from Quime on the route to Inquisivi. In the present study, specimens of *S. okadae* were collected at the village of Pongo (2,810 m) among natural vegetation [about 15 km from Quime (2,750 m)] at the exit from Quime (on the plain boarding the track), and at about 8 km along the Quime-Inquisivi route before reaching Rosasani (2,720 m) (again among the natural vegetation). This suggests that its widest original distribution must have lain between these altitudes and Inquisivi. Its population density was intermediate, suggesting that it might be endemic to the area of influence of Quime. Under natural conditions the plants grew to 10-15 cm in height; some isolated specimens were in flower. All over the area of influence of Quime, *Eucalyptus* plantations now form the dominant

vegetation; forestry is therefore one of the most important occupations, in fact more important than agriculture or stock raising. The effects these plantations have had on the natural vegetation are obvious; no specimens of *S. okadae* were found in any areas where *Eucalyptus* had been planted. Under natural conditions this species is affected mainly by late blight (*P. infestans*).

Solanum soestii was collected only at Rosasani (2,680 m) (on the Quime-Inquisivi route), approximately 2 km from Quime, both in disturbed areas and areas with natural vegetation; it therefore appears restricted to its type locality. In March 1981, Hawkes, Aviles and Hoopes (Hawkes and Hjerting, 1989) collected holotypes 4.5 km from Quime on the route to Inquisivi. Ochoa (1990) collected samples near Rosasani (2,750 m), in an open area near the edge of a shrub-wood. The mean population density recorded in the present work was low. Indeed the species was always very scarce, being found along the edge of the route which it shared with *S. brevicaulis*. The plants recorded were of medium height and had well dissected leaflets, creamy-white flowers, and star-shaped corollas. The species was drastically affected by the pathogens *Septoria lycopersici* and *Erysiphe* sp. Forest plantations (mainly *Eucalyptus*) appear to be affecting the distribution of the natural vegetation in this area, including the wild potato species. The species was hardly seen at all where these plantations dominated.

Solanum virgultorum

Solanum virgultorum (Bitter) Cárdenas and Hawkes was collected in 1864 by Mandon at Munaypata (today's Villa Rosa), near Sorata (Cardenas, 1973). Ochoa (1990) indicated the type localities for this species to be Villa Rosa, Ilabaya (some 10 km from Sorata on the track to Achacachi) and Tacacoma. In the present work, even though diligent searches were made at Villa Rosa and Ilabaya, not a single specimen was found. Between 1978 and 1979, Ochoa (1990), in one of this author's most extensive expeditions in Bolivia (which included the Sorata Valley), was unable to find *S. virgultorum* either, and reported it to be under threat of extinction. The description of this species provided by this author refers to that of sample N° 399 collected by Mandon. Similarly, Cárdenas (1973), in a collecting trip undertaken in 1946, indicated *S. virgultorum* to be «rare»; this author reported a specimen just outside the Hotel Prefectural (Sorata) in the direction of La Paz.

The taxonomic descriptions of this species provided by Bitter (1913), Cárdenas and Hawkes (1945), Hawkes and Hjerting (1989), and Ochoa (1990), are based on the collection of Mandon (1860) from Munaypata-Sorata, close to Cerro Coromi (Hawkes and Hjerting, 1989). However, according to Hawkes and Hjerting (1989), no «Coromi» range of mountains exists on any map; neither is it known at the popular level. In the present study, it was certainly unknown to the people of Villa Rosa. Ochoa (1990) reported not a single specimen from a considerable area of the community of Munaypata (today's Villa Rosa). In the present study, no specimens were found here or in its area of influence towards the Cerro de San Pedro (northeast of Villa Rosa), at Condorpata towards the foothills of the Nevado Illampu, the area of the Hotel Prefectural of Sorata, or along the River Sorata. Referring to this species, Cárdenas (1973) indicated that in his 1946 voyage a specimen of this «*even rarer species was bumped into just outside the Hotel Prefectural (Sorata) in the direction of La Paz*». Some 125 years ago, Mandon found *S. virgultorum* between bushes and natural vegetation at Munaypata (Villa Rosa). It may still exist, but it is clear that it has suffered at the hands of Man who has used it for food, at least in its type locality where it could be extinct (Ochoa, 1990). Nowadays much of the area of Villa Rosa has been given over to *Eucalyptus* plantations and agricultural land, although it is possible to find some natural vegetation alongside rural tracks. The farmers of the area themselves indicate that there are no more wild potatoes (*monte ch'ogue*) in the area.

In conclusion, *S. achacachense*, *S. virgultorum*, *S. soestii* and *S. okadae*, are rare species threatened with extinction in their type localities. *Solanum candolleianum* and *S. circaeifolium* are also threatened in type localities, but in this work were found in new areas.

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