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Ancient Potato Varieties of the Canary Islands: Their History, Diversity and Origin of the Potato in Europe

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Abstract

The journey of the potato (*Solanum tuberosum* L.) from South America to the rest of the world has generated a prolific literature regarding the discovery of this crop, its early consumption and cultivation in the Old World. An important part of that literature concerns the Canary Islands. The islands were the only exception to the Spanish trade monopoly with the New World, which reserved Seville as the only port for imports and exports to the colonies. The first potatoes to arrive from America, both from the Andes and the Chiloé archipelago, passed through the Canary Islands, and it is likely that the islands were initially the place where this crop became acclimatised. The orography, the volcanic soils, the climate and the intermediate photoperiods of the islands contributed to the acclimatisation of potatoes that came from various origins of America. The current biodiversity of potatoes in the Canary Islands includes different cultivars, such as local ones that arrived from South America after the conquest, which have evolved on the islands and are taxonomically classified as *Solanum* ssp. *tuberosum*, *Solanum* ssp. *andigena* and *Solanum chaucha*. These potatoes have been preserved by farmers, generation after generation, with between 600 and 800 ha being devoted to their cultivation (mainly on the island of Tenerife), in a traditional way, though with low productivity, often due to high virus pressure. This article traces the history of ancient potatoes in the Canary Islands and investigates in depth the introduction of potatoes in Europe through the Canary Islands. It contributes to describing the cultivated plant genetic resources of the *Solanum* spp. as well as their current situation and cultivation. It also describes traditional cultivation practices, the importance of the in situ conservation of theses varieties and the threats that affect them such as the Guatemalan potato moth.

Keywords Biodiversity · Canary Islands · In situ conservation · Landraces · Plant genetic resources · *Solanum*

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Fig. 1 Geographical location of the Canary Islands

Introduction

The Canary Island archipelago (Spain) consists of eight islands in the Atlantic Ocean (Figure 1) located at approximately 28° N latitude near the Tropic of Cancer. Interestingly, this location is similar to the southern latitude of the Tropic of Capricorn in northern Argentina, which represents the southern limit of native Andean potatoes found in the Andean highlands from eastern Venezuela to northern Argentina. Today, some 30 ancient varieties with unique characteristics are still grown in the Canary Islands. Indeed, these varieties have been maintained and cultivated for 450 years, allowing them to be conserved and evolve towards great diversity. In fact, except in South America, these ancient varieties can only be found in the Canary Islands. Between 600 and 800 ha are devoted to their cultivation. Approximately 95% of this area is on the island of Tenerife, with much smaller areas on the islands of La Palma and Lanzarote (Ríos et al. 1999; Ríos Mesa et al. 2013). The orography, soil conditions and climate of the Islands have contributed to their adaptation. Potatoes are planted between 300 and 1500 m altitude, in areas of dense cloud cover. Most of the local varieties are for the fresh market and are consumed locally, but there is potential for market differentiation as heirloom potatoes because of their unique colours and their morphological and organoleptic characteristics. In addition, some 4000 ha in the Canary Islands are devoted to the cultivation of recently introduced commercial varieties for the local market (Estadística Agraria y Pesquera de Canarias 2020). This article, after describing the origin of the potato, traces the history of ancient potatoes in the Canary Islands since their arrival from the Andean or Chiloé areas of

South America. It also analyses the characteristics of these varieties, which are still cultivated, and their specific genetic diversity, integrating morphological, molecular and agronomic data. The article also hypothesises about the existence in the Canary Islands of a possible secondary diversity centre for South American potatoes in Europe. Undoubtedly, the ancient potatoes of the Canary Islands are part of the heritage and origin of the potatoes that arrived in Europe in the sixteenth century. These potatoes are protected by the European recognition of the Denomination of Origin *Papas Antiguas de Canarias* (Official Journal of the European Union L 302 2012).

However, this potato biodiversity is threatened by the damage caused by the Guatemalan potato moth (*Tecia solanivora* Povolny) that was introduced to the Canary Islands from South America in 1999 (Ríos Mesa et al. 2020; Lobo et al. 2021) and whose damage to the crops often exceeds 50% of production.

Origin and Domestication of the Potato

The potato has more related wild species than any other cultivated plant in the world. Several hundred species of wild and cultivated tuber-forming potatoes (*Solanum* sect. Petota) have been described from the southwestern USA to southern Chile (Correl 1962; Hawkes 1978). In the taxonomic review of Hawkes (1990), 235 wild tuber species and 7 cultivated species were recognised as forming a polyploid series ranging from diploids (2n = 2x = 24) to hexaploids (2n = 6x = 72). According to Spooner and Hijmans (2001), there are many synonyms within these 235 wild species, which would reduce the number of different wild species to 199.

The first potatoes originated in the Andes, specifically in southern Peru and northern Bolivia around Titicaca Lake (Hawkes 1990). Cultivation originated in these areas about 10,000 years ago. According to Ugent (1970), ancient potato varieties have been cultivated in the terraced valleys of the ancient capital of the Inca empire, Cuzco, where the land is extremely rugged, thus conditioning a series of ecological niches that have favoured a great diversity of cultivars. Of them, those that had short stolons, as well as large tubers with good flavour and texture, were selected, and also, they did not have glycoalkaloids, such as solanine, in the tuber (Matsubayashi 1991). Glycoalkaloids are toxic and harmful components if consumed in large quantities. Hawkes (1967) considers that *S. stenotomum* might have been the first domesticated species, as attested by the high similarity between some of its cultivars and certain wild species, and even considers the possibility that certain diploid cultivated species such as *S. phureja* and *S. goniocalix* might be derived from selections of *S. stenotomum* towards short dormancy and better taste, respectively.

According to Hawkes (1990), there are 7 cultivated species, including 7 subspecies, belonging to the subgenus Potatoe, section Petota, subsection Potatoe and genus *Solanum*. However, this classification has been discussed at length by other taxonomists, and there are important discrepancies among them (Spooner and van den Berg 1992). Taxonomists of the Russian school, Bukasov (1971) and Lechnovich (1971), determine the existence of 21 cultivated species, separating *S. tuberosum* from *S. andigena*, both considered as subspecies of *S. tuberosum* by Hawkes (1990). Ochoa (1990; 1999) recognises nine species and

141 subspecies, varieties and forms. All these taxonomists classify cultivated potatoes under the guidelines of the International Code of Botanical Nomenclature (ICBN; Greuter et al. 1999). However, Dodds (1962) classifies cultivated potatoes under the International Code of Cultivated Plants (ICNCP; Trehane et al. 1995), determining the existence of 3 species with 5 groups. A reclassification of native South American potato cultivars by Huaman and Spooner (2002) recognises a single species, *S. tuberosum*, with eight cultivar groups: Ajanhuiri group, Andigena group, Chaucha group, Chilotanum group, Curtilobum group, Juzepczukii group, Phureja group and Stenotomum group. Within a short period of time, Spooner et al. (2007) proposed a new reclassification of cultivated potatoes into four species: (1) tuberosum with two groups of cultivars (the Andigenum group of Andean highland genotypes containing diploids, triploids and tetraploids, and the Chilotanum group of native Chilean lowland tetraploid varieties); (2) *S. ajanhuiri* (diploid); (3) *S. juzepczukii* (triploid) and (4) *S. curtilobum* (pentaploid). Gavrilenko et al. (2010) examined the Russian National Collections of Cultivated Potatoes at the N. I. Vavilov Institute using morphological characteristics and SSR, obtaining similar results in species recognition for *S. tuberosum*, *S. curtilobum* and *S. juzepczukii* but failed to distinguish *S. ajanhuiri* from other taxa.

After Spaniards conquered Peru in the sixteenth century, they brought the potato to Europe. Some authors believe that the ssp. *tuberosum* that predominates in Europe is derived from ssp. *andigena* due to its adaptation to a long day length (Salaman 1985). However, there is evidence that the varieties cultivated in Europe are descended from imports of potatoes from the island of Chiloé in Chile belonging to ssp. *tuberosum* (Grun 1990). The latest work on the origin of potatoes in Europe by Ames and Spooner (2008) established scientific evidence that potatoes of ssp. *andigena* persisted in Europe at least until 1892, i.e. after the late blight (*Phytophthora infestans* (Mont.) de Bary) disaster in Irish potato crops, and that potatoes from Chiloé existed in Europe prior to this. A similar conclusion can be drawn from the work of Ríos et al. (2007). Native potatoes of ssp. *tuberosum* are grown from western Venezuela to northern Argentina in the Andean Cordillera (Andean populations), and in the Chiloé and Chonos archipelagos towards southern Chile (Chilean populations) (Ovchinnikova et al. 2011). This subspecies is less common in Andean South America, where *Solanum tuberosum* ssp. *andigena* is the most important potato. However, potatoes of ssp. *tuberosum* predominate in most of southern Chile. Esnault et al. (2014) confirm the genetic closeness of current commercial potato varieties from Europe and America to native Chiloé potatoes (ssp. *tuberosum*), compared to potatoes of ssp. *andigena*.

Solanum chaucha (Fig. 2) for Marks (1966) is the triploid with the greatest variability. For Ochoa (1975), this triploid species is between a diploid and tetraploid. Hawkes (1990) considers that its distribution ranges from central Peru to central Bolivia at high altitudes. A very interesting study of this species in the Peruvian environment can be found in Ochoa's study of it in 1975.

Fig. 2 *Solanum chaucha* in the world collection of the International Potato Centre (CIP) in Huancayo, Peru

History of Potatoes in the Canary Islands

The world's first known description of potatoes is from the expedition of Licenciado Gonzalo Jiménez de Quesada, who arrived in the Grita valley in the province of Vélez, Colombia, in April 1537 and found potatoes in Sorocota, a Chibcha village on the River Suárez to the west of Moniquira. The account written by the anonymous conquistador states (Ruíz de Galarreta and Ríos 2008):

> ...the food of these people is like that of other parts of the Indies and some more, because their main food is corn and yucca, without these they have two or three types of plants which they use a lot for their food, some of which are like earth peat, which they call yomas, and others like turnips which they call cubias, which they add to their stews and are a great source of food for them. (Epitome of the New Kingdom of Granada 1920)

This account was expanded by Gonzalo Fernández de Oviedo in "*Historia general y natural de las Indias*".

Two years later, on 20 March 1539, the first bishop of Cuzco, Fray Vicente Valverde, wrote a letter to Emperor Charles V (*Archivo General de Indias, Patronato*, 192, N.1, R.19) in which he literally quotes the word papas and describes the Andean tuber as follows:

> ...potatoes which are things like earthen turmeric but bigger. And they don't taste as good. They call these dried roots chuño. And these are kept in very cold lands, such as "encollao" where they cannot pick corn.

Twelve years later, the conquistador of Chile, Pedro de Valdivia, in another letter to Emperor Charles V, dated 25 September 1551, wrote the following (Toribio Medina 1929):

> ...abundant with all the produce that the Indians sow for their sustenance, as well as corn, potatoes, quinoa, mare, garlic and beans....

As for the introduction of the potato in the Canary Islands, it could have taken place before the dates that have been published so far, probably between 1550 and 1560 (Ochoa and Salas, personal communication), which seems to agree with the dates of the first references to the potato by the Spaniards in South America. However, to date, the most reliable citations are those referring to the sixties of the sixteenth century (Table 1).

Until a few years ago, the earliest citation of potatoes in continental Europe was found by Hamilton (1934), later cited by Salaman (1949) and Hawkes and

Table 1 Key dates in the history of potato (*Solanum tuberosum* L.) in the Canary Islands

Date	Events
1532	Pizarro discovered Peru
1537	The potato without mentioning it explicitly is described by Spanish explorers
1539	The potato is described for the first time by the Archbishop of Cuzco Fray Vicente Valverde in a letter to Emperor Carlos V
1551	The potato is mentioned in Chile by Pedro de Valdivia among other agricultural products in a letter to Emperor Carlos V
1560	Probable first record of the potato in the Canary Islands, although it is not clear if it was *Solanum* sp. or *Ipomoea batatas*
1567	Potato was first documented from the Canary Islands (Grand Canary Island) for shipment to Antwerp, Belgium. It was also documented for consumption. Hawkes and Francisco-Ortega (1993) speculated that potato was brought to the Canary Islands as early as 1562
1573	First mention of potato consumption in continental Spain
1622	First record of potatoes arriving in Tenerife from a known place (Peru) and planted by Juan Bautista de Castro
1776	Potatoes were documented as the second most important crop for the Canary Islands (after wine grapes)
1800	First record of seed potato (tuber-stock for planting) imported from Europe (Holland) to the Canary Islands
1868	Alvarez-Rixo (1868) described 20 cultivars of Canary Island potatoes; most of their names are still in use there
Today	50 ancient varieties are still maintained and cultivated

Source: Adapted from Rios et al. (2007)

Francisco-Ortega (1992). Hamilton found the date 1573 in the account books of the Hospital de la Sangre de Sevilla in the *Archivo Hispalense* as the earliest citation of the arrival of potatoes in continental Europe. Hawkes and Francisco-Ortega (1992) added to Hamilton's suggestion that potatoes had been purchased by the hospital in December, which would indicate that they had been harvested in Spain, as it is highly unlikely that potatoes harvested in South America in March–April would have been consumed in Europe after September.

However, in the Canary Islands, the probable first mention of potatoes is made by the Portuguese author Gaspar Frutuoso in his description of the Canary Islands in Book I of "*Saudades da Terra*". According to the Spanish translator of this work, Professor Pedro N. Leal Cruz, the quotation made in this book for the islands of La Gomera and La Palma may have been the first text in Portuguese to use the term "*batata*" for "potato" (Leal Cruz 2004). This contribution by Frutuoso could be dated between 1960 and 1963.

> ...On the island of La Gomera, ..., and the island of La Palma are the only ones that have potatoes....

So far, the oldest reference to potatoes in Europe, and the one that has had the widest dissemination worldwide, dates from November 1567, in which a notary publicly attests to the shipment of goods from Gran Canaria to Antwerp (Lobo-Cabrera 1988).

> ...And I will also receive three medium-sized barrels which you say carry potatoes and oranges and green lemons.

Lobo Cabrera (1988) believes that these potatoes must have been planted around 1560, while Hawkes and Francisco-Ortega (1993) place it in 1562, as they estimate that at that time about 5 years of cultivation would be necessary to produce enough potatoes for export. A further citation of the potato in the Canary Islands is as follows (Hawkes and Francisco-Ortega 1993):

> ... . Two barrels of potatoes and eight (...) full of brandy came from Tenerife.

In these texts, it might be interesting to verify whether it is potato (*Solanum* sp.) and not sweet potato (*Ipomoea batatas* L.), since the use of the word potato and sweet potato were both used for the Convolvulaceae until the eighteenth century (Régulo Pérez 1973).

Potatoes were undoubtedly a commodity subject to trade, which would explain their early passage through the Canary Islands. It should not be forgotten that from the outset, the Canary Islands enjoyed an exception to the rigid monopoly of Andean trade, which reserved a single port on the Spanish mainland (Seville) for imports and exports to the colonies, through which everything brought in or taken out of America had to enter or leave. This exceptionality, which allowed the ports of the Canary Islands to be a transit and docking route between Europe and America, can initially be explained by the need to supply the Indies and the natural advantage of doing so from the nearest Castilian territory (Peraza de Ayala 1977).

On the introduction and cultivation of potatoes in the Canary Islands, Bandini (1816) describes what is set out in manuscripts not published until 1866, but written

prior to 1799, in Viera y Clavijo's *Diccionario de Historia Natural de las Islas Canarias* (Dictionary of the Natural History of the Canary Islands). Viera y Clavijo (1866) mentions that it was D. Juan Bautista de Castro (in Bandini's text there is an error in the surnames) who planted potatoes on his lands in Icod el Alto (Fig. 3), having brought them from Peru in 1622. Bandini (1816) puts the production of potatoes in the Canary Islands at 127,697 *fanegas* (a measure of weight equivalent to 70 kg), as well as determining the presence of potatoes on the seven islands of the archipelago.

The potatoes that exist today on the European continent differ significantly from those first entries, as farmers and breeders have been selecting the most suitable cultivars with the best quality and yields. Yet in the Canary Islands, the process has not been the same, as there are many local cultivars that resemble those of the Andean countries or those cultivated in the Chiloé archipelago, and which have been multiplied by farmers, generation after generation. This suggests that they are descended from the first tubers that came to the islands from the Americas (Huaman 2000, personal communication; Ríos 2002; Ríos et al. 2007).

In the eighteenth century, potatoes started to become one of the most important foods in the diet of the Canary Islanders. According to Sánchez-Manzano (1984), the quantity and quality of the potato harvest affected the price of another staple food, wheat. The expansion of the American tuber in the Canary Islands coincided with the wine-growing crisis. The importance of the crop at the end of the seventeenth and beginning of the eighteenth century can be seen if we consider the

Fig. 3 Ancient potato cultivation terraces in Icod El Alto, Tenerife

moment from which a potato tithe was identified as one of those paid to the Church. Yet, according to Macías Hernández (1986), in Gran Canaria, it was not until 1809 that potatoes could be seen outside the group of "*huertas y pollos*", whereas in Tenerife, from 1681 onwards, we find them separate from the aforementioned group. In the Memoirs of Lope Antonio de la Guerra i Peña, Perpetual Alderman of the Island of Tenerife for the years 1778 and 1779, he mentions the importance of this crop:

> Potatoes, according to what has been done to increase their plantation, can be considered the second most important crop [after vines]. Notebook III. Pp. 56
> Potatoes are another of the crops that abound, and which have increased a lot in recent years (...). The poor people feed themselves a lot with this fruit. Notebook III. Pp. 20

In 1781, Lope Antonio de la Guerra i Peña also wrote that this crop had become very important among the working classes of the islands:

> The harvest of millet and legumes was good, with which the poor, whose main food is usually gofio de millo and potatoes, have been remedied. Cuaderno III. P. 72

Similarly, D. José de Bethencourt y Castro, in 1800, indicates that the poor, "... *prefer a fanega of potatoes to any other grain*" (Rodríguez Mesa 1992).

In the mid-nineteenth century, Madoz's Dictionary (Madoz 1845) reported the existence of potatoes in Gran Canaria "*...very sweet, yellowish in colour and with an exquisite taste...*" (Rodríguez Brito 1992).

The former mayor of Puerto de la Cruz, in Tenerife, Agustín Álvarez Rixo, in his study on potatoes "*Las Papas: memoria sobre su introducción, cultivo, importancia notable de su producto en las islas, y recomendable cualidad para los navegantes por ser dicho tuberculo eficaz preservativo contra la enfermedad del escorbuto*" (Potatoes: report on their introduction, cultivation, notable importance of their product in the islands, and recommendable quality for sailors as an effective protection against scurvy disease) (Álvarez Rixo 1868) lists cultivars such as Melonera, Peluquera, Negra del Sur, Bonitas, Blanca del Ojo Azul and Sietecueros, distinguishing them according to the time of year when the tubers are harvested: between "*summer, winter and in-between*".

The Santa Úrsula Archives contain data on the arrival of seed potatoes in the nineteenth century from Ireland, Holland and England, and from Lanzarote and Fuerteventura (Rodríguez Brito 1992).

As already mentioned, the first historical data, between1560 and 1567, on the presence of potatoes in the Canary Islands are prior to the first date of entry of potatoes into Europe (1573). These first cultivars could have belonged to ssp. *andigena*, both from the descriptions and from the herbariums preserved.

Also, according to Hawkes and Francisco-Ortega (1993), a ship carrying Chiloé potatoes (ssp. *tuberosum*) was not able to reach Europe with their potatoes in good condition, which is further confirmed by the fact that a direct trip through the Strait of Magellan did not take place until 1579. However, Ríos et al. (2007) question this probable origin, determining a high probability that there could have been potato

cultivars in the Canary Islands that were introduced in parallel from the Andes and Chiloé, making it difficult to determine the specific origin of all the potato cultivars that are grown on these islands today. Also, as Spooner and Hetterscheid (2005) state, potatoes could have been brought to Europe not only as tubers, but also as pot plants or sexual seeds, which was very likely at the time. Everything seems to indicate that both potatoes from the Andes and Chiloé arrived in the Canary Islands during these first introductions, and that both adapted perfectly to the different agro-ecosystems with very varied agro-climatic conditions and altitudes.

First Morphological and Taxonomic Studies of Canary Island Potatoes

The first descriptions of cultivars appear in the literature of the Canary Islands in 1816 when Bandini, in *Lecciones Elementales de Agricultura: teórica, práctica y económica* (Elementary Lessons in Agriculture: Theoretical, Practical and Economic), states:

> There are many varieties: early and late; with white, pink, ashy or blue flowers; with a white, brown, yellow, red, red or purple skin; round, long, oval, cornered, with excrescences....

In the "*Diccionario de Historia Natural de las Islas Canarias*", Viera y Clavijo (1866) describes some potatoes from the end of the seventeenth century as follows:

> ...according to the variety of their castes, some are pale-skinned, others purple, others reddish, others yellowish.

According to Hernández (2000), potatoes shared cultivation areas with millet, vegetables and legumes, occupying an important area from the seventeenth century onwards, as it was a crop that allowed for several harvests a year and was soon incorporated into the basic diet. According to this author, many local varieties were planted, some of which have disappeared or are on the verge of disappearing. He also considers that in 1772, the Steward of the Hacienda de las Palmas de Anaga (a hamlet located in the Anaga massif in Tenerife) was referring to the old variety of Mora potato (*Solanum tuberosum* ssp. *tuberosum*) when he said:

> ...as for the purple potatoes, I owe eleven bushels and my friend Salbador a bushel and a half. I have ordered them from Francisco Meliá, who said he would tell me when to go for them.

This quotation is of enormous importance for the origins of the local potatoes of the Canary Islands, since it is a potato of the ssp. *tuberosum* cited long before the Irish famine occurred that would indicate that already in the eighteenth century there was coexistence of Andean potatoes with Chiloé potatoes in the Canary Islands.

In the "*Tratado sobre el Cultivo, Uso, y Utilidades de las Patatas o Papas*" by Enrique Doyle (1797), there are already morphological and agronomic differences in the cultivars described in the Canary Islands:

> …in the Canary Islands three crops of potatoes are planted and harvested each year. The first are planted in January and harvested at the end of July, which are called 'veraneras' (summer ones). The second, which are called 'tempranas' (early ones), are planted in September and harvested in December. Others, which are called 'las de Mayo' (May ones), are planted in November and harvested in the month of May.

It is very important to note that Doyle describes several growing cycles with different durations, between 4 and 6 months, which indicates the coexistence of different genotypes with different physiological characteristics.

Some of the cultivars cited by Álvarez Rixo (1868) in his magnificent memoir on potato cultivation in the Canary Islands coincide in their names with the current cultivars: Negra del Sur, Blanca del Ojo Azul, Melonera or Amarillosa, Blanca Rosada that they say Peluquera, Triste or Violada, Blanca Montañera, Colorada Montañera, Borralla, Violet or Morada, Blanca con Vetas Encarnadas or Ojo de Perdiz, Blancas con Vetas Violadas, Sietecueros, Encarnada Sucia, Canaria Encarnada con Ojos Blancos, Londreras and Norteras, Londreras and Norteras de Color Acarminado, Encarnadas de Lanzarote or Bonitas and Moradas de Lanzarote.

Much later, in 1955, Zubeldia et al., in their work, *Estudio, Descripción y Clasificación de un Grupo de Variedades Primitivas de Patata Cultivadas en las Islas Canarias* (Study, Description and Classification of a Group of Primitive Potato Varieties Cultivated in the Canary Islands) confirmed the presence of seven cultivars belonging to *Solanum tuberosum* ssp. *andigena* (Torrenta, Bonita, Bonita Ojo de Perdiz, Bonita Colorada, Bonita Negra and Torrenta or Bonita Sietecueros), two cultivars of *Solanum tuberosum* ssp. *tuberosum* (Peluca Rosada and Moruna) and a triploid cultivar taxonomically included in the species *S. mamilliferum*, known locally as Negra, today part of the heterogeneous group of the species *S. chaucha*, which was later confirmed by Hawkes and Francisco-Ortega (1993) (Table 2).

Chico (1986) confirms what was established by Zubeldia et al. (1955) by pointing out the presence of more recently introduced cultivars, probably from South America due to the high migratory flows to the Canary Islands. The short dissertation on the taxonomic classification of the black potato (triploid) at the end of his work is very interesting.

Table 2 Varieties, species and subspecies described by Zubeldía et al. (1955)

Species or subspecies	Cultivars	Ploidy
S. tuberosum ssp. *andigena*	Torrenta, Bonita, Bonita Ojo de Perdiz, Bonita Colorada, Bonita Negra and Torrenta or Bonita Sietecueros	4x
S. tuberosum ssp. *tuberosum*	Peluca Rosada and Moruna	4x
S. chaucha	Negra	2x

Marrero (1992; 2007), in the first ethnobotanical work carried out through interviews with farmers, establishes a classification of cultivars for the whole of the Canary Islands, differentiating between:

a) Autochthonous cultivars of the Andígena group, derived from the first ones that arrived in the Canary Islands from the middle of the sixteenth century. Marrero includes here Azucenas, Coloradas (synonyms: De Baga, Baga Colorada or Bonita Rosada Tardía), Bonitas (synonym: Marruecas), of various types (Blanca, Colorada, Negra, Ojo de Perdiz), Corralera, Blanca Yema de Huevo (synonym: Blanca Yema de Huevo), Negra Yema de Huevo (synonym: Papa de Huevo), Negra Yema de Huevo (synonym: Papa de Huevo), Negra Yema de Huevo (synonym: Papa de Huevo), Palmeras, Borralla and Torrenta triploid cultivar Negra (synonyms: Negra Ramuda, Negra del Sur, Negra Yema de Huevo) related to *S. mamilliferum*.
b) Current South American cultivars of the Andigena group, which in the last decades have arrived from different regions of Venezuela, Colombia, etc. The cultivars cited are Andina, Brasileña, Caraqueña, Colombiana and Venezolana. Moreover, the cultivars Venezolana and Andina were brought from Venezuela by emigrants returning from the State of Mérida at the end of the 1970s and beginning of the 1980s.
c) Autochthonous cultivars of the Tuberosum group arrived from Europe around the eighteenth and nineteenth century.
d) Traditional European commercial cultivars of the Tuberosum group, coming from England, Holland, Ireland, ...
e) Current commercial cultivars of the Tuberosum group whose "seed" comes from Northern Europe (Northern Ireland, Republic of Ireland, Scotland and Denmark) and in recent years from Cyprus and Egypt.

Marrero (1992, 2007) does not establish any group of potatoes originating from Chiloé, as he considers that all the autochthonous cultivars of the Tuberosum group originated in Europe. With regard to group b established by Marrero (1992, 2007), it should be noted that the cultivar known as Venezolana or Andina Negra, which comes from Venezuela, specifically from the region of Mérida, and whose most outstanding morphological characteristic is its purple tuber with light brown eyes, is an improved variety based on an isogenic population with different resistances (frost, fungal diseases, etc.) achieved in Venezuela by Dr Mittelholzer in the early 1970s, from selected material of *S. tuberosum* ssp. *andigena*, which was called Merideña (Estrada-Ramos, personal communication).

Álvarez and Gil (1996) confirm that the cultivars studied by Zubeldia et al. (1955) are still present in the fields of Tenerife. Gil (1997), based on Zubeldía et al.'s description, places the following cultivars within ssp. *andigena*: Terrenta, Azucena Negra, Azucena Blanca, Borralla, Bonita Blanca, Bonita Negra, Bonita Llagada, Bonita Colorada, Bonita Ojo (de) Perdiz and Colorada de Baga. Cedrés (1998) preliminarily confirms the triploidy of the Negra variety, placing it within the *Solanum chaucha* species.

Álvarez and Gil (1996); Gil (1997) classify and locate the cultivars of Tenerife, differentiating: (1) potatoes corresponding to local varieties whose age is unknown, which belong in principle, due to their morphological characteristics, to ssp. *andigena* or to the species *Solanum* × *chaucha*; (2) potatoes introduced during the twentieth century, probably from the UK, whose seed has not been imported for many years and are preserved only by the work of the farmers themselves; (3) potatoes brought more recently by emigrants returning from South America and (4) recently imported potatoes, which are still in use today.

Using the microsatellite technique, Pérez et al. (1999) determined the differences between the Peluca Negra, Negra, Palmera Negra and Borralla cultivars and compared them with the commercial variety King Edward. These authors found that the Negra and Borralla cultivars on one side, and Peluca Negra and Palmera Negra on the other, were grouped together, and that both groups are very clearly united and differentiated from the commercial variety King Edward.

Rodríguez (2000) makes a basic morphological characterisation of 14 local cultivars from the island of Tenerife: Azucena Blanca, Azucena Negra, Bonita Blanca, Bonita Colorada, Bonita Llagada, Bonita Ojo de Perdiz, Bonita Negra, Colorada, Torrenta, Borralla, Mora, Negra, Andina Blanca and Andina Negra. Based on this characterisation, he maintains that 11 of these cultivars have characteristics of ssp. *andigena* and 2 (Mora and Borralla) have characteristics of both ssp. *andigena* and ssp. *tuberosum*. A chromosome count of the 14 cultivars confirms the triploidy of the Negra cultivar and the tetraploidy of the rest of them. Gil et al. (2000) published data sheets with the basic characterisation of the cultivars studied by Rodriguez (2000).

Regarding potatoes from other islands, Gil and Peña (2007) make a basic characterisation of the potatoes from the island of Lanzarote, determining the existence of four varieties of potatoes that farmers consider ancient varieties, although without determining their taxonomic location.

The Morphology of Canary Island Potatoes by Means of Numerical Taxonomy Studies

The first morphological studies of Canary Island potatoes using numerical taxonomy methods were carried out by Ríos (2002) using 52 qualitative and quantitative characteristics, mostly coded and metric, proposed by Huaman in several publications. With similar approach to that of Huaman and Spooner (2002), Ríos (2002), after 3 years of characterization (one preliminary and two exhaustive), prepared groupings of 41 entries of potatoes from Tenerife (Table 3, shown in Fig. 4). A cytogenetic study of the entries was also carried out according to the methodology of Watanabe and Orillo (1991; 1993), determining their ploidy.

In this study, an excellent correlation was found between the groups obtained by cluster analysis and the popular classification made by farmers, as shown in Fig. 4.

In the same work, Ríos (2002) performed a principal component analysis (PCA). Figure 5 shows the results of the first two principal components, with component 1 having a greater contribution to characteristics of length of the

Table 3 Tenerife Island entries characterised by Ríos (2002)

Common name	Zone	Municipality	Coded name	Chromosome number
Bonita Blanca	Benijos	La Orotava	BbO	48
Bonita Negra	Benijos	La Orotava	BnO	48
Bonita Colorada	Benijos	La Orotava	BcO	48
Bonita Ojo de Perdiz	Benijos	La Orotava	BpO	48
Colorada de Baga	Benijos	La Orotava	CoO	48
Azucena Negra	El Pastel	Tacoronte	AnT	48
Azucena Blanca	El Pastel	Tacoronte	AbT	48
Blanca Negra	El Pastel	Tacoronte	NbT	36
Colorada de Baga	Las Rosas	El Rosario	CoE	48
Terrenta	La Esperanzsa	El Rosario	T-E	48
Negra Yema de Huevo	La Esperanza	El Rosario	N-E	36
Azucena Negra	El Palmar	Buenavista	AnB	48
Melonera	Teno Alto	Buenavista	MIB	48
Peluca Blanca	Teno Alto	Buenavista	LbB	48
Peluca Negra	Teno Alto	Buenavista	LnB	48
Bonita Negra	Palo Blanco	Los Realejos	BnR	48
Marrueca Blanca	Palo Blanco	Los Realejos	MbR	48
Peluca Rosada	Los Charcos	La Matanza	LrM	48
Bonita Negra	Fuente Grande	La Guancha	BnG	48
Bonita Llagada	Fuente Grande	La Guancha	BIG	48
Bonita Ojo de Perdiz	Fuente Grande	La Guancha	BpG	48
Marrueca	Fuente Grande	La Guancha	MaG	48
Borralla	Las Carboneras	La Laguna	BoL	48
Palmera Colorada	Roque Negro	Santa Cruz	PcS	48
Palmera Lagarteada	Roque Negro	Santa Cruz	PIS	48
Brasileña o Grasileña	Roque Negro	Santa Cruz	G-S	48
Venezolana Negra	Arese	Fasnia	VnF	48
Bonita Colorada	Icod el Alto	Los Realejos	BcR	48
De Baga	Icod el Alto	Los Realejos	CoR	48
Azucen Negra	La Canaria	La Guancha	AnG	48
Azucena Blanca	La Canaria	La Guancha	AbG	48
Colorada de Baja	La Canaria	La Guancha	CoG	48
Moras	Las Carboneras	La Laguna	MoL	48
Palmera Negra	La Zarza	Fasnia	PnF	48
Palmera Colorada	La Zarza	Fasnia	PcF	48
Palmera Blanca	La Zarza	Fasnia	PbF	48
Peluca Rosada	Benijos	La Orotava	LrO	48
Terrenta	B. Las Lajas	Tacoronte	T-T	48
Peluca Blanca	Pinolere	La Orotava	LbO	48
Negra Yema de Huevo	El Pastel	Tacoronte	N-T	36
Negra Oro	El Pastel	Tacoronte	NoT	36

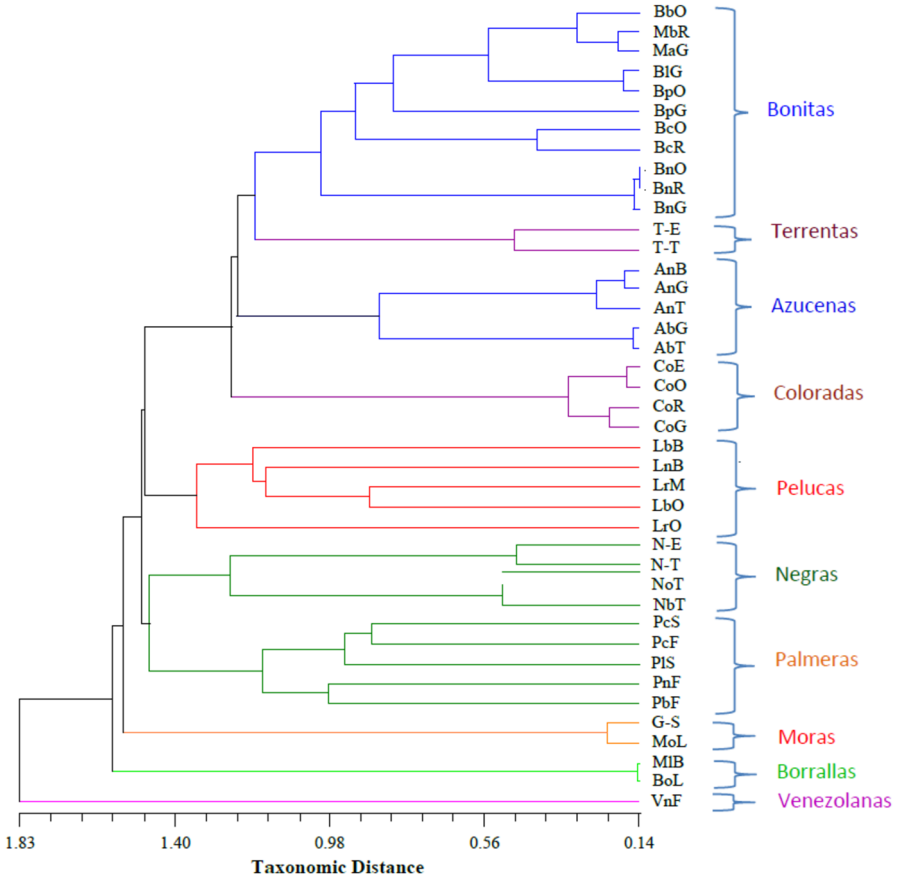

Fig. 4 Cluster analysis with quantitative characteristics (Ríos 2002)

terminal leaflet, number of stems per plant and length of the first lateral leaflet, while the second component has a greater contribution to the characteristics of number of tuber eyes, shape of the base of terminal leaflet and overlapping of lateral leaflets.

Like the cluster analysis, PCA (Fig. 5) also correlates with traditional knowledge. The PCA results seem to indicate the existence of three clear clusters:

- A cluster consisting of all potato entries with ssp. *tuberosum* characteristics (upper left), among which we find Pelucas (Fig. 6a), Palmeras Moras, Borrallas and strangely the triploid Negra. All these entries, except for the triploid Negra (Fig. 6b), are classified by Ríos (2002) as belonging to ssp. *tuberosum*.
- An intermediate group formed by the Venezolanas, probably the hybrid cultivar Merideña obtained by plant breeding (Estrada-Ramos, personal communication) and the Coloradas or De Baga at the bottom middle.

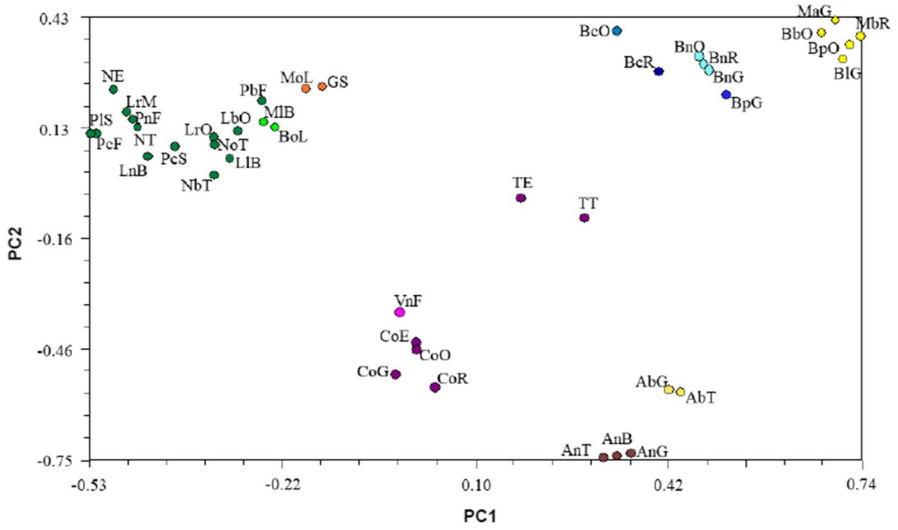

Fig. 5 Principal component analysis (Ríos 2002)

Fig. 6 Ancient potatoes varieties: **a** Peluca Negra (*Solanum tuberosum* ssp. *tuberosum*); **b** Negra (*Solanum chaucha*); **c** Bonita Negra (*Solanum tuberosum* ssp. *andigena*) and **d** Azucena Negra (*Solanum tuberosum* ssp. *andigena*)

– Finally, all the entries of Bonitas (Fig. 6c), Azucenas (Fig. 6d) and Terrentas were mainly grouped according to component 1, forming a group of cultivars that Ríos (2002) placed in ssp. *andigena*.

The location by morphology of the triploid cultivar Negra does not seem to respond with total clarity to that of the species *Solanum chaucha*. For Ríos (2002), it is necessary to deepen studies to provide valuable information about the origin of the triploid cultivars that we attribute to the species *Solanum chaucha*, since as Ochoa (1975); Jackson et al. (1977) pointed out for South America, these triploids could have originated in different places and by different ways.

These morphology works are published in a catalogue of ancient varieties from Spain (Ruiz de Galarreta and Ríos 2008) and another exclusively for Tenerife (Ríos 2013). The first catalogue characterises the ancient varieties of all Spain, including those of the Canary Islands (Tenerife and La Palma), while the second is exclusively of Tenerife potatoes.

Diversity Studies Using Molecular Techniques

Barandalla et al. (2006), with the same entries that Ríos (2002) characterised morphologically, carried out a molecular study using 19 SSR markers. The results obtained show a great similarity with the morphological ones, establishing very similar groups. Figure 7 shows the dendrogram with the groupings obtained in this work.

Subsequently, Ríos et al. (2007), using 24 microsatellites and a DNA marker of a deletion characteristic of cultivars belonging to ssp. *tuberosum* (Hosaka, 2002),

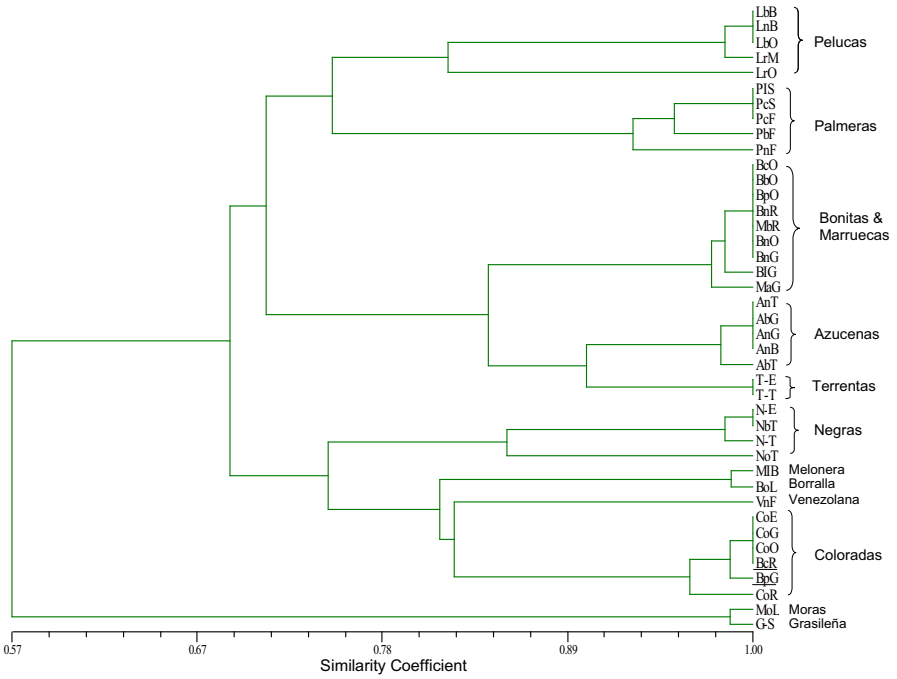

Fig. 7 Dendrogram obtained using 19 SSR markers (Barandalla et al. 2006)

Table 4 Accessions analysed by Ríos et al. (2007)

Taxon	Accessions	Common name	Location
Cultivated entries			
Grupo Andigenum	CV1	'Bonita Blanca'	Tenerife. La Orotava
Group Andigenum	CV15	'Azucena Negra'	Tenerife. Buenavista
Group Andigenum	CV 21	'Bonita Negra'	Tenerife. Los Realejos
Group Andigenum	CV30	'Bonita Llagada'	Tenerife. La Guancha
Group Andigenum	CV44	'Bonita Colorada'	Tenerife. Los Realejos
Group Andigenum	CV50	'De Baga'	Tenerife. Los Realejos
Group Andigenum	CV51	'Azucena Negra'	Tenerife. La Guancha
Group Andigenum	CV52	'Azucena Blanca'	Tenerife. La Guancha
Group Andigenum	CV53	'Colorada de Baga'	Tenerife. La Guancha
Group Andigenum	CV61	'Terrenta'	Tenerife. Tacoronte
Group Andigenum	CV8	'Azucena Blanca'	Tenerife. Tacoronte
Group Andigenum	700031	'Hualash'	Peru. Carrion Palca
Group Andigenum	700223	'Yana' or 'Chiar Imilla'	Peru. Puno
Group Andigenum	700921	'Ccompis'	Peru. Cuzco
Group Andigenum	702477	'Yana Puma Maqui'	Peru. Tambillo
Group Andigenum	703240	'Sani Imilla'	Bolivia. Cochabamba
Group Andigenum	703243	'Imilla Blanca'	Bolivia. Cochabamba
Group Andigenum	703284	'Puca Ticka'	Bolivia. Cochabamba
Group Andigenum	703346	'Huaycha Pacena'	Bolivia. Cochabamba
Group Andigenum	703748	'Huagalina'	Peru. La Libertad
Group Andigenum	704353	'Puna'	Ecuador. Chimborazo
Group Andigenum	704429	'Guincho Negra'	Peru. Chachapoyas
Group Andigenum	705665	'Pellejo de Cuy'	Peru. Santa Cruz de Miopapa
Group Chaucha	CV63	'Negra Yema de Huevo'	Tenerife. Tacoronte
Group Chaucha	CV9	'Blanca Negra'	Tenerife. Tacoronte
Group Chaucha	702230	'Huayro'	Peru. Ayacucho
Group Chaucha	704710	Unknown	Peru. Huanuco
Group Chilotanum	CV18	'Melonera'	Tenerife. Buenavista
Group Chilotanum	CV20	'Peluca Negra'	Tenerife. Buenavista
Group Chilotanum	CV25	'Peluca Rosada'	Tenerife. La Matanza
Group Chilotanum	CV36	'Palmera Lagarteada'	Tenerife. Anaga
Group Chilotanum	CV37	'Brasileña or Grasileña'	Tenerife. Anaga
Group Chilotanum	CV58	'Peluca Colorada'	Tenerife. Fasnia
Group Chilotanum	703606	'Papa Chonca'	Chile. Chiloé, Chonos Archipiélago
Group Chilotanum	703610	'Papa Cacho'	Chile. Chiloé, Chonos Archipiélago
Group Chilotanum	703611	'Papa Colorada'	Chile. Chiloé, Chonos Archipiélago
Group Chilotanum	705040	Unknown	Chile. Chiloé, Chonos Archipiélago
Group Chilotanum	705045	'Estrella'	Chile. Chiloé, Chonos Archipiélago
Group Phureja	705154	Unknown	Colombia. Dept. Nariño
Group Phureja	705825	Unknown	Colombia. Mercaderes
Group Stenotomum	703783	Unknown	Peru. Puno

Table 4 (continued)

Taxon	Accessions	Common name	Location
Group Stenotomum	705987	'Perla Limeña'	Peru. Cajamarca
Group Stenotomum	706025	'Puca Runtush or Cibra'	Peru. Carrion, Chinchi
Group Stenotomum	706668	'Yana Huayro'	Peru. Canchaplaca
Wild species outgroups			
S. bukasovii	761220		Peru. Huarochiri
S. bukasovii	761223		Peru. Huarochiri
S. chilliasense	761590		Ecuador. Cordillera Chillia

carried out the first phylogenetic study of Canary Island potatoes. In this work, 25 entries of South American cultivars from the collection of the International Potato Centre (CIP) were analysed. Specifically, from the Andean region, 12 of *S. tuberosum* ssp. *andigena*, 2 of *S. chaucha*, 4 of *S. stenotomum*, 2 of *S. phureja* and 3 outgroups formed by 2 entries of the wild species *S. bukasovii* and 1 of *S. chilliasense*. In addition, 5 accessions from the Chiloé archipelago in Chile classified in ssp. *tuberosum* are included. Finally, 19 accessions from the Canary Islands previously studied by Ríos (2002) and Barandalla et al. (2006) and included in the different species existing in Tenerife (Table 4). In addition, the marker for the typical deletion of ssp. *tuberosum* was analysed in 150 entries of *S. chaucha* from CIP and the typical deletion of the subspecies *tuberosum* was not detected in any case, although it was present in the two Canary triploids analysed.

Ruiz de Galarreta et al. (2008) evaluated 19 potato entries from the Canary Island of La Palma and compared them with potatoes from Tenerife of the Bonitas, Pelucas and the triploid Negra groups. Subsequently, genetic relationships were analysed using microsatellite markers among 105 accessions from mainland Spain and the Canary Islands (Ruiz de Galarreta et al. 2011), showing an excellent correlation with the results obtained by Ríos et al. (2007).

Using the Nei72 similarity coefficient and the neighbour-joining method (Saitou and Nei 1987), a phylogenetic tree was constructed and is presented in Fig. 8. The results show that the cultivars belonging to ssp. *tuberosum* form a group, highlighting the existence in all of them of the typical deletion of this subspecies that has been indicated in the tree with a T at the end of each cultivar. In addition, the Mora cultivar (synonymies Brasileña or Grasileña) is found together with entries from the Chiloé archipelago. Here, it is important to review again the previously mentioned quote of 1772 by Hernández (2000), which named the Morada potatoes in the Hacienda de las Palmas in Anaga, current stronghold of cultivation of this potato cultivar, which states:

> ...as for the purple potatoes, I owed eleven bushels and my father Salbador a bushel and a half. I have ordered them from Francisco Meliá, who said he would tell me when he sent for them.

Hernández (2000) considers that the Steward of Las Palmas de Anaga was referring to the ancient potato cultivar of the Canary Islands known as Moras, which

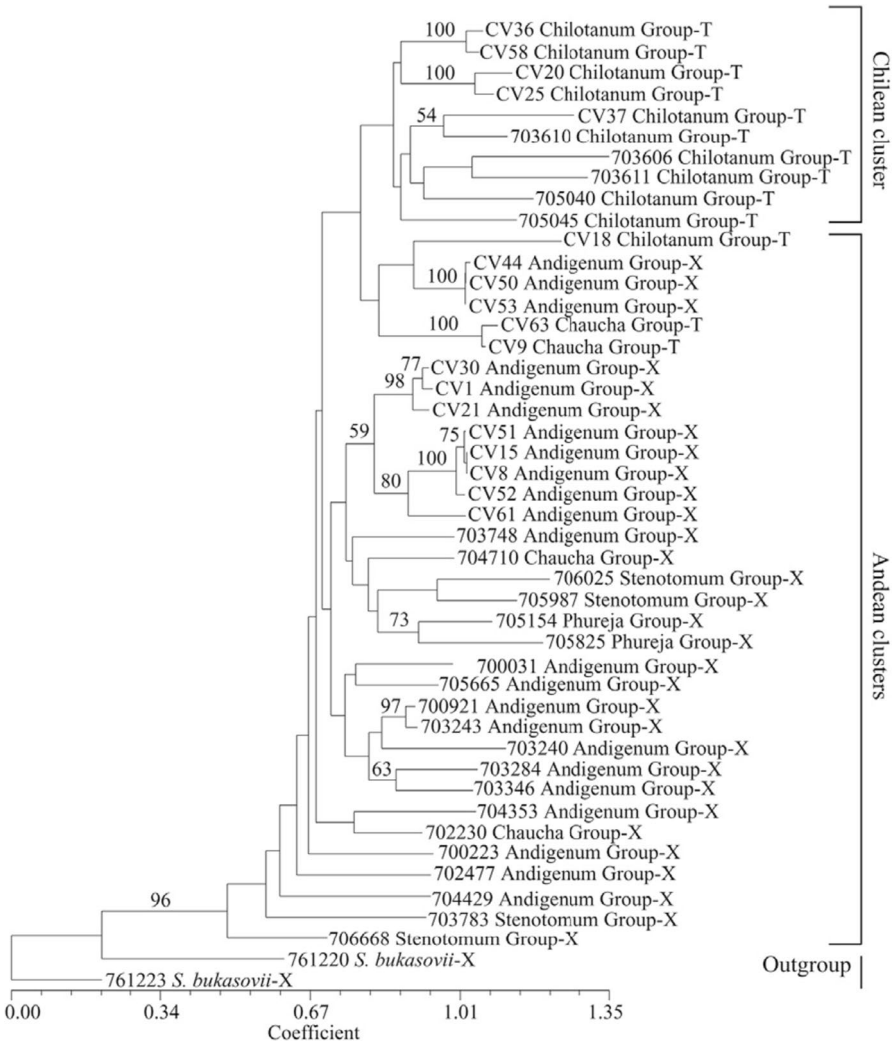

Fig. 8 Phylogenetic tree relating Canary Island, Andean and Chiloé entries (Ríos et al. 2007)

belongs to the ssp. *tuberosum*. This is of utmost importance, since it would be the first citation of a potato belonging to ssp. *tuberosum* in the Canary Islands, and therefore well before the famine of 1845 in Ireland.

Groups of potatoes such as the Meloneras, Coloradas and Negras form a branch within ssp. *tuberosum* but are very close genetically to the group of ssp. *andigena*, and with the specific feature that Meloneras and Negras have the deletion of ssp. *tuberosum* (T), what Ríos et al. (2007) justify by their probable hybrid nature. This would be very much in agreement with the morphological groups established by Ríos (2002), since the Meloneras or Borrallas are included within the cultivars of ssp. *tuberosum*, the Negras are morphologically grouped with them and the

Coloradas are among the groupings formed by the potatoes belonging to hybrids of ssp. *andigena* and ssp. *tuberosum*.

Ríos (2002), in an eco-physiological study of Negra cultivars at two altitudes on the island of Tenerife has already determined their good behaviour at low altitudes, while the cultivars such as Bonitas belonging to ssp. *andigena* hardly managed to tuberise at these altitudes. This agronomic behaviour of the triploid cultivar Negra is extraordinarily rare, since, according to Hawkes (1990), it is a species of high altitudes in the Andean Cordillera. It is therefore a triploid hybrid probably originating in the Canary Islands.

The Canary Island entries of ssp. *andigena* form an independent cluster but are joined at a certain genetic distance to the South American entries of the same subspecies, which would indicate some evolution of the Canary Island cultivars that distinguishes them from the Andean ones. This could indicate the existence in the Canary Islands of a possible secondary centre of diversity of Andean potatoes.

According to the new taxonomic classification of Huaman and Spooner (2002), Spooner et al. (2007, 2010), Gavrilenko et al. (2010), Ovchinnikova et al. (2011), all accessions that have been classified in this work in *Solanum tuberosum* ssp. *tuberosum* should be reclassified in the *Solanum tuberosum* Chilotanum group, and the accessions of *Solanum tuberosum* ssp. *andigena* and the triploid *Solanum chaucha* in the *Solanum tuberosum* Andigenum group. However, we have some doubts as to the proper classification of this triploid from the Canary Islands in the Andigenum group, since it shows morphological, physiological and even genetic characters that make it group with the accessions of the Chilotanum group.

Traditional Cultivation of Ancient Potatoes of the Canary Islands

Next, the cultivation practices carried out for growing ancient potato cultivars of the Canary Islands, mainly on the island of Tenerife, are presented.

Planting Time

Most ancient potato cultivars are harvested once a year. This is largely due to their more or less long cycle, long tuber dormancy and good storability. However, there are some cultivars from which more than one harvest per year can be obtained, mainly the Negra cultivar (*S. chaucha*). The Negra has a cultivation cycle of less than 4 months (Ríos et al. 1999; Ríos et al. 2013).

Planting is a highly socially charged event, being a combined operation and shared effort between families and neighbours. After manually opening the furrows, planting is a practice carried out mainly by women (López 2001).

Regarding the most frequent planting periods (Estévez et al. 1995; Lopez 2001; Ríos Mesa et al. 2013), these involve:

a. Planting in January and harvesting in June and July (these are called early or summer potatoes) is the main planting period. This is when the greatest produc-

tion of ancient potatoes is concentrated, the largest numbers of different cultivars are planted, and the best yields are obtained. Under these conditions, the tubers need to remain in the soil for more than five and a half months for cultivars of the Bonitas group, Azucenas, Colorada de Baga or Moruna, Torrentas.... (ssp. *andigena*) and 4 months for Negras Yema de Huevo (*S. chaucha*) and Pelucas (ssp. *tuberosum*).

b. Planted in June, July, August or September, "summer" and harvested in December (called late, August or winter potatoes). They are grown in cool highlands, as well as in lowland or coastal areas of deep-rooted tradition. These cultivars have poor conservation or shorter cultivation cycle such as Negra Yema de Huevo (*S. chaucha*), Borralla and Pelucas (ssp. *tuberosum*). They are usually marketed at Christmas.

c. Planting in October and November and harvesting in January and February for the Negra Yema de Huevo potatoes, and March and April (Easter) for the Bonitas group. Colorada de Baga, Azucenas,.... (ssp. *andigena*) are locally known as early potatoes. Yields are lower compared to the January planting, and they have a shorter cultivation cycle.

Seed Handling and Planting

The selected planting material generally corresponds to a seed of 30 to 40 g, sometimes even smaller, so two seeds per stroke are placed at the time of planting (Ríos et al 1999; López 2001).

Fig. 9 Seed selection by women farmers

Normally the seed is selected by women farmers according to its shape and size at the time of harvesting (Fig. 9), although in the past, women went ahead in the harvest and chose the best plants for keeping their seed (Ríos and Armas 2007). This seems to indicate the use of positive selection by farmers from almost the beginning of the introduction of the ancient potato in the Canary Islands.

Another practice that is carried out is the cutting of large seeds, more than 40 g, in two or three pieces lengthwise and leaving at least two to three sprouts for each portion. This practice is done immediately before planting (López 2001).

In the last 20 years, the company Cultivos y Tecnología Agraria de Tenerife (CULTESA) has cleaned up 10 old potato varieties through tissue culture and has multiplied them after the registration by the Cabildo Insular de Tenerife of 16 conservation varieties in the Spanish Office of Plant Varieties under the Ministry of Agriculture, Fisheries and Food of the Government of Spain. This has meant that farmers can access healthy seeds with higher yields.

Traditionally, planting is done by hand because the orography of the land and the size of the plots do not allow mechanised planting.

The planting density is usually variable and depends on the geographical location zones, preferably for this crop can be schematised as follows:

a. The spacing between rows varies between 65 and 75 cm on a northern slope and around 40 to 50 cm on a southern one. The latter planting density is very high, aiming to form a very homogeneous vegetation cover, which counteracts the constant prevailing winds.
b. Between tubers it is normal to "plant at the foot", which consists of placing the potatoes at the bottom of the furrow at a distance of one foot (approximately 20 to 30 cm).
c. The traditional depth of planting is between 15 and 20 cm.

This leads to a planting density of approximately 50,000 to 100,000 plants per hectare.

Planting ends with the placement of the tuber at the bottom of the furrow, followed by the incorporation of mineral fertiliser and manure, and ends with the covering of the potato with a layer of approximately 10 to 15 cm of soil, which is done manually or with power tillers.

Traditional Cultivation Tasks

The traditional cultivation of ancient varieties of potatoes in the Canary Islands is carried out manually, with animal traction (Fig. 10) or with motorised cultivators, in chronological order (Ríos et al. 1999; López 2001):

a. The "*arrienda*": which consists of pulling soil to begin to form a "*camellón*" (ridge) before the potato begins to emerge or has just emerged. This is done approximately 20 to 30 days after planting. This eliminates weeds and loosens the soil, facilitating aeration and reducing moisture losses by breaking the surface

Fig. 10 The traditional cultivation of ancient varieties of potatoes in the Canary Islands with animal traction

porosity. The high sensitivity of these local cultivars to herbicides means that the use of herbicides is not normal (López 2001).

b. The "*sachada*": this is done when the plant reaches 15 to 25 cm in height, by hoeing the soil at the base of the stems, which facilitates the development and grouping of the tubers, avoiding the cracking of the soil and the appearance of these on the surface; it is done manually with a hoe or power tiller.
c. "*Arrima de tierra*": similar to the previous one, but the contribution of soil is made only from one side. It is carried out only in certain areas in the north of Tenerife, and in long-cycle cultivars, 1 month after the "*sacha*" has been carried out. Its function is to increase the late tuberisation zone of the stem and avoid the greening of the shallower tubers. This work is only done on ancient varieties because of their tendency to tuberise very high and continue to do so until the end of the cycle.

Fertilisation

Since ancient times, Canary Island farmers have used manure as the main and best fertiliser for ancient varieties. Manure is incorporated into the soil a few months or even 15 days before planting, or during sowing directly in the furrow once the seed has been placed.

In other locations, the use of green manure, alone or supplemented with animal manure, is a very traditional practice. The most commonly used green manures are mixtures of lupin-barley or only lupin (*Lupinus albus*) (Gil 1997; Perdomo 1998; Ríos et al. 1999; López 2001).

Pests and Diseases

The main potato pest in the Canary Islands is the Guatemalan potato moth *Tecia solanivora* Povolny, detected for the first time in Tenerife in 1999. The difficulties in controlling it, its ease of dispersal and its adaptability to the environmental conditions of the islands have caused losses of more than 50% of the crop in certain areas. Since 2000, the pest has been included in the EPPO (European and Mediterranean Plant Protection Organization) pest and disease alert list. One of the greatest risks that this pest can cause is the disappearance of the biodiversity of ancient potatoes in the Canary Islands (Ríos Mesa et al. 2020; Lobo et al. 2021). Other pests are *Phthorimaea operculella* (Zeller), *Agrotis* sp. and various virus-transmitting aphid species.

Late blight (*Phytophthora infestans* (Mont.) de Bary) together with numerous viruses (PVY—potato virus Y, PLRV—potato leaf roll virus, PVX—potato virus X, etc.) are the most important diseases affecting these ancient potato varieties. Other diseases that can occur are *Rhizoctonia solani*, *Alternaria solani*, *Spongospora subterranea* f. sp. *subterranea*, *Streptomyces scabies*, *Pectobacterium atrosepticum* and post-harvest silver scab *Helminthosporium solani*. Moreover, nematodes can often

Table 5 Observed pathogen resistances in ancient potato cultivars from Tenerife (Alor et al. 2015)

Variety	Species	*P. infestans* (Leaf)	*P. infestans* (Tuber)	*G. pallida*	*G. rostochiensis*	*Pectobacterium atrosepticum*
Bonita Colorada	ssp. *andigena*	S	PR	S	S	R
Azucena Negra	ssp. *andigena*	S	S	PR	S	PR
Terrenta	ssp. *andigena*	S	S	S	S	R
Peluca Rosada	ssp. *tuberosum*	S	S	S	S	S
Bonita Ojo de Perdiz	ssp. *andigena*	S	S	PR	S	PR
Borralla	ssp. *tuberosum*	S	S	S	S	S
Venezolana Negra	ssp. *andigena* × ssp. *tuberosum*	PR	S	PR	S	PR
Moras	ssp. *tuberosum*	PR	S	S	S	PR

R resistant, *PR* partially resistant, *S* susceptible

cause significant damage to these potato varieties crops: mainly *Globodera rostochiensis*, *Globodera pallida* and *Meloidogyne* spp.

The positive selection made by farmers over the centuries as well as the broad genetic base of Canary Island varieties have contributed to the fact that some of them show resistance or tolerance to some diseases. However, not much work has been done to determine resistance to pests and diseases in these varieties, except for the work of Alor et al. (2015), whose data are presented in Table 5.

Harvesting and Marketing

Harvesting is carried out for these varieties with animals or motorised cultivators, although more mechanisation is beginning to be used. Potatoes are bagged in 25–35 kg sacks, and then transported to packing sheds or to the farmers' own premises ("*trojas*") or caves for storage and sale (Gil 1997; Ríos et al. 1999; López 2001).

The ancient potatoes are marketed locally, because of the Guatemalan potato moth, the sale of potatoes has been prohibited in any market outside the Canary Islands. Despite their lower productivity compared to modern commercial varieties introduced from continental Europe, their higher market prices still make it a crop without major losses. Support from necessary policies to promote this differentiated product, through gastronomic and market innovations as typical special potatoes and emblematic foods of Canary Highlands, would sustain the cultivation of the ancient potatoes by enhancing farmers' incomes. It would allow better conservation, by developing the concept of "conserving with farmers and for farmers".

Conclusions

The first historical data (1560–1567) of the presence of potatoes in the Canary Islands are prior to the first date of entry of potatoes in Europe (1573). These early introductions could belong to ssp. *andigena*, both from their descriptions and from the preserved herbaria. However, historical records on the first introduction are relatively scarce and undefined to confirm this hypothesis. The data presented in this article indicate that there is a high probability that there could have been potato cultivars in the Canary Islands introduced simultaneously from the Andes and Chiloé, therefore making it difficult to determine the exact origin of all the potato cultivars still grown today on these islands. The Canary Islands are comparable to a natural reservoir, where the crops that arrived from America in the sixteenth century, such as the ancient potato varieties, have been conserved and cultivated for 450 years.

The potato biodiversity of the Canary Islands means that the islands could be considered a secondary centre of variation of the Andean and Chiloé potatoes that came from South America, due to the possible selection that farmers have made over centuries and the use of sexual seed for their multiplication, as indicated in 1799 (date of writing) by the Canary Island scientific illustrator Viera y Clavijo (1866) (date of publication). In addition, the more than probable introduction of

Fig. 11 The diversity of ancient potatoes from the Canary Islands

other species, already lost on the islands, has led to a diversity somewhat different from that of their centre of origin in America. Thus, these ancient potatoes are similar to South American ones, but with their own identity, since today about 50 ancient cultivars exist and are grown, which show in all the characterisation works a certain genetic distance from the Andean and Chiloé varieties (Fig. 11).

The conservation in situ, i.e. in farmers' fields, of these potatoes is today more necessary than ever, and public authorities should establish policies so that farmers can continue to grow them and differentiate this product in the markets as special potatoes typical of the Canary Islands, to improve their incomes. Although these local varieties can generate greater added value, they also have higher production costs due to their production system. The cultivation of these ancient varieties is unique, still being very artisanal and carried out by hand or with animal traction, although in recent years there has been a notable increase in mechanisation. Considering that the area planted with ancient potatoes has decreased in the last 30 years, these policies should promote the best possible conservation and best possible use according to the saying "*conserve with the farmers and for the farmers*". On the other hand, ex situ conservation of these potatoes requires research programmes and adequate funding, establishing projects to continue and maintain existing conservation projects under controlled conditions. Ex situ conservation is mainly carried out by the Centre for Conservation of Agricultural Biodiversity of Tenerife, which currently maintains an in vivo collection of 155 accessions of local potato varieties and twenty-three these are maintained in vitro thanks to the collaboration of the public company CULTESA.

Regarding the production of quality seed, the work carried out by the public company CULTESA stands out by obtaining the production of high-quality seed tubers, using tissue culture and producing certified seed of at least ten cultivars of ancient potato varieties. This effort has begun to ensure adequate health and productivity of these varieties compared to the seed produced by farmers, themselves, that are heavily infected by numerous viruses. This certified seed has been a great success among growers, contributing to greater farm profitability and the production of excellent quality potatoes. However, it is necessary to promote this programme among traditional producers, as even today seed exchange and self-production with minimal selection are part of the usual production techniques.

Research programmes are also needed to better analyse the gene pool of Tenerife's ancient potatoes, differentiate their characteristics and identify resistance or tolerance to pests and diseases. Currently, the greatest danger to these local potato varieties is the presence of the Guatemalan potato moth (*Tecia solanivora*), which is very difficult to control. Control of this potato moth is a major challenge that must continue to be addressed by the authorities through research projects to develop new and efficient technologies that can be made available to growers.

This latest work on biodiversity opens new research opportunities for Canary Island potatoes, as every day they seem to be more and more a stronghold of Andean and Chiloé potatoes, yet with distinctive features, which are important elements for the study of the first potatoes that entered Europe and their subsequent evolution.

The quote "*the Andes end in the Canary Islands*" is reflected both in the relationship between the biodiversity of Andean and Canary Island potatoes and in the similarity of agricultural practices and conditions on the island of Tenerife, where these potatoes are grown in mountainous areas with similar cultivation practices, in small plots on terraces similar to the Andean ones.

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Declarations

Conflict of Interest The authors declare no competing interests.

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