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Verónica Soledad Lema

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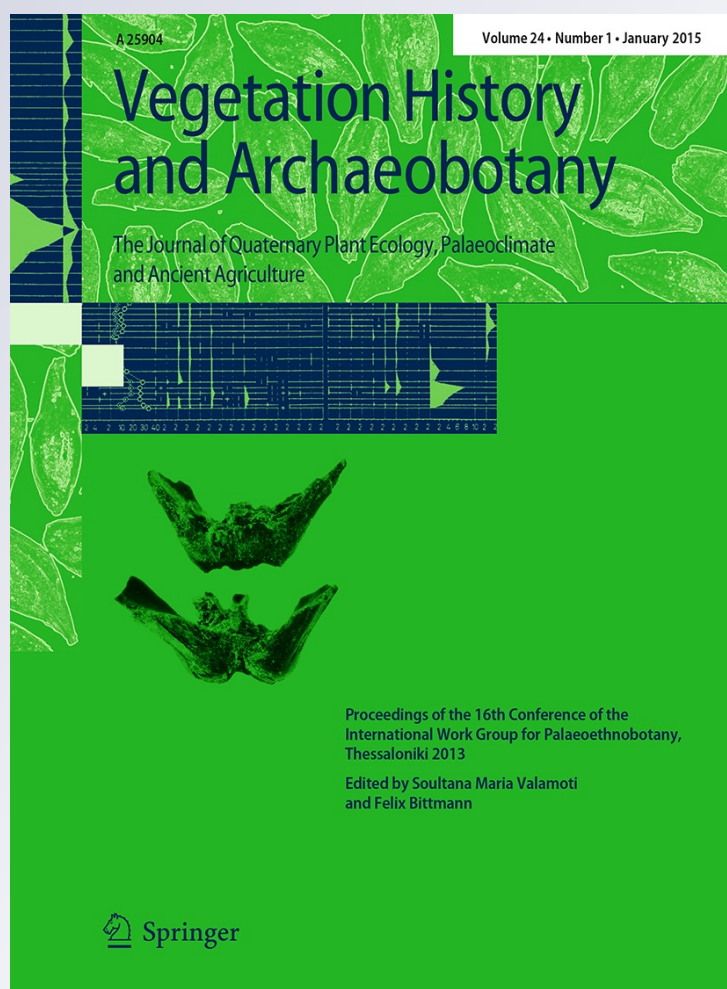
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Non-domesticated cultivation in the Andes: plant management and nurturing in the Argentine northwest

Verónica Soledad Lema

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Abstract This contribution summarizes archaeobotanical analyses dealing with the identification of practices such as cultivation of morphologically wild or weedy plants, as opposed to the gathering and cultivation of morphologically domestic plants, in northwestern Argentina. The presence of “intermediate” forms of *Cucurbita maxima* (squash) and *Phaseolus vulgaris* (common bean) together with their wild and domestic counterparts in the same archaeological contexts suggests the presence of wild/weedy/domestic crop complexes in the past. Practices which lead to these kinds of complexes (allowing the presence of wild relatives and interbreeding) seems to represent a long term modality of people-plant interaction in northwest Argentina detected in archaeological sites of different ages, spanning from 2,000 BP until modern local communities. This evidence, together with other morpho-anatomical traits of macro remains showing low standardization in size and shape (highly diverse biometric and qualitative features), points to a low incidence of selective pressures in crop populations throughout cultural development of the area. This argues for a horticultural system as opposed to large scale agriculture, entailing “mutual nurturing” which for this region demonstrates an alternative to the classic model of domestication.

Keywords Domestication · Nurturing · Cultivation · Andes · Argentina

Introduction

In this contribution I present a summary of archaeobotanical research dealing with the recognition of cultivation practices in the Argentine Northwest (ANW). The remains analysed were recovered mainly from archaeological sites corresponding to the first farming societies in the area, and also to later agrarian societies, in which domestic crops are usually assumed as the main plant resources. Considering that cultivation in a broad sense (intentional plant husbandry) is not always associated with domestic forms, the results that I present in this paper propose a different scenario for these early agropastoralist societies, in which cultivation and domestication can no longer be considered as steps in a lineal pathway of evolution and social change.

Brief archaeological background

Despite the fact that the ANW is a region with its own environmental and cultural identity, interconnected with the Southern Andean Area through its historical development as well as with the eastern lowlands and central regions of Argentina, no unified model for the advent of agriculture has been proposed to date. This lack is due to the uneven development of research programs dealing with this subject, with most of them focused on the highlands (“puna”) sectors, and some new minor contributions in the valley and lowland areas. This section presents a brief outline of the information generated by archaeological research in these regions.

Evidence of hunting and gathering is present in the ANW since 10,000 BP at a few archaeological sites, where the presence of elements from the Pacific coast and the eastern forests has been recorded together with local resources and artefacts. In the lapse between 8,000 and

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V. S. Lema (✉)
Laboratorio de Etnobotánica y Botánica Aplicada, División
Arqueología, FCNYM-UNLP-CONICET, La Plata, Argentina
e-mail: vslema@hotmail.com

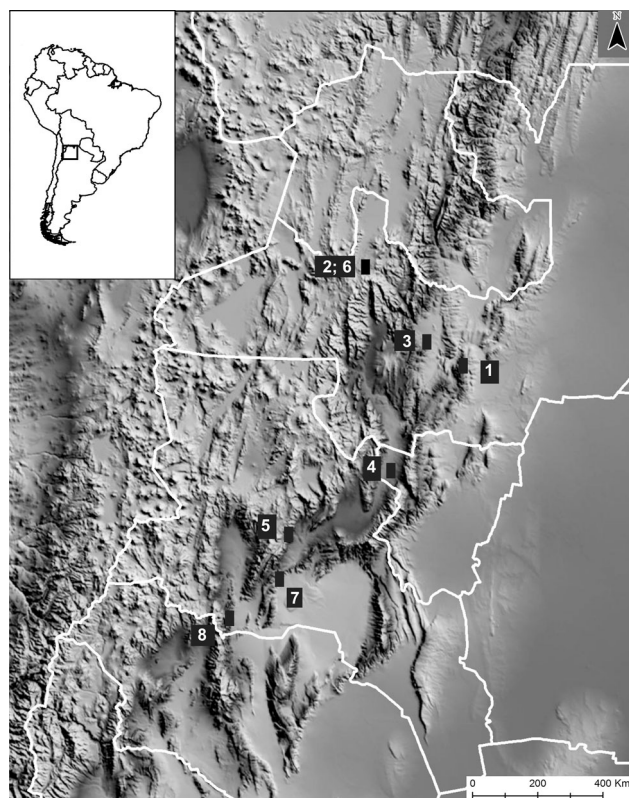


Fig. 1 Map of the Argentine Northwest area (ANW) showing the study sites mentioned in the text. 1 Pampa Grande, 2 SSalLap20, 3 Puente sobre río La Viña, 4 Cueva los Corrales I, 5 Los Viscos, 6 SSalCac91, 7 El Shincal, 8 Bebe de la Troya. The square on the South America map indicates the location of the ANW area

6,000 BP, the process of economic intensification consolidates and the consumption of tubers, roots and wild *Amaranthaceae* is present in the highlands sector (Babot 2011; Arreguez et al. in press). The spectrum of consumed plants increases in the time span between 5,000 and 4,500 BP, when seeds and fruits are incorporated together with storage practices; ca 4,500–3,200 BP taxonomic diversity increases once again, in combination with the first evidence of crops such as *Chenopodiaceae*, highland roots and *Capsicum*, and also a diversification of cooking techniques (Lema 2012; Aschero and Hocsman 2011; Babot et al. 2012). The latter period is considered as the moment of transition to a small-scale food production system; an increase in average humidity is recorded in the ANW highlands and additional contemporary archaeological sites are detected. Agropastoral systems emerge in the ANW valleys and highlands between 3,000 and 2,000 BP together with an increase in human population, the presence of several crops (including *Zea mays*), llama breeding and persistence of hunting and gathering practices, without any decline of the exchange networks linking the Pacific coast with the eastern forests. In the time span between 2,500 and 1,500 BP (Formative), residential units are associated with

field systems and this period is usually considered as representing the establishment and consolidation of food production systems in the ANW. The archaeobotanical remains analysed in this paper belong mostly to Formative archaeological sites and, in two cases, to subsequent ones.

Analysed materials

Analysed plant remains include two crops (squash: *Cucurbita maxima* Duch. ex Lam. ssp. *maxima*, and common bean: *Phaseolus vulgaris* L. var. *vulgaris*) whose wild ancestors (*C. maxima* ssp. *andreae* Naudin Filov and *Phaseolus vulgaris* var. *aborigineus* (Burk.) Baudet) occur on the eastern slopes of the Andes in Bolivia and the ANW (Piperno and Pearsall 1998; Lema 2009). Analysed archaeobotanical macroremains were recovered from different sites in the latter area (Fig. 1; Table 1).

Considering that both domestic taxa are very diverse, having numerous landraces and varieties, that they are interfertile with their wild counterparts and that they show—mostly *C. maxima*—weedy tendencies, variation is great. This variation and the persistence of diagnostic traits can be monitored through a reference collection formed of numerous specimens.

Our collections include several herbarium samples from different wild populations and also a broad spectrum of different local landraces and commercial varieties of these crops. Thus, both wild and domestic diversity of these taxa is well represented. Samples from close relatives (i.e. *C. moschata*, *C. ficifolia*, *Lagenaria siceraria*, *Ph. lunatus*) were also included in the analysis since they are usually recovered in archaeological sites in the southern Andes. In addition, both mature and immature samples were incorporated into the reference collection, as well as those resulting from different processing techniques (i.e. boiling, roasting).

Methodology

Biometrical, morphological and anatomical analyses were made, including both seeds and fruits, achieving the characterization of diagnostic traits for different plant parts. The same kind of analysis was carried out on macroremains. In the case of squash seeds, given that charred remains were present in the archaeological samples, experimental carbonization (300 °C for 2 h) was also applied to modern seeds, obtaining a new set of diagnostic traits (Lema et al. 2008; Lema 2009) (Fig. 2a, b).

Cucurbita maxima reference collection

A macroscopic and biometric analysis of *C. maxima* seeds showed no overlapping in length and width measurements

Table 1 Archaeological sites of the ANW where the archaeobotanical remains were recovered

Site (N° see Fig. 1)	Site type	Chronology	Archaeobotanical remains	
			Taxa	Organ
1 Pampa Grande	Site with seven caves of different size, situated in gorges over fluvial terraces; each rock shelter has evidence of residential and funerary occupations (2,800 m a.s.l.)	1,720 ± 50 BP (259–433 BC)	<i>C. maxima</i> <i>Ph. vulgaris</i>	Seeds, peduncles, rinds, pods (dry)
2 SSaLap20	Rock shelter in a gorge over fluvial terraces with evidence of residential and funerary occupations (3,000 m a.s.l.)	ca. 2,000 BP	<i>C. maxima</i> <i>Ph. vulgaris</i>	Seeds (dry)
3 Puente sobre río La Viña	Domestic compound in fluvial terraces (1,300 m a.s.l.)	1,440 ± 60 BP (510 ± 60 BC)	<i>C. maxima</i>	Seeds (charred)
4 Cueva los Corrales I	Rock shelter in a gorge over fluvial terraces, with evidence of residential occupations (3,000 m a.s.l.)	2,060 ± 60 BP	<i>C. maxima</i>	Rind (dry)
5 Los Viscos	Rock shelter in a gorge over fluvial terraces, with evidence of residential occupations (3,000 m a.s.l.)	2,270 ± 230 BP	<i>C. maxima</i>	Seeds (dry)
6 SSaCac91	Domestic compound in fluvial terraces (2,300 m a.s.l.)	2,540 ± 70 BP (779 BC) 2,680 ± 60 BP (682–670 BC)	<i>C. maxima</i>	Seeds and rinds (charred)
7 El Shincal	Inka administrative centre; ceremonial platform; ritual context (1,240 m a.s.l.)	1435–1536 BC	<i>C. maxima</i>	Seed (charred)
8 Bebe de la Troya	Urn burial of an infant in fluvial terraces (1,400 m a.s.l.)	603 ± 37 BP	<i>C. maxima</i>	Seeds (dry)

between *C. maxima* ssp. *maxima* and ssp. *andreana* before and after experimental charring. A range of measurements which represents *C. maxima* ssp. *andreana* was obtained through measurements of rind thickness. The anatomical analysis allowed recognition of several criteria of rind and seed coat tissues, useful to distinguish the different members of the Cucurbitaceae family (Lema et al. 2008; Lema 2009). The peduncles were shown to be the best elements to identify *Cucurbita* spp. and the increase in their diameter is a good indicator of changes occurring under domestication; thus, the peduncles of ssp. *maxima* can be distinguished from those of ssp. *andreana* by their basal diameter. Increase in peduncle diameter, fruit size and rind thickness are correlated from an evolutionary point of view (Cowan and Smith 1993).

Phaseolus vulgaris reference collection

Observations of seed length, width, thickness, shape and colour were useful to distinguish different varieties (Menéndez Sevillano 2002). Quantitative and qualitative traits of seed coat tissues, in cross section and in superficial view, were classified as diagnostic or non-diagnostic. For pods, superficial cuticle striation (more noticeable in var. *aborigineus*); stoma length (with a small range of measurement overlapping) and pod thickness (no overlapping) are criteria that can be used to distinguish between wild and domesticated forms. In order to study changes in the

mechanism of dehiscence, orientation of pod tissues in three different sections (cross section, tangential to surface and longitudinal section) in three pod areas (main surfaces, dorsal and ventral sutures) was examined, and diagnostic differences were found between the *aborigineus* and *vulgaris* varieties (Lema 2009) (Fig. 3a, b).

Identification criteria based on modern reference material

Cucurbita maxima

- (a) The seeds are flat, oval and with no pronounced marginal bulge, ssp. *maxima* can be white or brown; ssp. *andreana* always light brown. Seeds between 13 and 30 mm long and 7–17 mm wide correspond to ssp. *maxima*, while seeds between 6.5 and 10 mm long and 4–6.5 mm wide correspond to ssp. *andreana*. The anatomy of the seed coat shows a rounded to flattened marginal bulge in ssp. *maxima* and is broadly rounded in ssp. *andreana*. The seed coat in both ssp. has narrowed or absent submarginal bulges, long epidermal cells forming a protuberance or enclosing one-third or the entire marginal bulge, hypodermis not as a sinuous layer, sclereids with thin walls and wide lumens of homogeneous morphology and uniform walls. Epidermal cells have thin walls in both ssp., being thick only in ssp.

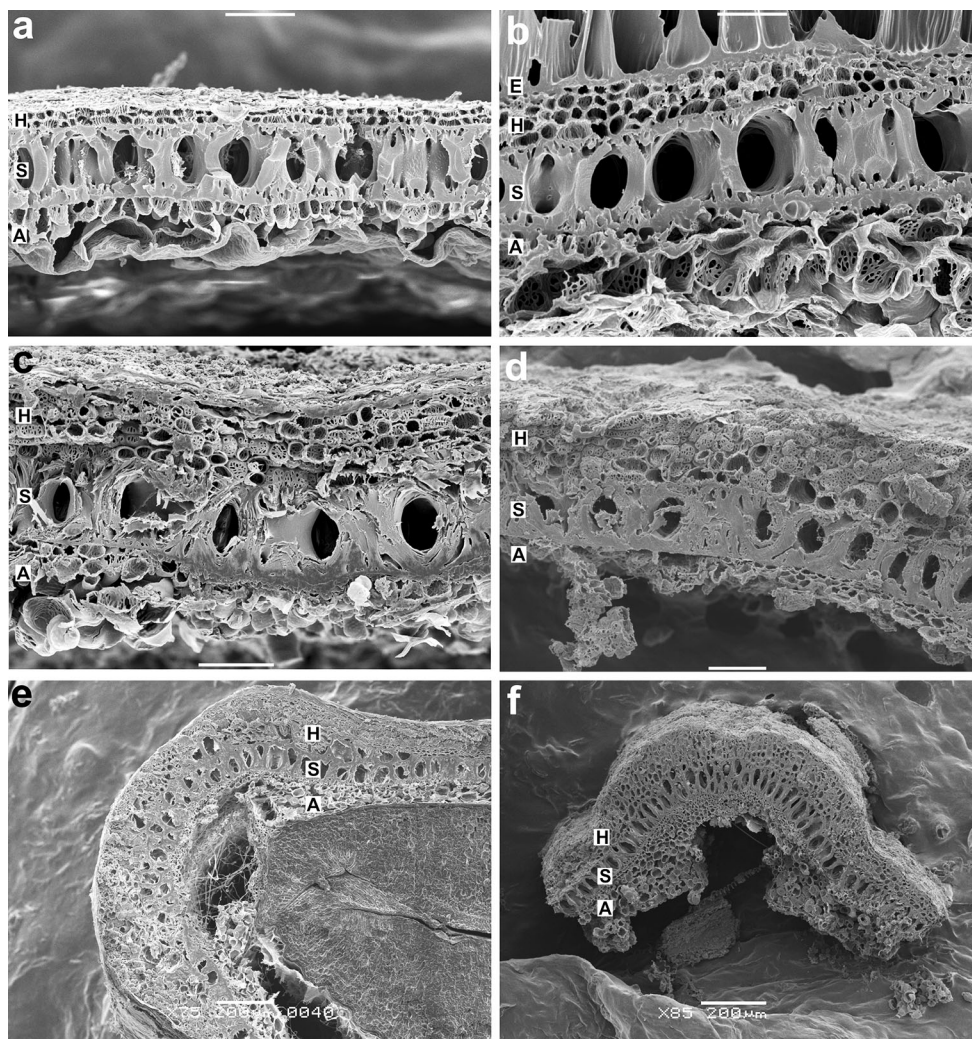


Fig. 2 *Cucurbita maxima* (squash) seeds in cross section (**a–d** major faces, magnification bar: 50 µm; **e–f** marginal bulge) **a** *C. maxima* ssp. *andreana* charred seed. **b** *C. maxima* ssp. *maxima* charred seed. **c** Archaeological dry seed from SSaLap20 site. **d** Archaeological dry

seed from Pampa Grande site, **e** *C. maxima* ssp. *maxima* var. *zapallito*. **f** Archaeological dry seed from Pampa Grande site; **E** epidermis, **H** hypodermis, **S** sclereids, **A** aerenchyma

maxima, in this ssp. epidermal cell length is more than 315 or less than 213 µm and width greater than 40 µm. Hypodermis in main surfaces has 4–5 layers, is thicker than 47 µm and its cells are larger than 10 µm; in the margin it has 7–8 layers. Ssp. *andreana* hypodermis has 2–3 layers in main surfaces and 5–7 layers at the margin; ssp. *maxima* sclereids are more than 95 µm (length) and 89 µm (width) in cross section and between 366 and 587 µm in tangential longitudinal section whereas ssp. *andreana* range of sclereid length and width in cross section is never less than 65 and 50 µm respectively. Aerenchyma thickness between 150 and 200 µm in ssp. *maxima* (more than two cell layers) and less than 55 µm in ssp. *andreana* (two cell layers) (Lema et al. 2008) (Fig. 2).

- (b) Peduncle is corky in ssp. *maxima*, but fibrous in ssp. *andreana*. Both have solid marrow with a central cavity and bicollateral vascular bundles evenly distributed along it. Diameters less than, or equal to, 8 mm correspond to the spontaneous ssp. and diameters greater than, or equal to 17 mm, to the domestic one.
- (c) Ssp. *andreana* rinds (pericarp) have smooth surface, colour goes from light green to light yellow with clear longitudinal striations; ssp. *maxima* may have smooth or warty surfaces, lobes and varied colours (green, yellow, orange, grey or brown with different hues). Mean rind thickness for ssp. *andreana* is 1.85 mm (range 0.79–5.97 mm) and for ssp. *maxima* 4.09 mm (range 2.08–6.64 mm). Epicarp (epidermis) in ssp. *andreana* shows quadrangular cells with

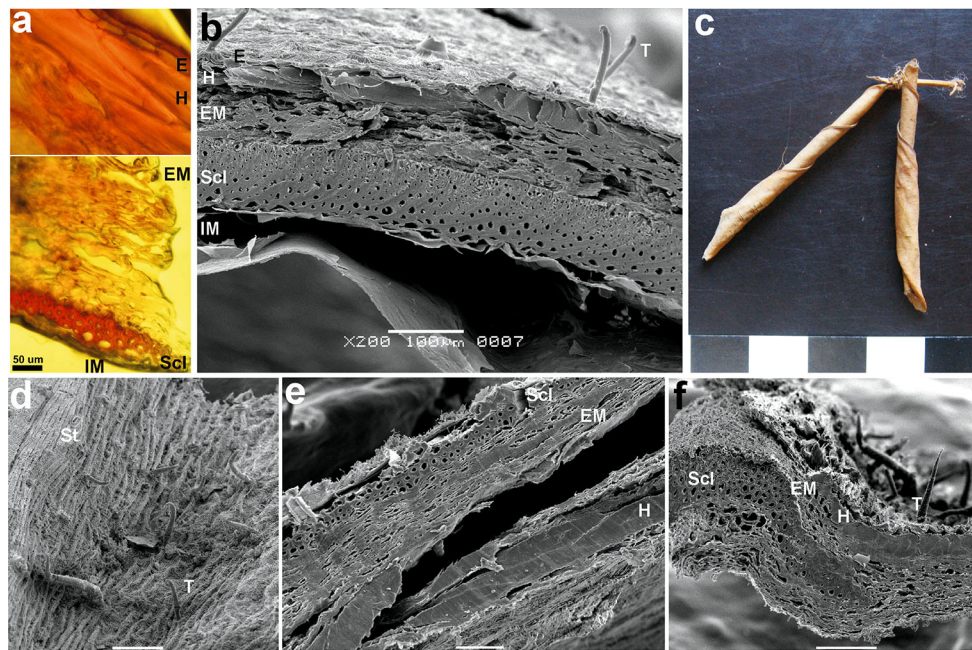


Fig. 3 *Phaseolus vulgaris* (common bean) pods; **a** *Ph. vulgaris* var. *vulgaris*, cross section through main surfaces. **b** *Ph. vulgaris* var. *aborigineus*, cross section through main surfaces. **c–f** preserved pod recovered at Pampa Grande. **c** pod, each division correspond to 1 cm. **d** superficial view, magnification bar: 100 µm. **e** cross section in

major faces, magnification bar: 50 µm. **f** cross section of dorsal suture, magnification bar: 100 µm; *E* epidermis, *H* hypodermis (collenchyma), *EM* external mesocarp, *Scl* sclerenchyma, *IM* internal mesocarp, *T* trichome, *St* stomata

thick walls and mild depressions on their external surface; in ssp. *maxima* depressions are more accentuated. Hypodermis is between 5 and 6 layers thick in domestic form and more than 10 layers thick in spontaneous one. Phytoliths are present in ssp. *andreana* (between 39 and 67.5 µm, measurements taken on phytoliths included in the pericarp) and in lignified varieties of ssp. *maxima* (50–90 µm), absent in non-lignified ones. In ssp. *andreana* the outer mesocarp has flattened stone cells with straight walls, isodiametric or transversally elongated. The middle mesocarp has cells with thick walls, larger than those of the outer mesocarp. The inner mesocarp has big cells with thin walls and lax disposition. In non-lignified varieties of ssp. *maxima* mesocarp cells have thin walls and are progressively larger (from outer to inner mesocarp). In lignified varieties the outer mesocarp has faceted and isodiametric stone cells, the middle and inner have elongated or isodiametric circular cells with thin walls, those of the inner mesocarp being larger (Lema 2011).

Phaseolus vulgaris

- (a) Seeds have an elliptical form in both varieties, in var. *vulgaris* it may also be oblong or spherical. While var. *aborigineus* colour is dark brown with black

striations, var. *vulgaris* is very diverse in colour (white, orange, brown, yellow, purplish), with hues and patterns. Seeds of var. *aborigineus* are smaller than var. *vulgaris*, with length less than 8.5 mm, width less than 6 mm and thickness less than 4 mm, var. *vulgaris* measurements are greater in all three cases. In both varieties the general structure of the seed coat is the same: a thin cuticle above the testa; outer epidermis formed by two rows of sclereid cells arranged in palisades, with macro sclereids (outer row) higher than the inner ones. Spongy parenchyma, one-celled layer of inner epiderm and cotyledons with aleurone and starch grains. Regarding testa thickness, var. *aborigineus* has a range between 52.6 and 59.8 µm. This range overlaps with the one of var. *vulgaris* (41.8–78.6 µm.). The number of macro sclereids per surface area of the seed coat in var. *aborigineus* is less than 172 and in var. *vulgaris* more than 200.

- (b) Pod colour is light yellow in both cases. Wild form is dehiscent and therefore both valves of the pod are curled after maturation. Domestic form is indehiscent and does not present this trait except when opened as mature—but fresh—and the valves curl when drying. Also in some cases pods of var. *aborigineus* can remain closed after maturation. Var. *aborigineus* pods are smaller, with length less than

Table 2 Results of identifications of *Cucurbita maxima* ssp. *maxima* and ssp. *andreana* remains from the ANW; quantity and type of remains with intermediate traits are given

Site	<i>n</i>	Whole, dry	Whole, charred	Dry, fragments	Charred, fragments	<i>C. maxima</i> ssp. <i>maxima</i>	<i>C. maxima</i> ssp. <i>andreana</i>	With intermediate traits
Pampa Grande								
Los Aparejos cave								
Seed	9	x				9		9
Peduncle	5			x		5		4
Rind	39			x		24	6	9
Pampa Grande								
El Litro cave								
Seed	1	x				1		1
Rind	4			x		4		
Pampa Grande								
cave II								
Rind	1			x		1		
Pampa Grande								
cave III								
Seed	1	x				1		1
Pampa Grande								
cave IV								
Peduncle	1			x		1		1
SSaLlap20								
Seed	3	x				3		3
Los Viscos								
Seed	1	x				1		1
Peduncle	6			x		6		6
SSaLlac91								
Seed	2		x			2		2
Rind	6				x	6		
Puente sobre								
Río La Viña								
Seed	7		3		4	2		1; 4
Cueva Los Corrales I								
Rind	1			x			1	
Bebe de la Troya								
Seed	10	x				10		3
El Shincal								
Seed	1		x			1		

90 mm, width less than 7.5 mm and thickness less than 6.5 mm, var. *vulgaris* measurements are greater for length (86–164.5 mm), width (more than 9 mm) and thickness (more than 7 mm); cuticular striation is more pronounced in var. *aborigineus*. Orientation of the collenchyma and sclerenchyma in ventral and dorsal sutures differs between both varieties, due to differences in dehiscence. Both varieties have one-

celled trichomes in pod surface. Stomata length ranges between 20.5 and 31 µm in the wild form and between 26 and 45 µm in the domestic one (Fig. 3).

Results

Archaeobotanical analysis of *Cucurbita* sp. macroremains

Morphological, biometrical and anatomical analysis of archaeological seed, peduncle and rind allowed the identification of domestic and wild specimens, including the recognition of macroremains with “intermediate” traits (Table 2, Fig. 2). Intermediate remains were those having a mix of traits present in modern samples of both ssp. (i.e. seed coats with sclereid measurements corresponding to ssp. *andreana* and number of hypodermal layers such as those present in ssp. *maxima*) or having traits not registered in modern samples (such as seed length and width values in a range between those of ssp. *maxima* and *andreana*, seed coats with characters that correspond to those of modern ssp. *maxima* or *andreana* but with smaller sclereids).

Archaeobotanical analysis of *Phaseolus vulgaris* macroremains

At the Pampa Grande archaeological site, seed analysis showed the presence of the domestic variety together with a few wild and intermediate forms (Table 3; Fig. 3). The intermediate form had biometric macroscopic characters (length, width and thickness) that fell within the range of values typical of wild varieties, but with the number of sclereids in surface view corresponding to the values present in the domestic form, and testa thickness values similar to that of the domestic form or falling in the area of overlapping values between both modern varieties. The only seed found in SSaLlap20 has a combination of traits occurring in both modern *Ph. vulgaris* varieties: colour, shape and thickness as in modern domestic seeds, and length in the range of wild populations (with values near its upper limit).

All pods showed intermediate traits, some remains had a combination of characters found in the *vulgaris* and *aborigineus* varieties (i.e. orientation of the collenchyma and sclerenchyma in all three pod areas—main surfaces of the valve, ventral and dorsal sutures—combining those observed in both modern varieties, pods with stomata lengths corresponding to wild and domestic ranges) and others had traits not found in the reference collection (i.e. orientation of the collenchyma and sclerenchyma in ventral and dorsal sutures, biserial trichomes).

Table 3 Results of identifications of *Ph. vulgaris* var. *vulgaris* and var. *aborigineus* remains from the ANW; quantity and type of remains with intermediate traits are given, all remains are whole and dry

Site	<i>n</i>	<i>Ph. vulgaris</i> var. <i>vulgaris</i>	<i>Ph. vulgaris</i> var. <i>aborigineus</i>	With intermediate traits
Pampa Grande				
Seed	2,685	2,682	2	1
Pod	4	4		4
SSalLap20	1	1		1

Discussion

Up to the present, in the ANW wild forms have been always recovered together with their domestic counterparts and “intermediate” forms in the same archaeological contexts, mainly from Formative (ca. 2,500–1,500 BP) sites. I interpret them as part of past wild/weedy/domestic crop complex (Beebe et al. 1997) resulting from the existence of husbandry practices and selective pressures that promoted diversity as opposed to homogeneity. The intermediate forms may represent hybrids or weedy forms which were probably cultivated and harvested together with their domestic counterparts. In most of the analysed cases, intermediate forms were recovered from the same archaeological context as the wild and domesticated types, including burials, residential areas, occupational floors and discard areas.

The main goal of *C. maxima* domestication in the ANW seems to have been the use of its fruits as containers. This is suggested by the morphology of the earliest ceramic pots from the area and also by the fact that the earliest squash rinds are thick, lignified and with signs of exposure to hot ashes, also having perforations in order to be held or carried. This does not rule out the consumption of the fruit flesh and/or seeds, since thin pericarp remains are also found at the sites. Intermediate pericarps show no signs of processing, but are associated with domestic forms that do show these (Lema 2011).

Phaseolus remains do not have signs of processing in any of the archaeological cases analysed, and they may represent the storage of seeds and/or food. In the case of *Ph. vulgaris*, although some characters could be different from those of modern samples due to climatic and growing conditions (i.e.,

stomata length), some mature pods from Pampa Grande had the size (length and width) of var. *vulgaris* but were dehiscent (indicated by the orientation of tissues in sutures of the pod), therefore they can be considered as intermediate. These pod remains were recovered in this archaeological site mainly with domestic seeds and a few of wild and intermediate type. A similar association has been detected in modern “hybrid swarms” resulting from a wild/weedy/domestic crop complex (Beebe et al. 1997; Menéndez Sevillano 2002) and also in other archaeobotanical assemblages from Formative sites in the ANW (Oliszewski and Babot 2013). Pods are very scarce in archaeological contexts of the area, those of Pampa Grande being the only ones reported until now. The fact that all of these pods have intermediate characters while seeds are mainly domestic, could suggest that interbreeding is manifested in pods more than in seeds (Menéndez Sevillano 2002); anatomical analysis of more Pampa Grande *Ph. vulgaris* seeds is needed in order to test if they show intermediate traits or not.

Intermediate traits in seeds of *C. maxima* ssp. *maxima* have also been detected in archaeological sites from later periods (Bebe de la Troya site, see Tables 1 and 2). Despite the fact that further investigation is needed and more samples should be analysed, this is consistent with the presence of agrarian landscapes in late periods having the same spatial structure and physiography as those of the early (Formative) period (Korstanje et al. in press; Lema 2012).

Cultivation of morphologically wild, weedy and domestic plants is common in fields and plots of modern local communities throughout the different environments of the Southern Andean Area (Lema 2009, 2013). Cultivation practices that lead to the establishment of wild/weedy/domestic crop complexes (such as allowing the presence of wild types and interbreeding) appears to have occurred in the ANW, from 2,000 BP until modern times. The evidence, together with other morpho-anatomical traits of the remains, shows a high diversity in size and shape, indicating low selective pressures. This argues for a horticultural system (Lema 2009) as opposed to large scale agriculture, entailing “mutual nurturing” (*crianza mutua*) (Grillo Fernández et al. 1994) which for this region demonstrates an alternative to the classic model of domestication (Lema 2013). Indeed “mutual nurturing” is a local set of practices occurring in contemporary Andean communities where morphologically wild and weedy plants are cultivated alongside domesticated ones.

Conclusions

The archaeobotanical macroremains of both *C. maxima* and *Ph. vulgaris* from Formative archaeological sites may present characters that are a combination of those of

modern wild and domesticated subspecies and varieties, or may present traits found in reference collections together with others not registered in modern specimens. We cannot consider these intermediate characters as transitional because they are present in remains found in the same archaeological contexts as wild and domesticated forms.

Until now the South American archaeological record does not include any stage with exclusive exploitation of wild *C. maxima* ssp *andreana* or *Ph. vulgaris* var. *aborigineus*, and therefore it is not possible to reconstruct a *continuum* from exclusively wild to domesticated forms. Instead, wild/weedy/domestic crop complexes have been recognized and attributed to the probable absence of reproductive isolation in the past, with hybridization occurring under cultivation. These ancient practices encouraged diversity, due, perhaps to low selective pressures. In addition different varieties may have had different uses.

When this research started, it was considered that these selection criteria and husbandry practices were part of a productive agricultural system controlled by family units, which has been assumed for the first ANW farming societies. In the last year the focus has lain on understanding local traditional cultivation systems in the ANW. In fact the present-day traditional cultivation techniques performed under the mutual nurturing model, appear to correspond to the archaeological findings. Further work in both the ethnobotanical and palaeoethnobotanical arenas will be necessary in order to better assess the evidence from both the present and the past.

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