Short communication:

Solanum phureja Juz et Buk.: Valuable Source of Genetic Resistance to Potato Late Blight [*Phytophthora infestans* (Mont.) de Bary]

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Abstract

Bolivia is part of origin center of the potato, and production ecologies in which farmers maintain *in-situ* collections of *Solanum phureja* cultivars which are highly conducive to late blight.The research was conducted in the phytopathology laboratory from PROINPA Foundation, in order to identify sources of resistance to late blight (*Phytophthora infestans*) in cultivars of *Solanum phureja*, for its use in the potato plant breeding. After three years evaluation the results showed that phureja 7, Chulina 2, Chulina 13, Chulina 8 and Phureja 7 Rojo , were as resistant as Candelaria –1 (relative AUDPC = 8%) and Chulina–3 (relative AUDPC = 8%), and were more resistant than the cv. Runa Toralapa, "resistant check"(relative AUDPC = 38%), and Chulina-1, susceptible check (relative AUDPC = 23%).

Additional key words: *Collection, severity, source, diploid.*

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Comunicación corta:

Solanum phureja Juz et Buk.: Fuente valiosa de resistencia genética al tizón tardío de la papa [*Phytophthora infestans* (Mont.) de Bary]

Resumen

Bolivia forma parte del centro de origen de la papa, y la producción es ecológica en el que los agricultores mantienen colecciones de cultivares *in - situ* de *Solanum phureja* que son altamente propicios para el tizón tardío. La investigación se realizó en el laboratorio de fitopatología de la Fundación PROINPA, con el objetivo de identificar fuentes de resistencia a tizón tardío (*Phytophthora infestans*) en cultivares de la especie *Solanum phureja*, para utilizarlas en el mejoramiento genético de papa. Después de tres años de evaluación los resultados mostraron que Phureja 7, Chulina 2, Chulina 13, Chulina 8 y Phureja 7 Rojo, fueron resistentes como Candelaria 1 (AUDPC relativa = 8%) y Chulina 3 (AUDPC relativa= 8%) y fueron más resistentes que el cv. Runa Toralapa "testigo resistente", (AUDPC relativa = 38%) y Chulina 1, testigo susceptible (AUDPC relativa = 23%)

Palabras clave adicionales: *Colección, severidad, fuente, diploide.*

Introduction

Bolivia is part of the center of origin of the potato where production ecologies in which farmers maintain *in-situ* collections of *Solanum phureja* Juz et Buk. cultivars are highly conducive to late blight infection. It appears that farmers have been maintaining these cultivars because of their partial resistance to late blight, but these cultivars have not been used widely yet for their specific attributes or potential contribution to potato improvement with the exception of some cultivars in

Colombia, Perú (Estrada, 2000) and in other countries (Salomon-Blakburn and Barker, 2001; Trojnitz *et al*., 2002).
S. phureja is cultivated in the northern Departments of La Paz and Cochabamba (Coca-Morante and Tolin-Tordoya, 2013). This is the most southerly part of its distribution area which extends northwards through Peru, Ecuador, and Colombia into western Venezuela (Rodriguez, 2009).

The aymara name “Furejja” means “early” or “precocious”. This cultivar yields tubers in about 3 or 4 months, and it may be planted 3 or 4 times a year.

S. phureja is grown, to some extent, in the central region of Bolivia. below Apacheta and Paso Alto, for example, where the natural vegetation is very poor or even non-existent, a large portion of land has been given over almost exclusively to the cultivation of *S. phureja*. It is grown especially between Huarisata and Sorata to 15° 46 24” South latitude and 68° 38’ 00’’ West longitude in the vicinities of Paccoya and Umanata at elevations from 3200 and 3400 masl. In this same area, but at altitudes of 2800 and 3000 masl, are found a number of small farming communities famous for their cultivation of *S. phureja* (Rodriguez, 2005).

Especially notable in this regard are the villages of Curupampa, Chiripaca, Itabaya, Chihuani and Chullusirca. Much of the tubers of this species sold in the markets of La Paz originate from fields harvested in the Sorata vicinity, where this crop is grown at altitudes of 2600 and 2700 masl. Another market source for La Paz potatoes, including a form of *S. phureja* called “zapallo”, is the famous farming region of Chojñaccota, which lies southwest of Achacachi. Traditionally, forms of *S. phureja* are also grown in the vicinity of Timusi (north of Combaya, Province Muñecas, Department of La Paz) and Chojlla (region of the Yungas, near La Paz) (Ochoa, 2001). *S. phureja* is also cultivated in the vicinities of Queara and Puina in the Province of Franz Tamayo, Department of La Paz, at elevation of 3000-3200 masl. In this

poorly explored part of Bolivia, the species is called by its native name of *Chaucha* (Ochoa, 2001).

S. phureja is in general a cultivated diploid species. That has been poorly used in genetic studies and potato breeding programs (Estrada, 2000). It is a valuable source of resistance to bacterial wilt caused by *Ralstonia solanacearum* (Fock *et al*., 2005; Moslemkhani *et al*., 2012, Virupaksh *et al*., 2012). It is also known to be partially or horizontally resistant to late blight (Trojnitz *et al*., 2002; Costanzo *et al*., 2005; Mosquera, 2006; Mosquera *et al*., 2008, Tinjaca, 2010; Coca-Morante and Tolin-Tordoya, 2013) and to potato viruses PVX, PVS, PMV and PAV (Ochoa, 2001; Solomon-Blackburn and Barker, 2001). Hybrids *of S. phureja x S. tuberosum* subsp. *andigena* were found resistant to frost. *S phureja* is also a valuable source for heat tolerance and adaptation to the temperate zones (Ochoa, 2001). *S. phureja* is also related to the Colombian and Ecuadorian species *S. rybinii* that was reported as resistant to late blight (Trojnitz *et al*., 2002; Costanzo *et al*., 2005) and both species have similar flowers and have vines that mature very early, generally to about 3 or 4 months. Both also lack a tuber dormancy period (Vchinnikova *et al*., 2011). However, the two differ from one another with respect to habit, leaf shape, size of the terminal leaflet, characteristics of the calyx, and form and size of the stigma.

During the last ten years, PROINPA´s breeding program has evaluated internationally available germplasm and *Solanum* species including native cultivars from the Bolivian Germplasm Bank for late blight resistance (Gabriel, 2010). A diverse range of germplasm and genetic stocks has been evaluated more intensively to characterize the type of resistance they carry, and to determine their level and stability.

The present research was conducted in the phytopathology laboratory from PROINPA Foundation, in order to identify sources of resistance to late blight in cultivars of *Solanum phureja* for its use in potato breeding.

Materials and methods

The test was implemented in PROINPA Foundation facilities located in El Paso in Cochabamba, Bolivia.

Twelve new accessions of *S. phureja* (Table 1), six cultivars from Bolivian potatoes and 10 checks, were evaluated for late blight resistance under laboratory conditions. These cultivars were pathogen tested; seed tubers were sowed and grown in pots for their evaluation of resistance to *P. infestans* by the detached leaflet technique (Gabriel *et al*., 2011). Leaflets were collected from the upper third before flowering and disinfested with 1% sodium hypochloride during one minute. The accessions were distributed in a randomized incomplete block design with four replicates. They were put abaxial side up in inverted Petri plates with water agar on the top. A 20 µL drop of a suspension with 5000, 10000 and 20000 sporangia/mL of an A2 Bolivian complex isolate (1,2,3,4,5,6,7,8,9,10,11) was placed on each side of the leaflet midrib. The plates were incubated at 7- 19°C (minimum - maximum average, respectively).

After the third, fourth and fifth days of inoculation, the percentage of affected area (necrotic) and the pathogen sporulation was determined.

The percentages of necrotic or sporulating area were assessed and the area under the disease progress curve (AUDPC) values was calculated according to Gabriel *et al*. (2011). AUDPC reflects the advance of the disease in time, so that landraces can be statistically compared. The relative AUDPC (relative AUDPC) is calculated by dividing AUDPC by total peak area (Bonierbale *et al*., 2008).

Results and discussion

The analysis of variance shows large significant differences ($p<0.01$) between cultivars, concentrations and the interaction Cultivars x Concentrations, indicating the existence of a large

variability in the resistance of the evaluated *S. phureja* cultivars (Table 2).

The analysis of means by Tukey showed evident differences ($p<0.01$) between cultivars. Figure 1, shows that the accessions Phureja 7, Chulina-2, 13, 8 and Phureja 7 Rojo, were as resistant as resistant checks *S. phureja* Candelaria –1 (relative AUDPC = 8%), and Chulina–3 (relative AUDPC = 8%); but the other reported resistant checks cv. Runa Toralapa (relative AUDPC = 38%) behaved as susceptible. Some new cultivars of *S. phureja* such as Phureja 7, Chulina-2, 13, 8 and Phureja 7 Rojo showed good level of resistance. The analysis of variance for Cultivar Effects shows the frequency of those cultivars that were highly significant ($P<0.01$), indicating a wide variability of the relative AUDPC values and therefore a wide variability in the resistance of evaluated accessions.

Analysis of variance for concentration (5000, 10000 and 20000 sporangia/mL), shows large evident differences between the concentrations ($p<0.01$), indicating that the accessions showed different resistance reactions at the different levels of concentration.

As expected, the average of relative AUDPC for 20000 sporangia/mL was larger than the other two concentrations. However, with the concentration of 5000 sporangia/mL, it would be possible to identify clones with partial resistance.

Cultivars Phureja 7 and Phureja 7 Rojo, were the most resistant ones in the three leaflets detached test under laboratory and greenhouse conditions (Figure 1). However it will be convenient to test all accessions of *S. phureja* under field conditions, to observe the expression of partial resistance.

Moreover, it has been confirmed in Bolivia, that cultivar Waych'a is susceptible to late blight. In the traditional areas of seed potato production (Independencia, Morochata, Lope Mendoza

Table 1. Accessions, species, geographical location coordinates and resistance classification for *S. phureja* Juz et Buk. clones and checks evaluated in the laboratory in Cochabamba-Bolivia in 2004

Code	Common names	Species	Altitude (masl)	Latitude	Longitude	Resistance
Algodona- R check	-	tbr	-	-	-	R
Atzimba- R check	-	tbr	-	-	-	R
Candelaria – 2	-	phu	-	-	-	S
Candelaria – 3	-	phu	-	-	-	S
Candelaria – 1 – R check	-	phu	-	-	-	R
Chulina – 1 – S check	-	phu	-	-	-	S
Chulina – 2	-	phu	-	-	-	MR
Chulina – 4	-	phu	-	-	-	S
Chulina – 3- R check	-	phu	-	-	-	S
Chulina – 5	-	phu	-	-	-	S
Chulina – 6	-	phu	-	-	-	S
PDH 247- R check**	-	tbr	-	-	-	R
Phureja 1	Kinsa quillero	phu	2591	17□23.510’	66□16.271’	S

Phureja 3	Kinsa quillero	phu	2415	17□05.272’	65□56.081’	S
Phureja 4	Kinsa quillero	phu	2131	17□04.670’	65□55.719’	S
Phureja 5.1 amarilla	Phureja amarilla,	phu	2408	17□05.315’	65□56.011’	S
Phureja 5.2 blanca	Phureja blanca	phu	2408	17□05.315’	65□56.011’	R
Phureja 7	Kinsa quillero	phu	2571	17□07.817’	65□57.855’	MR
Phureja 7 rojo	Kinsa quillero	phu	2571	17□07.515’	65□58.735’	R
Phureja 8	Phureja	phu	2104	17□04.110’	65□58.875’	S
Phureja 8 rojo	Phureja “Redonda	phu	2104	17□05.112’	65□59.978’	R
Phureja 9	Bola phureja	phu	2068	17□04.829’	66□00.006’	S
Phureja 10	Bola phureja	phu	2235	17□05.115’	65□59.481’	S
Phureja 13	Bola phureja	phu	2372	17□08.505’	65□56.154’	R
Runa Toralapa- R check	-	adg x tbr	-	-	-	S*
Waych'a- S check	-	adg	-	-	-	S
Yema de huevo- R check	-	phu	-	-	-	R
Yungay- R check	-	adg x tbr	-	-	-	S*

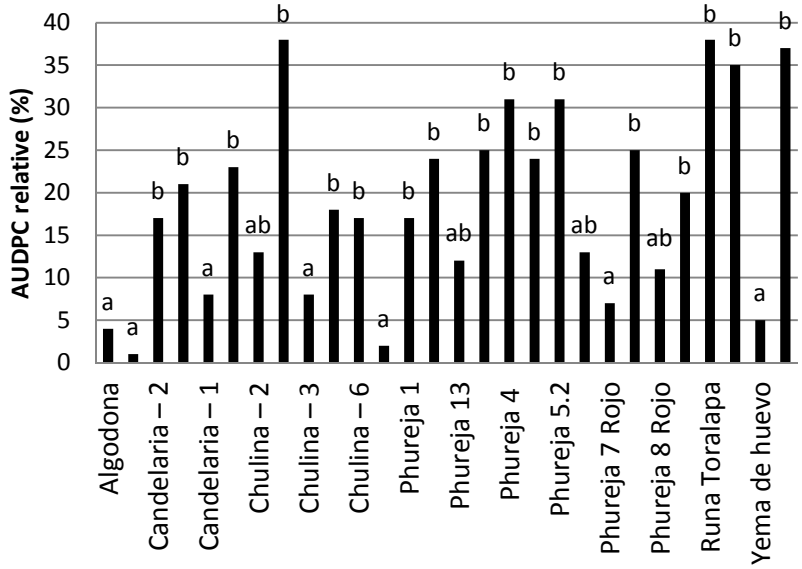
LB: Late blight; R: Resistant to LB; S: Susceptible to LB; MR: Moderately Resistant; phu: *S. phureja;* adg: *S. andigena;* tbr: *S. tuberosum.*
*: Previously reported as resistant, **: tbr - dihaploid

Table 2. Analysis of variance for *Solanum phureja Juz et Buk* cultivars

Source	DF	Mean Square	F Value
Total	305		
Repetition	3	2227.41	3.70*
Cultivar	27	10517.93	17.45**
Concentration	2	31573.08	52.39**
Cultivar x Concentration	54	2770.04	3.32**
Error	219	602.61	
C.V. (%)		48.53	

Figure 1. Relative AUDPC in *S. phureja* Juz. et Buk. Evaluated cultivars. Values with the same letter are not significantly different to p<0.01.

(AUDPC Area under the development disease progress curve)



and Colomi) in the Dept. of Cochabamba, and in other areas of the Depts. of Chuquisaca and Tarija, endemic late blight has to be controlled via eight or more application of fungicide (Coca-Morante and Tolin-Tordoya, 2013). In contrast, phurejas potatoes are usually grown in their traditional areas without the need for such protection.

Finally, the Runa Toralapa cultivar was reported with R-gene resistance (Estrada, 2000), but we observed that this cultivar has lost its resistance, as well as the Peruvian cultivar Yungay. Instead, it was confirmed that cultivars Algodona, Atzimba, dihaploide *S. tuberosum* PDH 247 and Yema de huevo (*S. phureja*) have confirmed their high levels of late blight resistance (Figure 1), something that was already reported by Gabriel *et al.* (2007).

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