

Distribution of wild potato species in the north of the Department of La Paz, Bolivia

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Abstract

From 2001 to 2003, field collections of wild potatoes (*Solanum* Section *Petota* Solanaceae) were made in the north of the Department of La Paz, Bolivia, with the aim of determining their current distribution in this region. The collection embraced sectors of five provinces: Omasuyos, Larecaja, Camacho, Muñecas and Bautista Saavedra. Five previously described wild species were collected: *Solanum acaule* Bitter, *S. achacachense* Cárdenas, *S. brevicaule* (Bitter) Juz and Buk, *S. candolleanum* Berthault and *S. circaeifolium* Bitter, as well as four unidentified species. Some wild potato species in Bolivia, such as *S. achacachense*, are rare and in danger of extinction because of the destruction of their habitat. In contrast, *S. brevicaule*, *S. candolleanum* and *S. circaeifolium* were recorded in new areas. Some species were affected by pests (*Premnotrypes* sp.) or the fungus *Phytophthora infestans*. This is the first time that 'Lelekoyas' potatoes (*S. tuberosum* subsp. *andigena*) have been detected in the area of influence of Lake Titicaca. In summary, this work reports degrees of genetic erosion for some species, the finding of taxa in new geographical areas, some probable new species, and the presence of *P. infestans* in some of the species detected.

Additional key words: danger of extinction, *Phytophthora infestans*, rare wild species, *Solanum* spp.

Resumen

Distribución de especies silvestres de papa en el norte del Departamento de La Paz, Bolivia

Entre los años 2001 y 2003 se realizaron recolecciones de las principales especies silvestres de papa (*Solanum* Section *Petota* Solanaceae) en el norte del Departamento de La Paz, Bolivia, con el objetivo de conocer de su distribución en esta región. La recolección abarcó sectores de cinco provincias: Omasuyos, Larecaja, Camacho, Muñecas y Bautista Saavedra, y se recolectaron cinco especies silvestres ya descritas (*Solanum acaule* Bitter, *S. achacachense* Cárdenas, *S. brevicaule* (Bitter) Juz and Buk, *S. candolleanum* Berthault y *S. circaeifolium* Bitter) y cuatro especies no identificadas. Algunas especies silvestres de papa en Bolivia, como *S. achacachense*, son raras y se encuentran amenazadas de extinción por la destrucción de su hábitat. En cambio, se registraron nuevas zonas con presencia de *S. brevicaule*, *S. candolleanum* y *S. circaeifolium*. Algunas especies se encuentran afectadas por plagas (*Premnotrypes* sp.) y por patógenos como *Phytophthora infestans*. Es la primera vez que se registran papas 'Lelekoyas' (*S. tuberosum* subsp. *andigena*, una especie primitiva) en el área de influencia del Lago Titicaca. Se evidencian grados de erosión genética, distribución en nuevas áreas geográficas, probables nuevas especies y presencia de *P. infestans* en algunas especies.

Palabras clave adicionales: erosión genética, especies silvestres raras, peligro de extinción, *Phytophthora infestans*, *Solanum* sp.

Introduction

Bolivia is home to 36 of the 196 known species of wild potato (*Solanum* Section *Petota* Solanaceae); only in Peru are more species found (Hijmans *et al.*, 2002). The collection of wild potato species in Bolivia goes back to 1851. Between this date and 1861, Gilbert

Mandon collected the plants—including wild potato plants— of the Sorata Valley in the Dept. of La Paz (Cárdenas, 1973). Later, several explorer-botanists, among the most important of whom were Cárdenas (1966), Ochoa (1990), Spooner *et al.* (1994) and Hawkes (1997), made collections of wild and cultivated potatoes.

Two monographs exist on the taxonomy of wild potatoes in Bolivia, that of Hawkes and Hjerting (1989) and that of Ochoa (1990). Some time later, Spooner and Hijmans (2001) reported taxonomic modifications.

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Both works describe 36 species of potato for Bolivia, although they differ in their descriptions of subspecies and varieties. Between 17 and 19 species (and their variants) are found in the Dept. of La Paz, all of which are represented in potato germplasm collections.

Hawkes (1994) indicated some of Bolivia's wild potato species (*S. achacachense*, *S. bombycinum*, *S. circaeifolium* ssp. *circaeifolium*, *S. flavoviridens*, *S. okadae*, *S. soestii* and *S. violaceimamorum*) to be rare¹, and some to be threatened by extinction because of the destruction of their habitat. In addition, Ochoa (1990) reported *S. virgultorum* to be facing extinction in its type locality². These wild species are mainly found in the north of the Dept. of La Paz, where actions over the last few decades designed to achieve rural development, along with other anthropic influences, have led to environmental degradation. The conservation of wild species *in situ* is important to the food security and economies of different countries worldwide, and certainly, wild potatoes play an important role as sources of resistance to pathogens (Cárdenas, 1966).

Late blight of potatoes³, caused by *Phytophthora infestans*, is a disease of world importance, mainly in the temperate to temperate-cold regions (Erwin and Ribeiro, 1996). In the provinces to the north of La Paz, late blight is a common disease in the Interandean valleys (altitude 2,000-3,600 m) and occasionally in areas of higher altitude (3,600-4,500 m).

The aim of the present work was to determine the current *in situ* distribution of wild potato species in the north of the Dept. of La Paz, and to look for signs of the presence of *P. infestans* in these species.

Material and Methods

Between January and March (the time of flowering and fruiting in potato species) of 2001, 2002, and 2003, a number of expeditions were made to the type localities of the wild potato species of different provinces belonging to the north of the Dept. of La Paz (Fig. 1). These provinces were:

— Omasuyos. Two areas were contemplated, a) the shores of Lake Titicaca (altitude 3,820 m), between the communities of Ajllata Grande and Santiago de Huata to the highlands of Cruz Pata (4,000 m), and b) towards

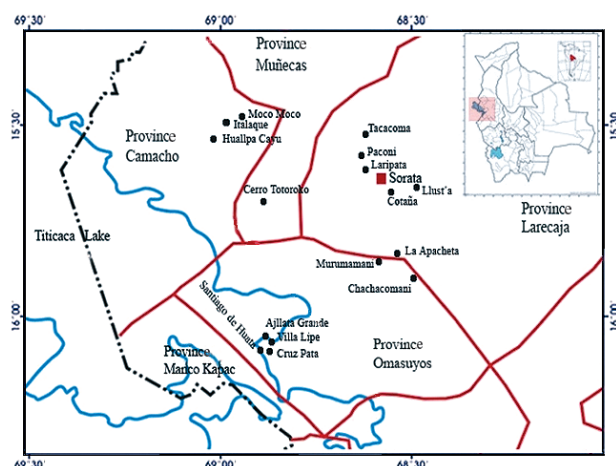


Figure 1. Geographical locations of the areas where the distribution of wild potatoes was investigated. Black dots correspond to study sites, the dashed line to the frontier with Peru, the light blue line to the edge of lake Titicaca, and the red lines to the boundaries of the provinces in the Dept. of La Paz.

the Cordillera Real de La Paz, the mountain ranges of the communities of Murumamani (4,200-4,400 m) and Chachacomani (4,250 m).

— Larecaja. Towards the Cordillera Real (Nevado Illampu, 6,424 m), including the highlands of Chojchoni – Millipaya (3,200-4,100 m), the Valley of Sorata (2,650 m) (including the village of Sorata), the communities of Cotaña and Cerro Iminapi-Laripata, the foothills of the Nevado Illampu (Llust'a sector), and the village of Tacacoma (3,050 m).

— Camacho. Including the highlands of Huallpa Cayu (4,300 m), the village of Italaque (3,150 m), and Timusi in the Valley of Moco Moco (2,600 m).

— Muñecas. Including the highlands of Cerro Totoro (4,350 m) and the area of influence of Timusi.

— Bautista Saavedra. Including the areas of influence of the settlements of Charazani (3,050 m) and Chulina (3,250 m).

In each province, collection expeditions were made to the type localities reported by Cárdenas (1973), Hawkes and Hjerting (1989) and Ochoa (1990), and to new sectors, generally those suggested by local farmers. The altitude, longitude and latitude of each collection point was recorded with the aid of a Global Positioning System receptor (GPS 12, GARMIN). Characteristic specimens of each species at each stage of flowering

¹ Species with a restricted geographical distribution according to Ochoa (1990) and Hawkes and Hjerting (1989).

² The site of original collection according to Ochoa (1990).

³ Known to farmers as Llejte, an Aymaran word meaning «burnt».

were collected. Their characterisation and morphological description were undertaken following the descriptors of Ochoa (1990). Whenever signs of *P. infestans* infection were noted, leaflet or stem samples were taken for laboratory analysis as described by Erwin and Ribeiro (1996).

Results

Between three and five samples of typical plants of the species *S. acaule* Bitter, *S. achacachense* Cárdenas, *S. brevicaule* (Bitter) Juz and Buk, *S. candolleanum* Berthault, and *S. circaeifolium* Bitter were collected at each site where they were found in the different provinces, along with three samples of each of the four undescribed species (Table 1).

— Province of Omasuyos. The most common species in the area of influence of the shores of Lake Titicaca and the communities of Ajllata Grande and Santiago

de Huata was *S. brevicaule*⁴. In these areas, this species was found towards the slopes, between stone walls, species of cactus and native vegetation. Isolated samples of *S. acaule*⁵ were also recorded, as well as 'Lelekoyas' plants, which, according to Cárdenas (1973), correspond to a primitive form of *S. tuberosum* subsp. *andigena*. *S. acaule* was found in the highlands of the community of Cruz Pata; isolated specimens of a taxon that might represent a new species were also found. Towards the Cordillera Real de La Paz (close to Nevado Illampu), in the communities of Murumamani and Chachacomani, plants of *S. acaule* were collected, quite often affected by the Andean potato weevil (*Premnotrypes* sp.).

— Province of Larecaja. *S. achacachense*⁶, and rarely *S. acaule* were found distributed towards the Cordillera Real (Nevado Illampu), at certain sites along the track between Achacachi and Sorata in the community of Chojchoni Alto in the «La Apacheta» area. In the Valley of Sorata *S. circaeifolium*⁷ was the main species, although its distribution was dispersed. In

Table 1. Wild potato species collected in the different provinces of the north of the Dept. of La Paz, Bolivia

Province	Locality	Altitude ¹ (m)	Latitude S	Longitude W	Species
Omasuyos	Murumamani	4,290	15° 52' 55.4"	68° 40' 26.5"	<i>S. acaule</i>
	Chachacomani	4,050	15° 58' 22.6"	68° 28' 14.3"	<i>S. acaule</i>
	Cruz Pata	3,950	16° 04' 31.1"	68° 43' 33.3"	<i>S. acaule</i>
	Villa Lipe-Santiago de Huata	3,950	16° 03' 0.6"	68° 40' 0.3"	NN-1 ²
	Ajllata Grande	3,845	16° 03' 12.0"	68° 40' 01.0"	<i>S. brevicaule</i>
	Santiago de Huata	3,887	16° 04' 29.6"	68° 42' 0.0"	<i>S. brevicaule</i>
Larecaja	Chojchoni (La Apacheta)	4,186	15° 52' 32.2"	68° 38' 32.2"	<i>S. acaule</i>
	Chojchoni (La Apacheta)	4,186	15° 52' 32.2"	68° 38' 32.2"	<i>S. achacachense</i>
	Chojchoni (La Apacheta)	4,186	15° 52' 32.2"	68° 38' 32.2"	NN-2 ²
	Chojchoni (La Apacheta)	4,186	15° 52' 32.2"	68° 38' 32.2"	NN-3 ²
	Laripata (Cerro Iminapi)	3,099	15° 45' 02.7"	68° 40' 04.0"	<i>S. circaeifolium</i>
	Cotaña	3,168	15° 47' 35.8"	68° 38' 44.3"	<i>S. circaeifolium</i>
	Sorata (village)	2,664	15° 46' 30.4"	68° 38' 25.0"	<i>S. circaeifolium</i>
	Paconi	3,489	15° 52' 30.7"	68° 37' 04.5"	<i>S. candolleanum</i>
	Foothills of Illampu (Llust'a)	3,855	15° 56' 11.4"	68° 35' 12.5"	<i>S. candolleanum</i>
	Tacacoma (cemetery)	3,150	15° 48' 03.5"	68° 48' 31.1"	<i>S. candolleanum</i>
Muñecas	Cerro Totoroko-Timusi	4,113	15° 43' 45.2"	68° 54' 33.8"	<i>S. acaule</i> (dark lilac flower)
	Cerro Totoroko-Timusi	4,113	15° 43' 45.2"	68° 54' 33.8"	<i>S. acaule</i> (light lilac flower)
Camacho	Huallpa Cayu	4,215	15° 30' 21.0"	69° 08' 21.2"	<i>S. acaule</i>
	Italaque (Rio Uyo Uyo)	3,677	15° 28' 48.5"	69° 02' 54.4"	<i>S. circaeifolium</i>
	Italaque (Rio Uyo Uyo)	3,677	15° 28' 48.5"	69° 02' 54.4"	NN-4 ³
	Moco Moco (Cotusi)	2,966	15° 25' 52.5"	68° 58' 27.7"	<i>S. circaeifolium</i>

¹ Metres above mean sea level. ² Unidentified species. ³ Unidentified species not undergoing characterisation due to lack of samples.

⁴ Known to farmers as «Jamach'i Ch'ogue», an Aymaran word meaning «bird food».

⁵ Known to farmers as «Apharu Ch'ogue», an Aymaran word meaning «inedible potato».

⁶ Known to farmers as «Achachil Ch'ogue», an Aymaran word meaning «old potato».

⁷ Known to farmers as «Monte Ch'ogue», an Aymaran word meaning «country potato».

Table 2. Characteristics of potentially new wild species

Characteristics	NN-1	NN-2	NN-3
Collection area	Villa Lipe-Santiago de Huata	La Apacheta	La Apacheta - ENTEL
Growth habit	Simple	Simple	Sub-rosetted
Stem	Erect	Erect	Erect
Leaf	Imparipinnate, pubescent	Heart-shaped with pigmented underside	Glabrescent, elliptic, simple
Shape of flower	Rotaceous	Pentagonal	Stellate
Colour of flower	Not observed	Violet - purple	Purple

areas close to this valley (the area of the Hotel Prefectural and neighbouring area) this species was very rare. Approximately 10 km along the track from Sorata to Millipaya this species was found at Cotaña⁸ – a site not reported by Hawkes and Hjerting (1989) or Ochoa (1990). Here, it grows on the high parts of the Cerro Cotaña, between stones and under the protection of bushes; its population density is high. Some plants show prostrate growth (aerial stem length 85 cm). Towards the foothills of the Nevado Illampu (a sector known as Llust'a), and at certain sites on the track towards Tacacoma (Sorata-Laripata-Tacacoma) in a sector of the community of Paconi (approximately 4,012 m), *S. candolleianum* was found, as were isolated specimens in the Tacacoma cemetery. 'Lelekoyas' potatoes were also recorded in the Cerro Iminapi sector.

— Province of Camacho. Specimens of *S. acaule* were collected in the highlands of the community of Huallpa Cayu (4,300 m). At the entrance the village of Italaque (on the slopes close to the river), specimens of *S. circaeifolium* were collected, as well as those of a potentially new species; *S. circaeifolium* was also collected in the Valley of Moco Moco (2,550 m) (community of Cotusi).

— Province of Muñecas. Specimens of two populations of *S. acaule* (one with whitish flowers and the other with lilac flowers) were collected on the Cerro Totoroko. Isolated 'Lelekoyas' plants were recorded in the area of influence of Timusi.

— Province of Bautista Saavedra. No wild potatoes were found at all in the areas of influence of the village of Charazani and the community of Chulina.

Four samples (NN-1, NN-2, NN-3 and NN-4), failed to coincide with any of the descriptions provided by Hawkes and Hjerting (1989) or Ochoa (1990), and

were recorded as unidentified species (Table 1). Table 2 shows a number of characteristics of three of these species. NN-4, which was collected at the entrance to the village of Italaque (Province of Camacho) in the grassy areas of the slopes, was not classified due to the poor quality and small quantity of specimens collected.

Specimen NN-1 (Table 2) was collected in the high mountains (on the track between Villa Lipe and Santiago de Huata) of the communities with a Lake Titicaca shoreline (Province of Omasuyos), where there are traces of Inca terraces now in decay. This species was rare, and found between stone walls. Its pubescent leaves have a particular shape, and the plant has a semi-rosetted growth habit. It has never been seen to flower, either in the field or under glass. Some of the samples collected are being characterised in collaboration with the International Potato Center (Peru).

NN-2, collected at «La Apacheta» (Province of Larecaja) along the high parts of the track between Achacachi and Sorata, grew erect, had a rather deep main root (Fig. 2), pubescent leaves, and flowers with a rotaceous corolla. The species appears to be rare; only two specimens were found in the field.

NN-3 was collected in a secondary mountain chain in the highlands of «La Apacheta» (Province of Larecaja), at the altitude of the ENTEL antenna. Sparsely distributed, its main notable characteristic is the form of its leaves (glabrescent and with a long main lobule) and its flowers with a stellate corolla.

Table 3 records the presence of *P. infestans* on the different species collected. All the species from wet areas (areas with permanent cloud) —*S. achacachense*, *S. candolleianum*, *S. circaeifolium* and *S. xjuzepczukii*⁹— were affected by this fungus.

⁸ An Aymaran word meaning «lagoon».

⁹ A species of bitter potato mainly cultivated at altitudes of $\geq 4,000$ m.

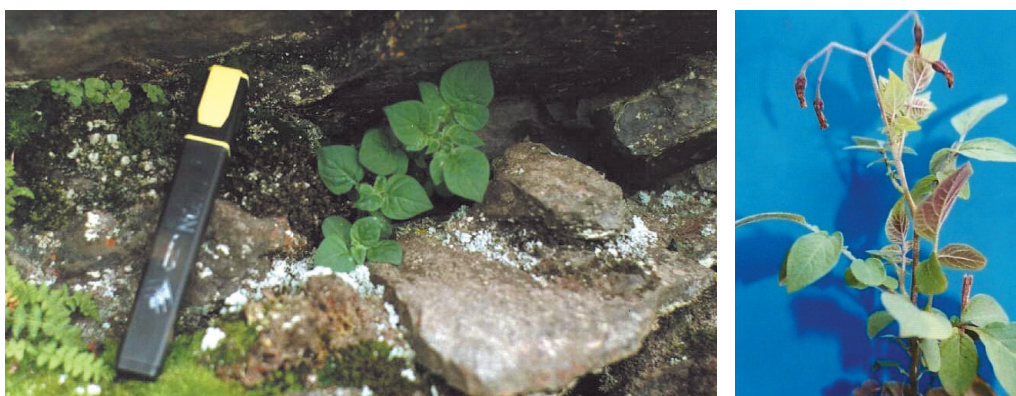


Figure 2. An unknown, potentially new, wild species of potato (NN-2). Left: in the field. Right: under glasshouse.

Discussion

S. acaule

This species was found in the high areas of Cruz Pata, around the shores of Lake Titicaca. All the specimens recorded for this species showed the morphological characteristics described by Ochoa (1990), except for variations in flower colour: the present specimens were lilac to lilac-white, while Ochoa describes the corolla to be blue-violet, dark purple, violet to lilac with whitish acumens, and more rarely white. According to Ochoa (1990), this species can also be found in the cultivated fields of the high plain near Lake Titicaca (Province of Omasuyos). However, it now appears to have disappeared from the entire microbasin close to the town of Achacachi. Agriculture and the intense dairy farming practised in the area appear to be the main causes of its erosion. Towards the sector of the Real de La Paz mountain range, at the localities of Murumamani and Chachacomani, *S. acaule* was the only species found. In these areas,

particularly Murumamani —which is known as a microcentre diversity of wild potatoes— the species appears to be threatened with extinction due to intense agricultural activity.

In the sectors of the Province of Camacho, in high areas such as the Huallpa Cayu (4,300 m), *S. acaule* is found dispersed among *S. xjuzepczukii* crops. The infestation of *S. xjuzepczukii* with *P. infestans* in this area may be due to the propagules (sporangia) of *P. infestans* arriving from the Valley of Italaque (3,150 m) in the permanent cloud. Different genotypes of *P. infestans* could reach areas of > 4,000 m in this manner.

The specimens of *S. acaule* recorded at Cerro Totoroko (Province of Muñecas), show slight morphological variations to the description provided by Ochoa; e.g., they have lilac or lilac-white flowers. The isolated ‘Lelekoyas’ (*S. tuberosum* subsp. *andigena*) plants recorded at Timusi show the wide distribution of this semi-cultivated potato which went unreported by Hawkes and Hjerting (1989) and Ochoa (1990).

Table 3. *Phytophthora infestans* in different species of wild potato

Species	Province	Locality	Altitude (m)	Latitude S	Longitude W	Symptoms
<i>S. achacachense</i>	Larecaja	La Apacheta	4,186	15° 52' 32.2"	68° 38' 25.0"	Stem
<i>S. circaefolium</i>	Larecaja	Sorata (Condorpata)	3,266	15° 49' 41.1"	68° 38' 27.1"	Leaves
<i>S. candolleianum</i>	Larecaja	Sorata (Llust'a)	3,855	15° 56' 11.4"	68° 35' 12.5"	Leaves-stem
<i>S. candolleianum</i>	Larecaja	Sorata (Paconi)	4,010	15° 52' 30.7"	68° 37' 04.5"	Leaves
<i>S. xjuzepczukii</i>	Camacho	Huallpa Cayu	4,215	15° 30' 21.0"	69° 08' 21.2"	Leaves
<i>S. circaefolium</i>	Camacho	Rio Uyo Uyo (Italaque)	3,678	15° 28' 48.5"	69° 02' 54.4"	Leaves
NN ¹	Camacho	Rio Uyo Uyo (Italaque)	3,678	15° 25' 52.5"	68° 58' 27.7"	Leaves

¹ Unidentified species.

S. achacachense

This species is only known in the «La Apacheta» sector between Sorata and Achacachi in the highlands of the Province of Larecaja. Nowadays, this locality belongs to the Province of Larecaja, and not Omasuyos as indicated by Cárdenas (1973) and Ochoa (1990). Until the 1970s, the land and the vegetation of the area conserved its natural character, but today they are altered by agriculture and cultivation practices associated with the production of phurejas potatoes¹⁰; this is threatening the existence of *S. achacachense*. Hawkes (1994) indicated the distribution of *S. achacachense* to be rare; it is now threatened with extinction. *P. infestans* is only rarely found in this area, and when present it mainly affects the stem (Fig. 3).

S. brevicaule

According to Ochoa (1990), this species is distributed between the Provinces of Manco Kapac and Omasuyos on the high plain north of La Paz. In the present work this species was found to be endemic to the shores of Lake Titicaca sector between Ajllata Grande and Santiago de Huata in the Province of Omasuyos. The finding of 'Lelekoyas' plants in this sector, mainly in the Sorata area, was not reported by earlier authors.

S. candolleanum

This was found in some sectors of the Province of Larecaja, as described by Hawkes and Hjerting (1989) and Ochoa (1990), but it was also recorded in new



Figure 3. *S. achacachense*. Left: with symptoms of *Phytophthora infestans* infection on the stem. Right: type specimen of this species.

areas such as the community of Paconi. In all cases its populations were small.

S. circaeifolium

This species was found in the Province of Larecaja, at Cerro Iminapi, in the locality of Laripata, as previously reported (Cárdenas, 1973; Hawkes and Hjerting, 1989; Ochoa, 1990). However, none of these authors recorded the size of the population nor the distribution of this species in this area. It now appears to be very rare and to be found only on the high part of the Cerro Iminapi.

Isolated specimens of *S. circaeifolium* were found in the sectors of Italaque (slopes on the river Uyo Uyo, Province of Camacho) and Moco Moco (Cotusi). This species was reported by Cárdenas (1966), Hawkes and Hjerting (1989), and Ochoa (1990), only at Sorata and Inquisive.

In conclusion, the present results show that, of the species of wild potato recorded in the north of the Dept. of La Paz by Cárdenas (1966), Hawkes and Hjerting (1989), and Ochoa (1990), *S. acaule* has a distribution greater than originally believed, reaching towards the Cordillera Real, but its survival is affected by a series of factors still to be quantified. The restricted distribution of *S. achacachense* is confirmed; its survival also appears to be threatened. *S. brevicaule* is endemic to the areas around Lake Titicaca. *S. candolleanum* seems to be most abundant in the foothills of Nevado Illampu, but is very affected by *P. infestans*. *S. circaeifolium* is affected in its home environment by a series of factors still to be quantified although it seems to have a wider distribution than originally believed. Morphological variations of some taxa were found as well as four probable new species, three of which are undergoing characterisation.

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¹⁰ Varieties of the native species *Solanum phureja*.

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