Rev. FCA UNCUYO. 2019. 51(2): 461-474. ISSN (en línea) 1853-8665.

Wild potato Genetic Reserves in Protected Areas: prospection notes from Los Cardones National Park, Salta, Argentina

Reservas Genéticas de especies silvestres de papa en Áreas Protegidas: notas de prospección del Parque Nacional Los Cardones, Salta, Argentina

Perla Carolina Kozub [1], Verónica Noé Ibañez [1], Ariana Digilio [2], Hugo Marcelo Atencio [2, 3], María Eugenia Garavano [3], María Elena Sánchez [4], Carlos Federico Marfil [1]

Originales: *Recepción:* 10/06/2019 - *Aceptación:* 18/10/2019

Abstract

Wild potato species (WPS) are vital genetic resources to improve the productivity and sustainability of the third most important food crop worldwide. Although *in situ* conservation of this germplasm has been considered the most appropriate strategy, establishment of Genetic Reserves is still incipient. Northwest Argentina is among the priority regions for establishing WPS Genetic Reserves, whose designation within Protected Areas is accepted as the most efficient approach. In this work, we present results of the prospection and collection of WPS in Los Cardones National Park, a Protected Area with high environmental heterogeneity and diversity of plant communities. Four wild and one cultivated potato species were identified in different physiognomic vegetation units: *Solanum acaule*, *S. brevicaule*, *S. boliviense*, *S. vernei* and *S. tuberosum* group A*ndigenum*. In the four WPS, characters of interest for plant breeding have been described. Through the development of environmental education workshops and the monitoring over two consecutive years within a worldwide priority site, we have established a baseline on which *in situ* conservation will be projected to preserve an essential component of the natural and cultural America's patrimony.

Keywords
crop wild relatives • *in situ* conservation • plant genetic resources for food and agriculture • Protected Areas • *Solanum acaule* • *Solanum boliviense* • *Solanum brevicaule* • *Solanum vernei*

1 Universidad Nacional de Cuyo. Facultad de Ciencias Agrarias. Instituto de Biología Agrícola de Mendoza (IBAM). Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). Almirante Brown 500. Chacras de Coria. Mendoza. M5528AHB. Argentina. * cmarfil@fca.uncu.edu.ar
2 Estación Experimental Agropecuaria (EEA) Balcarce. Instituto Nacional de Tecnología Agropecuaria (INTA). Argentina.
3 Universidad Nacional de Mar del Plata (UNMdP). Facultad de Ciencias Agrarias (FCA). Argentina.
4 Administración de Parques Nacionales (APN). Dirección Regional Noroeste. Argentina.

Resumen

Las especies silvestres de papa (ESP) son recursos genéticos vitales para mejorar la productividad y sustentabilidad del tercer cultivo alimenticio en importancia mundial. Aunque su conservación *in situ* se ha considerado la estrategia más adecuada, el establecimiento de Reservas Genéticas es aún incipiente. El Noroeste Argentino figura entre las regiones prioritarias para establecer Reservas Genéticas de ESP, cuya designación dentro de Áreas Protegidas es aceptada como el enfoque más eficiente. En este trabajo presentamos resultados de la prospección y colecta de ESP en el Parque Nacional Los Cardones, un Área Protegida con una alta heterogeneidad ambiental y diversidad de comunidades vegetales. Cuatro especies silvestres y una cultivada de papa fueron identificadas en distintas unidades fisonómicas de vegetación: *Solanum acaule*, *S. brevicaule*, *S. boliviense*, *S. vernei* y *S. tuberosum* grupo *Andigenum*. En las cuatro ESP se han descripto caracteres de interés para el fitomejoramiento. A través del desarrollo de talleres de educación ambiental y del monitoreo durante dos años consecutivos dentro de un sitio prioritario a nivel mundial, establecimos una línea de base sobre la que se proyectará la conservación *in situ* para preservar un componente indispensable del patrimonio natural y cultural de América.

Palabras clave

Áreas Protegidas • conservación *in situ* • parientes silvestres de los cultivos • recursos fitogenéticos para la alimentación y la agricultura • *Solanum acaule* • *Solanum boliviense* • *Solanum brevicaule* • *Solanum vernei*

Introduction

Warranting global food security now and for the future is the greatest challenge. In order to face it, increases in productivity, resilience and sustainability of current agricultural systems are necessary. Crop wild relatives (CWR), which include crop ancestors and genetic related species, have useful genetic diversity to produce crop varieties with drought, heat and cold tolerance, high nutritional quality and pest and disease resistance. For these characteristics, CWR are essential components of the genetic resources for food and agriculture, contributing to address the productivity and sustainability of farming systems.

The potatoes represent an essential example addressing the importance of CWR germplasm in global food security needs (29). The potato (*Solanum tuberosum* L.) is the third more important food crop worldwide (17) and was probably one of the first cultivated species in which genetic improvement was carried out for resistance to diseases (23). The late blight disease in Ireland during the years 1845 and 1846 produced the total loss of potato production due to the low genetic diversity in cultivated germplasm. Towards the end of the 19th century and the beginning of the 20th century, potato improvement programs focused on obtaining *Phytophthora* resistance using a single wild potato species: *Solanum demissum* (24). This strategy changed completely in the 1920s, when efforts were made to collect wild germplasm in the Andean countries of South America and Mexico. Explorations were realized from 1925 to 1967, and at least, 33 prospecting and collection voyages of wild germplasm and cultivated potato were carrying out (22). This *ex situ* conservation strategy initially leaded by the Vavilov's team, continued with a broad development during the second half of the 20th century (27, 29), until some authors suggested that for some wild potato species no further collecting are required (9).

Alternatively, *in situ* conservation of potato wild relatives has an incipient development. Around 50 years ago, it was already recognized that wild species are most effectively preserved in their natural state (18). Later on, the Convention on Biological Diversity (10) in its Article 9 state that the *ex situ* conservation could be implemented predominantly for the purpose of complementing *in situ* measures. However, *ex situ* strategies still prevail in potato conservation and in contrast to the CBD recommendations *in situ* programs have rarely been assessed.

The great long-term challenge of *in situ* conservation of CWR is the creation of Genetic Reserves, which implies the location, designation, management and monitoring of wild populations in their natural habitat to maintain their genetic diversity. In economic and politic terms, the most effective method to implement Genetic Reserves is to establish them in existing Protected Areas (35). Also, it is necessary to count with information related to species distribution, phenology, demography, genetics, ecology, politic and socioeconomic studies (16).

Protected Areas are geographically defined zones, designated, regulated and administered in order to reach specific conservation objectives and are the central axis of the national and international strategies of *in situ* conservation of the CWRs. In Argentina, the National System of Protected Areas is under the application authority of the National Parks Administration (APN in Spanish). In addition, there are provincial systems of Protected Areas. Taken together, all Protected Areas in Argentina created and administered by national, provincial or municipal organizations, or by NGOs or private entities, are integrated in the Federal System of Protected Areas (SIFAP in Spanish).

In Argentina, since 2006 the Potato Active Genebank of the Balcarce Agricultural Experimental Station (BAL) of the National Institute of Agricultural Technology (INTA in Spanish) started with *in situ* conservation initiatives, prospecting and collecting potato wild relatives in national Protected Areas. As a result of these activities, 12 wild potato species were identified inside these areas (13). In the same vein, since 2011, the Institute of Agricultural Biology of Mendoza (IBAM) is developing a pioneering *in situ* conservation program of potato wild relatives within Protected Areas. This challenge was assumed in an integral way, contemplating the generation of knowledge, the interaction with governmental and private entities linked to the management of natural resources, the training of Protected Areas professionals and the spreading of this initiative in academia and among the general public by means of environmental education workshops. Working with *Solanum kurtzianum* Bitter & Wittm., the wild potato of Argentina best adapted to dry environments, a baseline was generated with distribution data, biotic and abiotic interactions, population dynamics, phenotypic and genetic variability of natural populations of this species (28, 33, 34). Based on this information, a management plan for *in situ* conservation of potato wild relatives was presented and a working protocol was generated to be implemented at the national and regional level (34). At the same time, in the Paititi Natural Reserve (Buenos Aires) started an *in situ* conservation initiative of *Solanum commersonii* Dunal (19), a wild potato species that is important for genetic improvement because it has genes for resistance/tolerance to biotic and abiotic stresses that affect the crop (14). In addition, it is cited by Sajama as the highest priority to carry out conservation actions since it is one of the wild potato species that is losing the most geographical range (43).

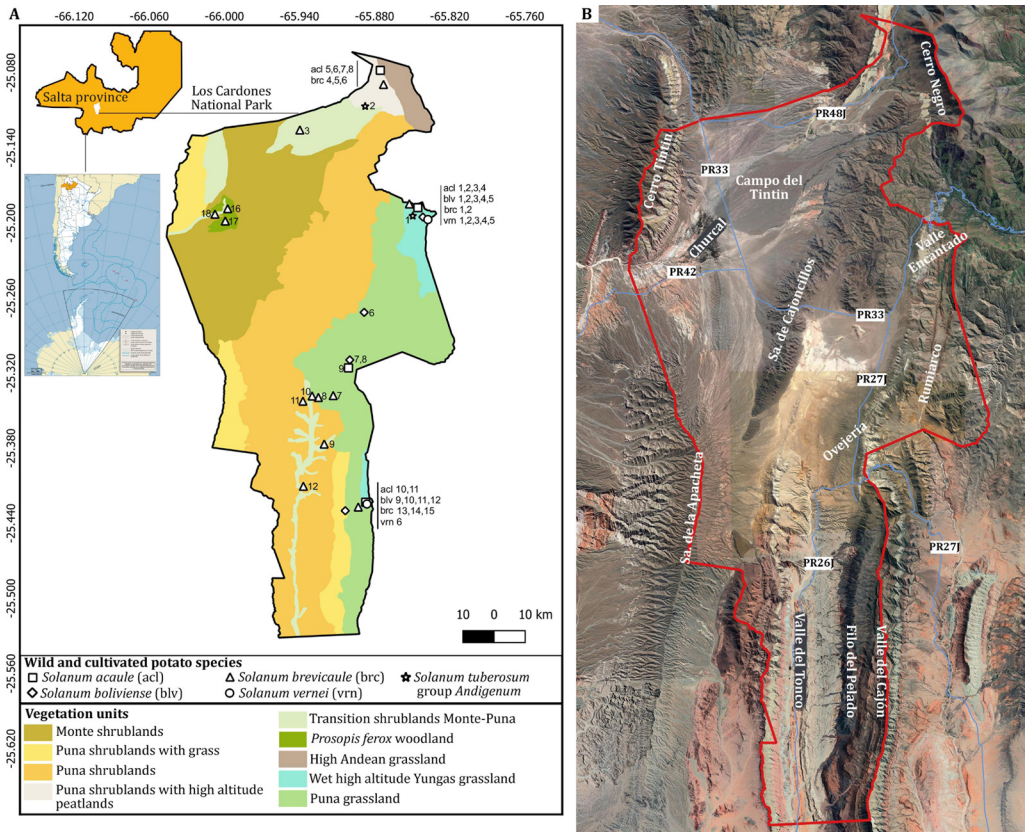
Based on the overlap of geographic coordinates of potato genebank accessions with those of the Argentine Protected Areas and on prospecting and collecting expeditions, Los Cardones National Park (LCNP) was identified as one of the priority sites for establishing a Genetic Reserve by its wild potato species richness (13, 34). LCNP was established in 1996. It is located in the western of Salta province in the localities of Cachi and San Carlos and covers an area of 64,117 hectares. Mountain ranges running north to south with a wide altitudinal range from 2600 to 5226 m a. s. l. (1), interspersed by narrow valleys that generates remarkable diversity of environments, based upon differences especially in precipitation and temperature. This environmental heterogeneity determines a high diversity of plant communities within the park. In fact, these characteristics are the basis of the creation of the LCNP. Five biogeographic provinces are represented in LCNP, namely Yungas, Monte, Puna, Prepuna and High Andean realms (6). According to Sánchez (2009), Puna and Monte biogeographical provinces occupy 90% approximately of the total area of LCNP and harbour the greatest number of vegetation units mainly shrublands but also grasslands. Yungas, Prepuna and the High Andes occupy a much smaller area, with unique vegetation units such as wet high-altitude Yungas grasslands, *Prosopis ferox* woodland, and High Andean grasslands respectively. We hypothesize that WPS from LCNP are associated with different vegetation units.

In the present work, we present results of two prospection and collection expeditions in Yungas, Monte, Puna and High Andean biogeographic provinces within LCNP and awareness activities through communication, education, and participative activities that were performed to establish a Genetic Reserve of wild relatives of one of the most important crop worldwide which is part of the natural and cultural heritage of the Americas.

Materials and methods

Two prospection and collection expeditions took place in LCNP, the first was achieved from March 6-11, 2017 and the second one was realized from March 5-9, 2018.

Five biogeographic provinces were recognized in LCNP according to Cabrera (1994): Yungas, Monte, Puna, Prepuna and High Andean. Within each biogeographic province different vegetation units were identified (45), where wild potato species were located: i) wet high-altitude Yungas grasslands (Site: Valle Encantado and Valle del Cajón), ii) Puna shrublands with high altitude peatland and transition shrublands Monte-Puna (Site: Cerro Negro, and road to Cerro Negro), iii) Puna grasslands (Site: Ovejería and Filo del Pelado), iv) transition shrublands Monte-Puna (site: Valle del Tonco) and v) *Prosopis ferox* woodland (Site: El Churcal) (figure 1 and table 1, page 465-466). We selected collection sites based on a previous expedition report carried out by INTA in 2010. Populations were defined *a priori* based on spatial distribution of plants and geographic characteristics (presence of physical barriers between populations). In general, plants spaced more than fifty meters were considered belonging to different populations. Population size was determined by counting all plants in an area of about 25x25 meters. Hybridization and gene flow are frequent in populations of wild potato species; therefore, we need to analyse the genetic structure of all sampled populations to corroborate the category of population assigned.



A. Distribution of populations of the wild potatoes species *Solanum acaule, Solanum boliviense*, *Solanum brevicaule* and *Solanum vernei*; and the cultivated species *Solanum tuberosum* group *Andigenum* in different vegetation units. **B.** Relief map of Los Cardones National Park and location of collection sites.

A. Distribución de poblaciones de las especies silvestres de papas *Solanum acaule*, *Solanum boliviense*, *Solanum brevicaule* y *Solanum vernei*; y la especie cultivada *Solanum tuberosum* grupo *Andigenum* en diferentes unidades de vegetación. **B.** Mapa de relieve del Parque Nacional Los Cardones y ubicación de los sitios de muestreo.

Figure 1. Potato species within Los Cardones National Park, Salta province, Argentina.

Figura 1. Especies de papa dentro del Parque Nacional Los Cardones, provincia de Salta, Argentina.

Table 1. Collected and monitored populations of wild and cultivated potato species in Los Cardones National Park during two years (2017-2018).

Tabla 1. Poblaciones de especies silvestres y cultivadas de papa recolectadas y monitoreadas en el Parque Nacional Los Cardones durante dos años (2017-2018).

Species	Population code	Collector number/ Germplasm collection[a]	Localization			Population size[b]		Phenological stage[c]	
			Site	Latitude (S) Longitude (W)	Altitude (m a. s. l.)	2017	2018	2017	2018
Solanum acaule	acl1	GaSAMaIb2/S, P, H	Valle Encantado	25°11.798' 65°50.454'	3083	>100	>200	Fr	Fr
	acl2	GaSAMaIb10/S, H	Valle Encantado	25°11.512' 65°50.386'	3110	~40	NM[b]	Fr	NM
	acl3	GaSAMaIb12/S, H	Valle Encantado	25°11.267' 65°50.726'	3174	~60	NM	Fr	NM
	acl4	DiLoMaKIb 6/S, H	Valle Encantado	25°11.691' 65°51.010'	3186	NM	~100	NM	Fl/Fr
	acl5	GaSAMaIb15/S, P, H	Cerro Negro	25°04.686' 65°52.527'	3952	>100	>500	Fl/Fr/Wi	Fl/Fr
	acl6	GaSAMaIb17/S, H	Cerro Negro	25°05.121' 65°52.469'	3878	>100	>500	Fr	Fr
	acl7	GaSAMaIb18/S, H	Cerro Negro	25°05.558' 65°52.186'	3867	>300	NM	Fl	NM
	acl8	DiLoMaKIb30/S, H	Cerro Negro (limit LCNP)	25°04.006' 65°52.546'	4024	NM	>200	NM	Fl/Fr
	acl9	GaSAMaIb20/S, P, T, H	Ovejería	25°18.948' 65°54.053'	3228	>100	>300	Fl/Fr	Fl/Fr
	acl10	DiLoMaKIb43/S, H	Valle del Cajón	25°25.446' 65°53.273'	3089	NM	>50	NM	Fl/Fr
	acl11	DiLoMaKIb44/S	Valle del Cajón	25°25.388' 65°53.225'	3095	NM	~20	NM	Fl/Fr
Solanum boliviense	blv1	GaSAMaIb3/S, P, H	Valle Encantado	25°11.784' 65°50.449'	3083	>100	>200	Fr	Fl/Fr
	blv2	GaSAMaIb6/S, P, H	Valle Encantado	25°11.128' 65°50.559'	3095	~40	NM	Fr	NM
	blv3	GaSAMaIb7/S, H	Valle Encantado	25°11.719' 65°50.484	3106	~100	NM	Fr/Wi	NM
	blv4	GaSAMaIb9/S, H	Valle Encantado	25°11.512' 65°50.386'	3110	>300	NM	Fr/Wi	NM
	blv5	DiLoMaKIb3/S, H	Valle Encantado	25°11.838' 65°50.244'	3168	NM	~60	NM	Fl/Fr
	blv6	DiLoMaKIb11/S, H	Ovejería	25°16.288' 65°53.298'	3154	NM	>100	NM	Fl/Fr
	blv7	GaSAMaIb19/P, H	Ovejería	25°18.568' 65°53.991'	3219	>1000	>1000	V	Fl/Fr
	blv8	DiLoMaKIb15/S, P, H	Ovejería	25°19.008' 65°54.056'	3229	NM	>1000	NM	Fl/Fr
	blv9	DiLoMaKIb39/S, H	Filo del Pelado	25°25.799' 65°54.208'	3247	NM	~100	NM	Fr
	blv10	DiLoMaKIb41/H	Filo del Pelado	25°25.841' 65°53.993'	3275	NM	~40	NM	V
	blv11	DiLoMaKIb42/S, H	Valle del Cajón	25°25.621' 65°53.583'	3160	NM	~80	NM	Fl/Fr
	blv12	DiLoMaKIb45/S, P, H	Valle del Cajón	25°25.474' 65°53.166'	3100	NM	>100	NM	Fl

[a] Germplasm collected for *ex situ* conservation in the active gene bank (BAL): S: seeds; T: tubers; P: plants; H: herbarium. [b] Number of plants. NM: Not monitored. [c] V: vegetative stage (plants without flower nor fruits); Fl: flowering; Fr: fruit development; Wi: withering. [d] Number of different cultivars present in farmers' field.

[a] Germoplasma recolectado para conservación *ex situ* en el banco activo (BAL): S: semillas; T: tubérculos; P: plantas; H: herbario. [b] Número de plantas. NM: No monitoreada. [c] V: estado vegetativo (plantas sin flores ni frutos); Fl: floración; Fr: frutos en desarrollo; Wi: marchitez. [d] Número de cultivares presentes en las huertas de los agricultores.

Table 1 (cont.). Collected and monitored populations of wild and cultivated potato species in Los Cardones National Park during two years (2017-2018).

Tabla 1 (cont.). Poblaciones de especies silvestres y cultivadas de papa recolectadas y monitoreadas en el Parque Nacional Los Cardones durante dos años (2017-2018).

Species	Population code	Collector number/ Germplasm collection[a]	Localization			Population size[b]		Phenological stage[c]	
			Site	Latitude (S) Longitude (W)	Altitude (m a. s. l.)	2017	2018	2017	2018
Solanum brevicaule	brc1	GaSAMaIb25/S, H	Valle Encantado	25°11.089' 65°51.135	3282	>100	>200	V/Fr	Fl/Fr
	brc2	GaSAMaIb5/T, P, H	Valle Encantado	25°11.128' 65°50.559'	3095	~20	NM	V	NM
	brc3	GaSAMaIb13/S, P, T, H	road to Cerro Negro	25°07.543' 65°56.383'	3208	>1000	>1000	Fl/Fr	Fl/Fr
	brc4	GaSAMaIb14/P, H	Cerro Negro	25°05.949' 65°52.251'	3756	~80	~80	Fl	Fr
	brc5	DiLoMaKIb34/S, H	Cerro Negro	25°05.361' 65°52.373'	3864	NM	~80	NM	Fr
	brc6	GaSAMaIb16/S, P, H	Cerro Negro	25°04.912' 65°52.567'	3926	~70	>100	Fr	Fl
	brc7	GaSAMaIb21/S, P, H	Ovejería	25°20.276' 65°54.782'	3213	>100	>100	Fr	Fl/Fr
	brc8	GaSAMaIb22/S, P, H	Valle del Tonco	25°20.366' 65°55.497'	3156	>100	>600	Fr	Fl/Fr
	brc9	GaSAMaIb23/P, H	Valle del Tonco	25°22.602' 65°55.216'	3046	>100	>100	V	Fr
	brc10	DiLoMaKIb19/S, H	Valle del Tonco	25°20.295' 65°55.795'	3142	NM	>100	NM	V
	brc11	DiLoMaKIb20/S, H	Valle del Tonco	25°20.543' 65°56.236'	3141	NM	>1000	NM	Fl/Fr
	brc12	DiLoMaKIb22/S, P, H	Valle del Tonco	25°24.625' 65°56.213'	2873	NM	~100	NM	Fr
	brc13	DiLoMaKIb38/S, P, H	Filo del Pelado	25°25.799' 65°54.208'	3247	NM	~30	NM	Fr
	brc14	DiLoMaKIb40/H	Filo del Pelado	25°25.842' 65°53.993'	3275	NM	~20	NM	V
	brc15	DiLoMaKIb42/S, H	Valle del Cajón	25°25.621' 65°53.583'	3160	NM	~30	NM	Fr
	brc16	GaSAMaIb24/P, H	El Churcal	25°11.319' 65°59.843'	2856	~30	NM	V	NM
	brc17	DiLoMaKIb9/P, H	El Churcal	25°11.908' 65°59.956'	2851	NM	~50	NM	V/Fl
	brc18	DiLoMaKIb10/P, H	El Churcal	25°11.580' 66°00.453'	2819	NM	~15	NM	Wi
Solanum vernei	vrn1	GaSAMaIb1/S, P, T, H	Valle Encantado	25°11.846' 65°50.498'	3087	>100	>100	Fr	Fr
	vrn2	GaSAMaIb4/S, T, H	Valle Encantado	25°11.784' 65°50.449'	3089	>100	>200	Fr	V/Fl
	vrn3	GaSAMaIb8/S, P, T, H	Valle Encantado	25°11.617' 65°50.434'	3100	>100	>100	Fr	V
	vrn4	DiLoMaKIb2/S, P, H	Valle Encantado	25°11.838' 65°50.244'	3168	NM	~50	NM	V/Fl
	vrn5	DiLoMaKIb5/P, T, H	Valle Encantado	25°11.690' 65°51.010'	3186	NM	>200	NM	Fl
	vrn6	DiLoMaKIb46/P, H	Valle del Cajón	25°25.474' 65°53.166'	3100	NM	~15	NM	V
	vrn7	GaSAMaIb 11/P, T, H	Valle Encantado	25°11.512' 65°50.386'	3110	NM	~40	V	NM
Solanum tuberosum group *Andigenum*	adg1	DiLoMaKIb8/T	Valle Encantado	25°11.666' 65°50.097'	3189	NM	4[d]	NM	-
	adg2	DiLoMaKIb29/T	Cerro Negro	25°06.408' 65°53.251'	3517	NM	8[d]	NM	-

[a] Germplasm collected for *ex situ* conservation in the active gene bank (BAL): S: seeds; T: tubers; P: plants; H: herbarium. [b] Number of plants. NM: Not monitored. [c] V: vegetative stage (plants without flower nor fruits); Fl: flowering; Fr: fruit development; Wi: withering. [d] Number of different cultivars present in farmers' field.

[a] Germoplasma recolectado para conservación *ex situ* en el banco activo (BAL): S: semillas; T: tubérculos; P: plantas; H: herbario. [b] Número de plantas. NM: No monitoreada. [c] V: estado vegetativo (plantas sin flores ni frutos); Fl: floración; Fr: frutos en desarrollo; Wi: marchitez. [d] Número de cultivares presentes en las huertas de los agricultores.

In total, 50 populations were sampled as true seeds, plants or tubers depending on the phenological stage of the populations. Phenological stages were defined as: shoot development (plant without flowers nor fruits), flowering, fruit development and withering (table 1, page 465-466). In 2017, 25 populations located in five different vegetation units and seven sites (Valle Encantado, Cerro Negro, road to Cerro Negro, Ovejería, Filo del Pelado, Valle del Tonco and El Churcal) were sampled. In 2018, populations were monitored and re-sampled and a new site, Valle del Cajón, was prospected and populations of the four wild potato species were found and collected.

In each collection site photographs were taken and the following information was recorded: date, geographical coordinates, altitude (m a.s.l.), number of plants per population, phenological stage, evidence of cattle grazing, trampling and dunging. Also, the target species (*Solanum acaule*, *S. boliviense, S. brevicaule, S. vernei*) were identified and collected. Depending on the phenological stage of the plants in each population, the type of plant material collected was: berries (B), tubers (T), and whole plant (P) (table 1, page 465-466). In each site all the plant species that grows together with the target species were identified, considering them as accompanying flora. The species were identified in the Agricultural Botany Laboratory (Faculty of Agricultural Sciences/ Mar del Plata National University) through observation under magnifying glass and the use of specific bibliography. Besides, herbarium specimens were made from potato wild relatives and accompanying flora, and finally were deposited at the Herbarium BAL - Integrated Unit Balcarce (Agricultural Experimental Station Balcarce/ National Institute of Agricultural Research and Faculty of Agricultural Sciences/ Mar del Plata National University). Farmers in Cerro Negro and Valle Encantado were visited. We carried out qualitative interviews focused on cultivation and conservation practices and inquiring about knowledge of wild potato species.

To characterise each year (2017 and 2018), environmental data from the nearest weather station of National Meteorological Service (SMN in Spanish) was used. "Salta Aero" meteorological station is located 24°50.565'S 65°28.972'W, approximately 50 kilometers northeast from the LCNP. Average temperature, accumulated precipitation and relative humidity from October to March were estimated for 2016- 2017 and 2017-2018 seasons. The biogeographic provinces and vegetation units present in LCNP were described according to Cabrera (1994) and Sánchez *et al.* (2015).

Results and discussion

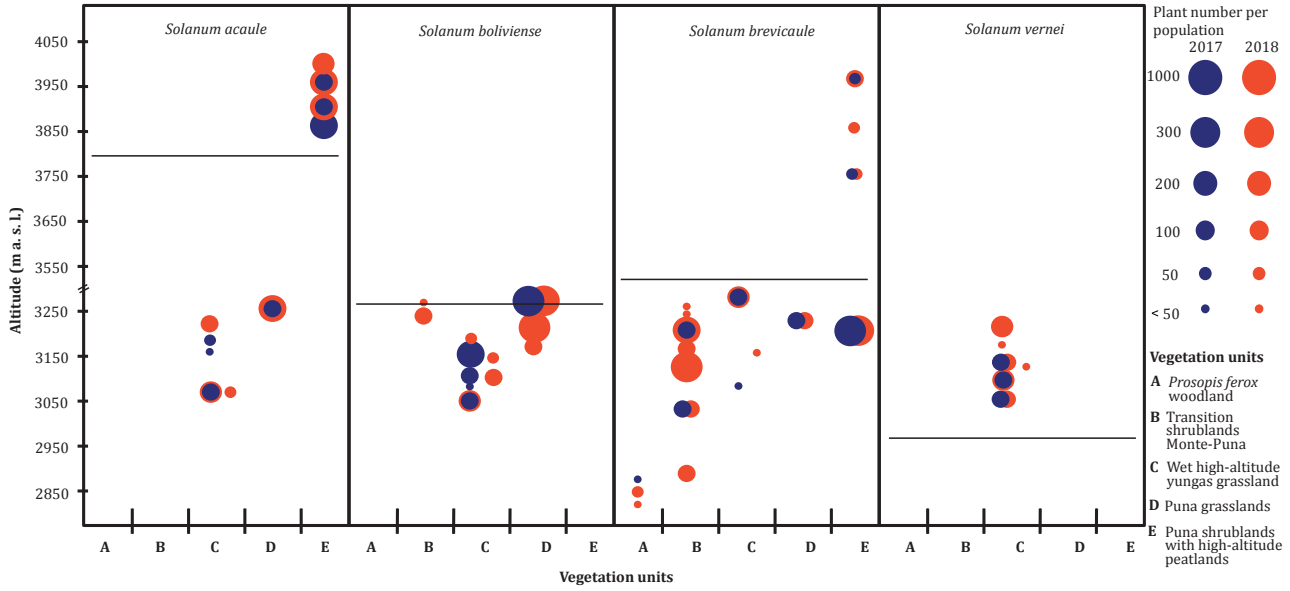
In the two prospecting and collecting expeditions to LCNP, four wild and one cultivated potato species were *in situ* identified: *Solanum acaule* Bitter (acl), *S. boliviense* Dunal (blv), *S. brevicaule* Bitter (brc), *S. vernei* Bitter & Wittm (vrn) and *S. tuberosum* group *Andigenum* (adg), respectively.

In wet high-altitude Yungas grasslands the greatest number of wild potato species was found, growing together with a high cover of herbaceous monocot and dicot species on the misty mountains of Valle Encantado and Valle del Cajón (figure 1, page 464). Evidence of cattle grazing, trampling and dunging was observed. Sympatric populations of the four species were found in Valle Encantado on both expeditions, whereas in Valle del Cajón very small distances separated populations (maximum 200 meters). In Valle Encantado Hugo Zerpa's farm was visited. He and his family cultivated Andean potatoes (*S. tuberosum* group *Andigenum*) and oca (*Oxalis tuberosa*) (table 1, page 465-466). Near the farm, populations of *S. vernei, S. boliviense* and *S. acaule* were growing.

In Cerro Negro we found two species: *S. acaule* in high altitudes above 3867 meters (in Puna shrublands with high altitude peatlands) and *S. brevicaule* in a wide range, from 3208 to 3926 meters [transition shrublands Monte-Puna and Puna shrublands with high altitude peatland (figure 2, page 468)]. Remarkable phenotypic differences (*i.e.* corolla color and shape and leaf pubescence) were detected among *S. brevicaule* populations. Populations in lower altitude showed pubescent leaf, light-purple and stellate corollas whereas populations from high altitude had no pubescent leaf and presented purple and pentagonal corollas. Populations of *S. acaule* were found mainly in peatlands (*i.e.* patches of herbaceous vegetation with permanent waterlogging).

In Cerro Negro, a farm was visited where Elsa and Elba Colque cultivate Andean potatoes in a small orchard; also commercial cultivated potatoes (*Solanum tuberosum* L.) were present in the field. In the Andean landraces, open pollinated seeds were observed. The farmers indicated that they do not use open pollinated seed for generated new germplasm, an ethnobotanical practice documented in other Andean farmer systems (40). Also, they evaluated as unlikely that some seeds produced by open-pollination of the potato landraces will germinate and introduce new genotypes to their farmer system. A common and ancestral practice in the region is the tuber exchange in local markets. The farmers exchange and often purchase tubers in markets in different localities of Salta province with the aim of increasing the diversity in their farms. Participatory exchanges of tubers among farmers is important to help them cope with environmental adversity and to avoid the loss of crop diversity. Adjacent to the orchard a *S. brevicaule* population (brc5) was found, a wild species that could contribute with its pollen in the origin of the open pollinated seed observed in landraces. Previous studies had demonstrated gene flow in the Andes between wild species and potato cultivars (11, 46). In order to evaluate this possibility in LCNP, berries from Andean landraces were collected in 2018. By molecular markers, gene flow between Andean landraces and *S. brevicaule* population will be determined.

In Puna grasslands, populations of *S. acaule*, *S. boliviense* and *S. brevicaule* were identified. In this vegetation unit, in the site named Ovejería, the largest population of *S. boliviense* (blv7) was found during both expeditions (figure 1, page 464; table 1, page 465-466). In 2018, most notoriously, the prospected areas in Ovejería were covered by *S. boliviense* in combination with grasses. Within this continuous of *S. boliviense*; *S. acaule* patchy populations were identified.



Horizontal lines show the mean altitude described for each species (26).

Overlapped circles show the same population surveyed in 2017 and 2018.

Líneas horizontales indican la altitud media descripta para cada una de las especies (26).

Círculos solapados muestran la misma población censada en 2017 y 2018.

Figure 2. Altitudinal range of the wild potatoes species *Solanum acaule, Solanum boliviense*, *Solanum brevicaule* and *Solanum vernei* within Los Cardones National Park, Salta province, Argentina. Circle area is a schematic representation of the population size surveyed in five vegetation units.

Figura 2. Rango altitudinal de las especies silvestres de papas *Solanum acaule*, *Solanum boliviense*, *Solanum brevicaule* y *Solanum vernei* dentro del Parque Nacional Los Cardones, provincia de Salta, Argentina. El área de los círculos es una representación esquemática del tamaño de las poblaciones censadas en cinco unidades de vegetación.

Several of the plants *in situ* evaluated, showed intermediate phenotypes between these two wild potato sympatric species, observation that allow inferring the presence of hybrids. Natural hybrids between *S. acaule* and *S. boliviense* had been already reported in northwest Argentina (38), and the documented scenario in Ovejería represents an ideal opportunity to study the natural hybridization as a source of variability in potatoes (7, 8, 31, 32).

On the way from Valle del Tonco to Valle del Cajón in a site named Filo del Pelado (vegetation units Puna grasslands) *S. boliviense* and *S. brevicaule* populations were found (figure 1, page 464). No morphological evidence about the presence of hybrids between these two species was observed in the field.

In transition shrublands Monte-Puna (Valle del Tonco) only *S. brevicaule* populations were found. An increase in aridity and a decrease in vegetation cover were observed while further south of the valley was reached. Evidence of plants having been eaten by some rodent species was detected. The most southern population sampled in this site showed strong symptoms of water deficit stress (brc12). In 2017 only one population of *S. brevicaule* (brc16) was sampled in the *Prosopis ferox* woodland whereas in 2018 this population was monitored and two new ones of the same species were sampled (brc17 and brc18).

Solanum vernei presented the narrowest distribution, natural populations were found in one vegetation unit within LCNP (wet high-altitude Yungas grasslands), from 3087 to 3186 m a.s.l. *Solanum boliviense* natural populations presented a narrow limit distribution and were found in three vegetation units (Puna grasslands, wet high-altitude Yungas grasslands and transition shrublands Monte-Puna), from 3083 to 3275 m a.s.l. *Solanum acaule* natural populations were found in three vegetation units (Puna grasslands, wet high-altitude Yungas grasslands and Puna shrubland with high altitude peatland) from 3083 to 4024 m a.s.l. The species with widest distribution was *S. brevicaule*, which was found in five vegetation units and from 2819 to 3926 m a. s. l. (figure 2, page 468). Natural populations of three species (*S. acaule*, *S. boliviense* and *S. brevicaule*) were found near the mean altitudinal range previously described (26). However, *S. vernei* was found in higher sites compared with previous reports (26) (figure 2, page 468).

During the two expeditions it was not possible to find populations of *S. microdontum* nor *S. venturii*. Clausen *et al.* (2018), based on data from an expedition performed on March 2010, mentioned these two species as present in two populations of LCNP. In 2018, which was as a favorable year for the growth of wild potato species due to the abundant precipitations, the absence of *S. microdontum* and *S. venturii* populations in the same site collected in 2010, indicates that the distribution of these species within LCNP is very limited and with small population sizes.

It has been informed that most often potato populations are very small (<100 plants) (15). These observations seem not to reflect the situation in LCNP, where above the 50% of the monitored population were composed by more than 100 plants. The potato population sizes are highly influenced by rainfall amount and timing (34). During the two expeditions, slight differences in sizes were observed for some populations (table 1, page 465-466 and figure 2, page 468). Climatological data were obtained from the LCNP nearest weather station in order to generate a baseline for future correlations with population sizes. Between January 2017 and January 2018 there was a difference of 100 mm in rainfall and 6.3% in RH (figure 3, page 470). Higher rainfall and humidity could play a role in the higher population sizes observed in 2018. However, to have reliable and comprehensive information about the influence of climatological variables on population size and phenology, population monitoring must be performed for a longer period (34). Considering the climatic heterogeneity in LCNP environmental data from meteorological stations in the park will be also necessary.

Plant community's heterogeneity and probably richness of wild potato species in LCNP are related with environmental conditions. According to Noé *et al.* (2012), central and western areas of LCNP are semiarid with mean annual precipitations of 200 mm approximately and mean annual temperature of 12°C, whereas in the eastern area increases in relative humidity and precipitation and decreases in temperature were reported (annual precipitation from 300 to 500 mm with a mean temperature of 9°C).

Livestock grazing is common in every site where we found wild potato species. Ugent (1981), reported the presence of seeds of *S. acaule* in animal droppings and also seedling emerging from fecal pellets in the Andes of Bolivia. It would be interesting to evaluate the contribution of domesticated animals to seed dispersal of wild potatoes species in LCNP. The current Management Plan for LCNP (1) contemplates total exclusion of cattle in certain areas like Cerro Negro and Valle Encantado; situation that could provide a good opportunity to study whether the presence of cattle represents a risk for wild potato populations or, in the other hand, contributes to their dispersion within the LCNP.

A widely used criterion for the CWR's conservation prioritizing is the gene pool concept defined by Harlan and de Wet (1971), which allows classifying species in primary, secondary, and tertiary "genepools" based on the degree of crossability of germplasm with cultivated species. Considering LCNP as a Genetic Reserve, three species of the primary gene pool (*S. acaule*, *S. brevicaule* and *S. vernei*) and one of the secondary gene pool (*S. boliviense*) are being *in situ* conserved (9, 14). In addition, several characters of breeding interest have been described for the four species (figure 4, page 471). Species of the primary gene pool can be directly crossed with cultivated species facilitating introgression of desirable traits. Whereas in species from the secondary gene pool certain reproductive barriers tend to difficult crosses.

Regarding to the *ex situ* conservation, the BAL active genebank contains germplasm of the four species found in LCNP. BAL active genebank initiated its activities in 1970 and its main objectives were to prospect, collect, conserve, characterize, evaluate and distribute germplasm of all the tuberous *Solanum* grown in Argentina, including CWR and cultivated species; and also germplasm from neighbouring countries. There are conserved 215 accessions of *S. acaule*, 27 of *S. boliviense*, 245 of *S. brevicaule* and 25 of *S. vernei*, most of them collected in Argentina, mainly from Northwest provinces.

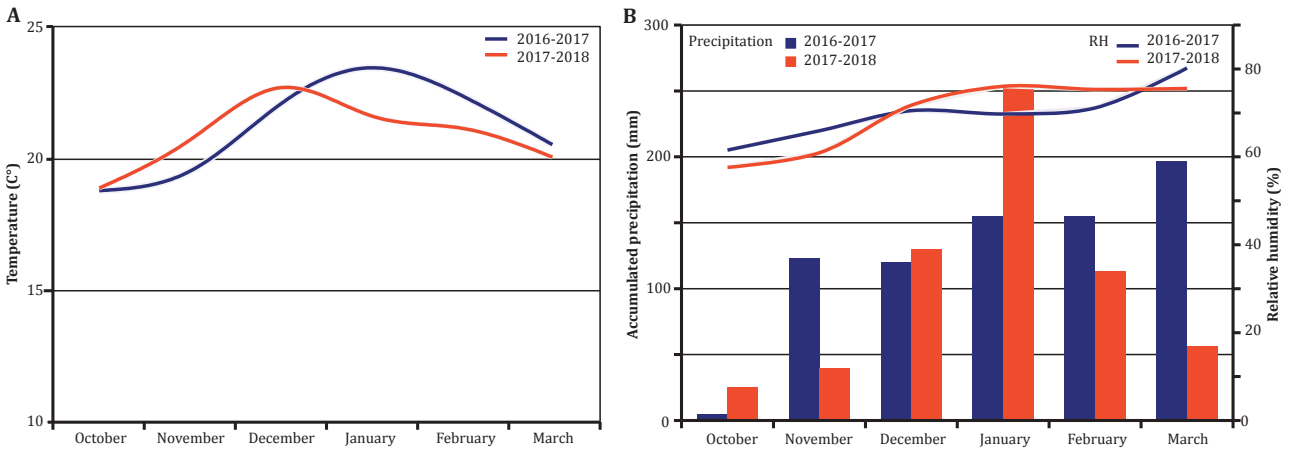


Figure 3. Expedition year characterization based on environmental data. **A.** Mean temperature from October to March for 2016-2017 and 2017-2018. **B.** Accumulated precipitation and relative humidity (RH) from October to March for 2016-2017 and 2017-2018.

Figura 3. Caracterización de los años de expedición sobre la base de datos climáticos**.** **A.** Temperatura media desde octubre a marzo para 2016-2017 y 2017-2018. **B.** Precipitación acumulada y humedad relativa (RH) desde octubre a marzo para 2016-2017 y 2017-2018.

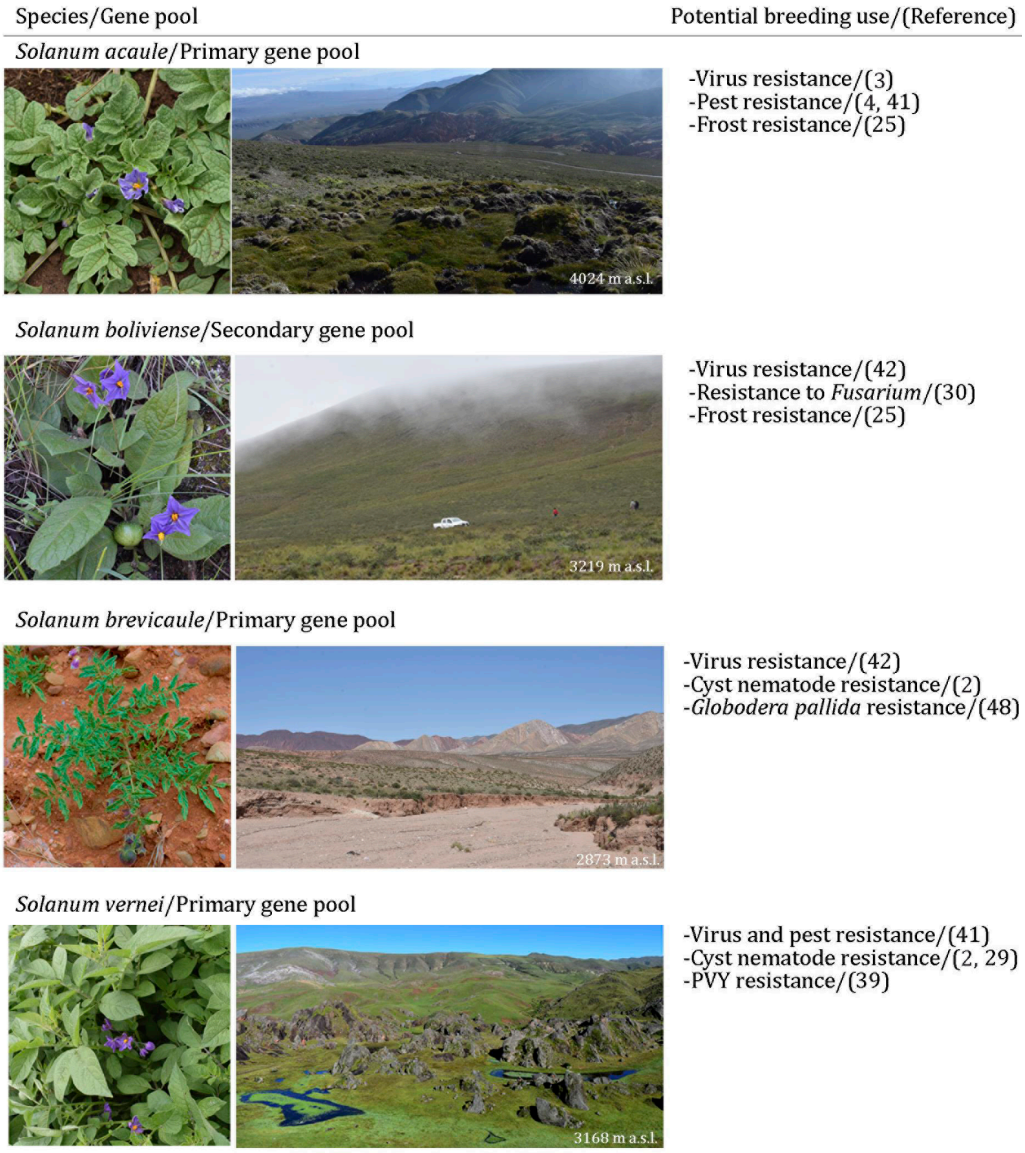


Figure 4. Representative plants and habitats of the four wild potato species monitored in Los Cardones National Park. *Solanum acaule*, Puna shrublands with high altitude peatlands; *Solanum boliviense*, Puna grassland; *Solanum brevicaule*, transition shrubland Monte-Puna; *Solanum vernei*, wet high-altitude Yungas grassland. According to the crossability with that cultivated potato the species are classified within the primary and secondary crop gene pool and in the four species several breeding interest characters have been described.

Figura 4. Fotos representativas de plantas y hábitats de las cuatro especies de papas silvestres monitoreadas en el Parque Nacional Los Cardones. *Solanum acaule*, arbustal puneño con vegas de altura; *Solanum boliviense*, pastizal puneño; *Solanum brevicaule*, arbustal de transición Monte-Puna; *Solanum vernei*, pastizal de neblina yungueño. De acuerdo con la posibilidad de cruzamiento con la papa cultivada, las especies se clasifican dentro del acervo genético primario y secundario del cultivo y en las cuatro especies se han descrito varios caracteres de interés para el mejoramiento genético.

For the cultivated species like *Solanum tuberosum* group *Andigenum*, clonal maintenance is required and *in vitro* conservation is implemented (12). There are 400 accessions of Andean potato landraces present in the genebank, mainly collected in the valleys and gorges of the Puna and Prepuna biogeographical provinces and also from local markets.

Local communities play a key role in the sustainability of any conservation program (20). Community based conservation programs apply different strategies to encourage participation and engagement of local communities and society in general, in order to achieve desired conservation goals. For example, some initiatives include the creation of socio-economic incentives for conservation and giving communities control over local natural resources (5). Changing individual or community behaviour is very complex but it is essential to achieve success in a conservation programme (36). In this sense, promoting a strategy of co-management which includes collaborative activities and interactions among local community of LCNP, Park Rangers, APN, INTA, and IBAM is fundamental to reach conservation goals in Protected Areas of Argentina, particularly in LCNP.

Development of this project has consolidated an interdisciplinary and intersectoral team. During 2017 and 2018 actions of communication, education, participation and awareness activities have been carried out. Two workshops were performed in the northwest branch office of Administration of National Parks (APN) in Payogasta, Salta. During the workshops advances in the project were exposed. A fruitful exchange of ideas and opinions was generated.

Currently, the groups are working together in initiatives related to environmental education. One of them is to develop an interpretive trail in Valle Encantado (a public and tourist site in the LCNP). Trail planning and layout were already done. Installation of interpretive panels is the next step. Workshops in local schools will be organized to promote knowledge and valorisation of wild and domesticated potatoes, which are part of our natural and cultural heritage. The interpretive trail in Valle Encantado will be used by tourists and also by the local school community.

Among the conservation values defined in the Management Plan for LCNP (1), the "useful or potentially useful plant genetic resources" were identified, including *Solanum* species. The presence of wild potato populations was known based on surveys carried out by INTA technicians (13). Years later, the implementation of the present program allowed increasing knowledge regarding the presence, diversity and geographic distribution of potato populations, thus cementing the basis for a specific conservation plan for this gene pool. It is important to emphasize that the existing populations are currently conserved in an indirect or passive way, through the protection of the habitats that contain them, and no concrete conservation actions on them are being undertaken.

Conclusions

The results of the two-year monitored populations represent a baseline for further strategy for long-term monitoring, which could require identifying threats and to develop mitigation measures, Only through a comprehensive conservation plan will be possible to consolidate the *in situ* Genetic Reserve of these populations.

The coming tasks may be summarized as follows: to study the morphological variability in the collected populations, pollen viability and sexual compatibility within and among collected populations and their genetic structure by molecular markers. Once all these issues are resolved, a monitoring and conservation strategy will be proposed and implemented for the *in situ* conservation of potato wild relatives in LCNP. Also, an adequate strategy for sampling populations for *ex situ* conservation in BAL genebank will be designed. Following this procedure, we hope to concretize one of the great challenges of the phytogenetic resources conservation: to reach the complementation between the *in* and *ex situ* conservation strategies.

References

1. Administración de Parques Nacionales. 2018. Plan de Gestión del Parque Nacional Los Cardones, Addenda y Anexos.
2. Bradshaw, J. E.; Ramsay, G. 2005. Utilisation of the commonwealth potato collection in potato breeding. Euphytica. 146: 9-19.
3. Bradshaw, J. E.; Bryan, G. J.; Ramsay, G. 2006. Genetic resources (including wild and cultivated *Solanum* species) and progress in their utilisation in potato breeding. Potato Research. 49: 49-65.
4. Bhardwaj, V.; Singh, B. P.; Khurana, S. P. 2016. Potato diversity and its genetic enhancement. In Gene Pool Diversity and Crop Improvement. Springer International Publishing. 187-226.
5. Brooks, J. S.; Waylen, K. A.; Mulder, M. B. 2012. How national context, project design, and local community characteristics influence success in community-based conservation projects. Proceeding of the National Academy of Sciences. 109: 21265-21270.
6. Cabrera, A. L. 1994. Regiones Fitogeográficas de Argentina. In A. L. Cabrera (Ed.), Enciclopedia Argentina de Agricultura y Jardinería. Buenos Aires, Argentina: ACME. Tomo II. Fascículo I. 185 p.
7. Cara, N.; Ferrer, M. S.; Masuelli, R. W.; Camadro, E. L.; Marfil, C. F. 2019. Epigenetic consequences of interploidal hybridisation in synthetic and natural interspecific potato hybrids. New Phytologist. 222: 1981-1993.
8. Cara, N.; Marfil, C. F.; Masuelli, R. W. 2013. Epigenetic patterns newly established after interspecific hybridization in natural populations of *Solanum*. Ecology and Evolution. 3: 3764-3779.
9. Castañeda-Álvarez, N. P.; de Haan, S.; Juárez, H.; Khoury, C. K.; Achicanoy, H. A.; Sosa, C. C.; Bernau, V.; Salas, A.; Heider, B.; Simon, R.; Maxted, N.; Spooner, D. M. 2015. *Ex Situ* Conservation Priorities for the Wild Relatives of Potato (*Solanum* L. Section Petota). PLoS ONE 10: e0122599.
10. CBD 1992. Convention on Biological Diversity: text and annexes. Secretariat of the Convention on Biological Diversity, Montreal: www.biodiv.org
11. Celis, C.; Scurrah, M.; Cowgill, S.; Chumbiauca, S.; Green, J.; Franco, J.; Main, G.; Kiezebrink, D.; Visser, R. G.; Atkinson, H. J. 2004. Environmental biosafety and transgenic potato in a center of diversity for this crop. Nature. 432: 222-225.
12. Clausen, A. M.; Ispizúa, V. N.: Digilio, A. 2010. Native andean potato varieties in Argentina: conservation and evaluation of an endangered genetic resource. The Americas Journal of Plant Science and Biotechnology. 3: 72-82.
13. Clausen, A. M.; Ispizúa, V. N.; Atencio, H. M.; Calandroni, M.; Digilio, A. 2018. Especies silvestres de papa (*Solanum* sect. Petota y sect. Etuberosum) identificadas en áreas protegidas de la Argentina. Boletín de la Sociedad Argentina de Botánica. 53: 67-75.
14. CWR (www.cwrdiversity.org/checklist/). Consult on 14th of March, 2019.
15. del Rio, A. H.; Bamberg, J. B.; Huaman, Z.; Salas, A.; Vega, S. E. 2001. Association of ecogeographical variables and RAPD marker variation in wild potato populations of the USA. Crop Science. 41: 870-878.
16. Dulloo, M. E.; Labokas, J.; Iriondo, J. M.; Maxted, N.; Lane, A.; Laguna, E.; Jarvis, A.; Kell, S. P. 2008. Genetic reserve location and desing. En: J. M. Iriondo, E. Dulloo y N. Maxted (Eds.), Conserving plant genetic diversity in protected areas. CAB International Publishing, Wallingford. 23-64.
17. FAOSTAT 2017. Food and Agriculture Organization of the United Nations. Available in: http://faostat3.fao.org/home.
18. Frankel O. H. 1970. Genetic conservation in perspective. In: Frankel, O.H., Bennett, A. (Eds.), Genetic Resources in Plants. Blackwell Scientific Publications. Oxford. Edinburgh. 469-489.
19. Garavano, M. E. 2018. Estudio de *Solanum commersonii* Dunal en un ecosistema serrano del Sistema de Tandilia (Buenos Aires) para implementar su conservación *in situ*. Tesis de maestría. Facultad de Ciencias Agrarias, Universidad Nacional de Mar del Plata. Buenos Aires. Argentina.
20. Grúňová, M.; Brandlová, K.; Svitálek, J.; Hejcmanová, P. 2017. Environmental education supports conservation action by increasing the immediate and long-term environmental knowledge of children in west Africa. Applied Environmental Education & Communication. 16: 3-16.
21. Harlan, J. R.; de Wet, J. M. J. 1971. Toward a rational classification of cultivated plants. Taxon. 20: 509-517.
22. Hawkes, J. G. 1970. Potatoes. In: Frankel, O. H.; Bennett, A. (Eds.), Genetic Resources in Plants. Blackwell Scientific Publications. Oxford. Edinburgh. 411-319.
23. Hawkes, J. G. 1990. The Potato: Evolution, biodiversity and genetic resource. Smithsonian Institution Press, Washington, DC.
24. Hawkes, J. G. 1994. Origins of cultivated potatoes and species relationships. In Bradshaw and Mackay (ed.). Potato Genetics, CAB International. Wallingford. UK. 3-42.
25. Hawkes, J. G.; Maxted, N.; Ford-Lloyd, B. V. 2000. The *Ex Situ* Conservation of Plant Genetic Resources. Kluwer. Dordrecht.
26. Hijmans, R. J.; Spooner, D. M. 2001. Geographic distribution of wild potato species. American Journal of Botany. 88: 2101-2112.

27. Huamán, Z.; Hoekstra, R.; Bamberg, J. 2000. The Inter-genebank potato database and the dimensions of "available" wild potato germplasm. American Journal of Potato Research. 77: 353-362.
28. Ibañez, V. N.; Berli, F. J.; Masuelli, R. W.; Bottini, R. A.; Marfil, C. F. 2017. Influence of altitude and enhanced ultraviolet-B radiation on tuber production, seed viability, leaf pigments and morphology in the wild potato species *Solanum kurtzianum* Bitter & Wittm collected from an elevational gradient. Plant Science. 261: 60-68.
29. Jansky, S. H.; Dempewolf, H.; Camadro, E. L.; Simon, R.; Zimnoch-Guzowska, E.; Bisognin, D. A.; Bonierbale, M. 2013. A case for crop wild relative preservation and use in potato. Crop Science. 53: 746-754.
30. Lynch, D. R.; Kawchuk, L. M.; Chen, Q.; Kokko, M. 2003. Resistance to *Fusarium sambucinum* in wild and cultivated *Solanum* species. American journal of potato research. 80: 353-358.
31. Marfil C. F.; Masuelli, R. W.; Davison, J.; Comai, L. 2006. Genomic instability in *Solanum tuberosum* x *Solanum kurtzianum in*terspecific hybrids. Genome. 49: 104-113
32. Marfil, C. F.; Camadro, E. L.; Masuelli, R. W. 2009. Phenotypic instability and epigenetic variability in a diploid potato of hybrid origin, *Solanum ruiz-lealii*. BMC Plant Biology. 9: 21.
33. Marfil, C. F.; Masuelli, R. W. 2014. Reproductive ecology and genetic variability in natural populations of the wild potato, *Solanum kurtzianum*. Plant Biology. 16: 485-494.
34. Marfil, C. F.; Hidalgo, V.; Masuelli, R. W. 2015. *In situ* conservation of wild potato germplasm in Argentina: Example and possibilities. Global Ecology and Conservation. 3: 461-476.
35. Maxted, N.; Hawkes, J. G.; Ford-Lloyd, B. V.; Williams, J. T. 1997. A practical model for *in situ* genetic conservation. In: Plant genetic conservation: the *in situ* approach (eds. Maxted, N.; Ford-Lloyd, B. V.; Hawkes, J. G.). Chapman & Hall. London. 339-367.
36. Nilsson, D.; Baxter, G.; Butler, J. R.; McAlpine, C. A. 2016. How do community-based conservation programs in developing countries change human behaviour? A realist synthesis. Biological Conservation. 200: 93-103.
37. Noé, Y. E.; Gonzalez, A. C., Elena, H. J.; Bianchi, A. R. 2012. Distribución geográfica de las lluvias en el noroeste de Argentina (región NOA). Ediciones INTA.
38. Okada, K. A.; Clausen, A. M. 1982. Natural hybridization between S*olanum acaule* Bitt. and *S. megistacrolobum* Bitt. in the province of Jujuy, Argentina. Euphytica. 31: 817-835.
39. Ortega, F.; Carrasco, A. 2005. Germplasm enhancement with wild tuber-bearing species: introgression of PVY resistance and high dry matter content from *Solanum berthaultii*, *S. gourlayi, S. tarijense* and *S. vernei*. Potato Research. 48: 97-104.
40. Quiros, C. F.; Ortega, R.; van Raamsdonk, L.; Herrera-Montoya, M.; Cisneros, P.; Schmidt, E. 1992. Increase of potato genetic resources in their center of diversity: The role of natural outcrossing and selection by the Andean farmer. Genetic Resources and Crop Evolution. 39: 107-113.
41. Ross, H. 1986. Potato breeding. Problems and perspectives. In: Fortschritte der flanzenzüchtung, vol. 13. Paul Parey. Berlin. Hamburg.
42. Ruiz de Galarreta, J. R.; Carrasco, A.; Salazar, A.; Barrena, I.; Iturritxa, E.; Marquinez, R.; Ritter, E. 1998. Wild *Solanum* species as resistance sources against different pathogens of potato. Potato Research. 41: 57-68.
43. Sajama, M. J. 2017. Los parientes silvestres de la papa en el noroeste de Argentina: distribución geográfica, amenazas y conservación. Tesis doctoral. Facultad de Ciencias Naturales y Museo. Universidad Nacional de La Plata. Buenos Aires. Argentina.
44. Sánchez, M. E. 2009. Línea base de vegetación del Parque Nacional Los Cardones - Salta. Argentina. Tesis de grado. Facultad de Ciencias Naturales. Universidad Nacional de Salta. Salta. Argentina.
45. Sánchez, M. E.; De Gracia, J. N.; Quiroga Mendiola, M. 2015. Guía visual de plantas nativas del Parque Nacional Los Cardones: Valles Calchaquíes, Salta-Argentina. Artes Gráficas S. A., Salta Capital. 52 p.
46. Scurrah, M.; Celis-Gamboa, C.; Chumbiauca, S.; Salas, A.; Visser, R. G. F. 2008. Hybridization between wild and cultivated potato species in the Peruvian Andes and biosafety implications for deployment of GM potatoes. Euphytica. 164: 881-892.
47. Ugent, D. 1981. Biogeography and origin of *Solanum acaule* Bitter. Phytologia. 48: 85-95.
48. Uhrig, H.; Wenzel, G. 1981. *Solanum gourlayi* Hawkes as a source of resistance against the white potato cyst nematode *Globodera pallida* Stone. Zeitschriftfiir Pflanzenzfichtung. 86: 148-157.

Acknowlegements

PCK and IVN are fellows of the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina. This work was supported by Agencia Nacional de Promoción Científica y Tecnológica (PICT-2016-110), SECTyP UNCuyo (2016-2018/A057) and REDGEN 1137021, Plan de gestión de recursos fitogenéticos -INTA (2014-2018). We are grateful to Los Cardones National Park's Park Ranger Team for their valuable assistance in the field.