# Identifying Domesticated and Wild Kañawa (*Chenopodium pallidicaule*) in the Archeobotanical Record of the Lake Titicaca Basin of the Andes

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Here, we present new data on how to identify both the wild and domesticated forms of kañawa (*Chenopodium pallidicaule* Aellen) in the archeological record of Andean South America using characteristics of their seed morphology. The ability to identify both the domesticated and wild forms of kañawa is an essential step in advancing our understanding of the processes of its domestication, diversification, and the role it has played in past food systems throughout the Andes.

Se presentan nuevos datos sobre la identificación arqueológica de las especies domesticadas y silvestres de kañawa (*Chenopodium pallidicaule* Aellen) utilizando características de la morfología de sus semillas. La capacidad de identificar las formas domesticadas y silvestres de kañawa es un paso clave para avanzar nuestra comprensión de los procesos de su domesticación, diversificación y entender su lugar en los sistemas alimentarios pasados de los Andes.

**Key Words:** *Chenopodium pallidicaule*, kañawa/cañihua, seed morphology, domestication, Andes.

## Introduction

The *Chenopodium* genus is a key taxon in understanding the origins of agriculture in the Andes of South America because it produced two important crops: quinoa (*Chenopodium quinoa* L.) and cañihua/kañawa (*Chenopodium pallidicaule* Aellen). In recent years, our knowledge of quinoa's domestication has advanced greatly with numerous archeological and genetic studies (e.g., Jellen et al. 2014; Planella et al. 2014). Much less attention has been given to its cousin, *C. pallidicaule*, known as cañihua in Quechua or kañawa in Bolivian Aymara.

Outsiders to the Andes have long overlooked it: some of the Spanish conquers did not differentiate it from quinoa (Vargas 1938), and it was not designated as its own species until 1926 (Gade 1970). Today, kañawa has not achieved the worldwide recognition of quinoa, but it continues to be a significant crop to indigenous Andean farmers because it is highly nutritious and is particularly resistant to frost, drought, salt, and pests (National Research Council 1989; IPGRI et al. 2005; Pinto 2011; Rojas et al. 2010).

Archeologists are also guilty of overlooking kañawa, often lumping it in with quinoa due to limited published guidelines for differentiating it (Bruno 2006). We seek to remedy this situation by presenting new data on how to identify both the wild and domesticated forms of kañawa in the archeological record using characteristics of their seed morphology. We also present evidence for the presence of both types in archeological samples from the southern Lake Titicaca Basin of Bolivia

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(Fig. 1). The ability to identify both the wild and domesticated forms of kañawa is an essential step in advancing our understanding of the processes of its domestication, diversification, and the role it has played in past food systems throughout the Andes.

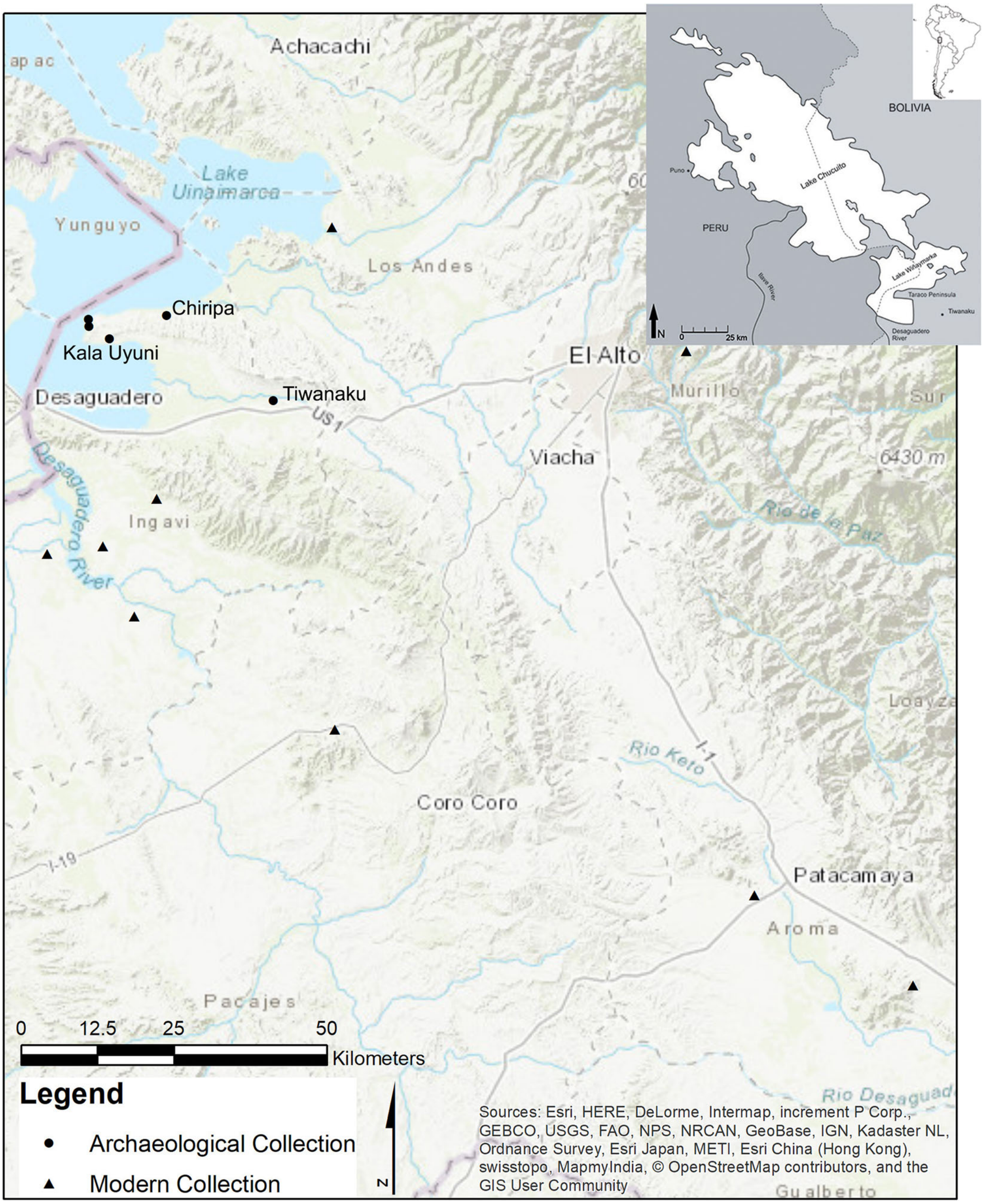

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**Fig. 1.** Location of archeological and modern collections of domesticated *kañawa* and wild *illama* seeds in the southern Lake Titicaca Basin of Bolivia.

## BOTANICAL PERSPECTIVES ON KAÑAWA AND ITS DOMESTICATION

The domesticated kañawa plant can vary in height between 20 and 60 cm. It is highly branched with small, concealed inflorescences that grow along the forks of the stem with a growth habit that can vary from fairly erect with few branches and a narrow width to more branched and leafy with a wider diameter (Fig. 2) (IPGRI et al. 2005: 26; Pinto 2011; Simmonds 1965).

It is a colorful plant ranging from red, yellow to green. Kañawa is an important crop in the high Andes, known for its resistant properties in cultivation, as well as being highly nutritious. Its seed contains 14–19% protein and many important amino acids (IPGRI et al. 2005; Rojas et al. 2010). Traditional preparation involves first toasting the grain and then grinding it into flour. The flour can be used to make a type of cookie called *kispiña*. It is most commonly eaten as a porridge where warm water or tea is added to a bowl or cup of kañawa flour. New recipes for baked goods such as cakes are also becoming popular. Because of its highly nutritive qualities, it is also used traditionally as a medicine (Vargas 1938; Rojas et al. 2010).

Kañawa has been described as a "rustic" domesticate because it maintains several wild characteristics such as self-seeding, differential maturation, and easily shattering seeds. It often grows spontaneously in fields of other crops and requires little attention to grow (National Research Council 1989; Gade 1970; Risi and Galwey 1984). These characteristics, however, make it a reliable crop in adverse environments, and it is thus primarily cultivated in the coldest, driest regions of the Andes, particularly in the high plain, known as the *altiplano* (3000–4200 masl) (IPGRI et al. 2005).

The wild species of kañawa (*Chenopodium pallidicaule* Allen var. *pampalasta*) have only recently been studied in detail by researchers in Bolivia (Rojas et al. 2010; Pinto 2011). The wild species is highly branched with stems growing an average of 12 cm long. Compared to the domesticated species, it has a greater number of smaller leaves and grows prostrate to the ground with erect ends (Fig. 2). It also has a thicker leaf that protects the grains from spilling. The plants range in color from dark green to red. As with wild quinoa, wild kañawa produces darker colored seeds (Hunziker 1943, 1952; Leon 1964). Common names in Bolivia for wild kañawa are *illama* or *illamancus*, and we will refer to it throughout the text as *illama*.

Overall, there has been very little botanical research into kañawa's domestication. Given its modern distribution and diversity, it may have been domesticated in the Lake Titicaca Basin region (IPGRI et al. 2005). Early studies proposed that it may have been a secondary domesticate, one brought under cultivation among people who were already farming (Heiser and Nelson 1974). Daniel Gade (1970:55) speculated that the wild progenitor of kañawa could have first appeared as a weed in quinoa or potato fields. He suggests that farmers eventually recognized its abilities to resist drought and frosts and began to manage it. The study

**Fig. 2.** From left to right (1) domesticated kañawa (*saihua* variety), (2) domesticated kañawa (*lasta* variety), (3) wild kañawa or *illama* (Photo: PROINPA).

presented here is a first step towards testing some of these ideas.

## ARCHEOLOGICAL PERSPECTIVES ON KAÑAWA AND ITS DOMESTICATION

Archeological projects that incorporate systematic flotation and archeobotanical analysis often encounter high numbers of seeds that possess the general characteristic of *Chenopodium*. This genus produces single-seeded indehiscent fruits with papery fruit coats or pericarp (Planchuelo 1975). The seeds have a rounded perisperm with a wrapping embryo both of which are encased by a seed coat with a shape that varies from biconvex, rounded to truncate (Fig. 3). To date, potential identification of kañawa has been based on seed diameter. Several studies have noted a bimodal distribution in the size of chenopod seeds with one group having a mean diameter of about 0.5 mm and another about 1.0 mm and suggest that the smaller seeds could be kañawa (Browman 1989; Caló 2014; Pearsall 1989; Planella and Tagle 2004; Planella et al. 2005; Whitehead 2007). For the site of Chiripa, Whitehead (2007:180) questioned whether or not the smaller seeds were even domesticated and suggested that they could be semi-domesticates or possibly wild quinoa.

In order to determine whether or not the inhabitants of Chiripa were cultivating domesticated chenopods, Bruno (2001, 2006) conducted a study of seed morphology employing methods used by archeobotanists in Eastern North America, particularly the examination of seed coat characteristics using scanning electron microscopy (SEM) (Fritz and Smith 1988; Smith 1984). While she was able to determine that the larger seeds (> 1 mm) from Chiripa were both domesticated quinoa and wild quinoa negra, she was unable to identify the smaller seeds. They did not match any of the chenopod specimens in the comparative collections made by herself and Christine Hastorf from the Taraco Peninsula and Tiwanku valley, which included domesticated kañawa, *C. ambrosioides*, and a species identified by the Bolivian National Herbarium as *Chenopodium* sp. that grows near the lakeshore (Bruno 2001, 2008; Bruno and Whitehead 2003). At the time, she noted that these seeds were not only smaller than quinoa and quinoa negra, but had a smoother, "shiny" seed coat, and tended to have more rounded margins (Bruno 2001:90) (Fig. 4a).

When Bruno (2008) analyzed the archeobotanical samples from other sites on the Taraco Peninsula for her dissertation research, she also encountered large quantities of the smaller

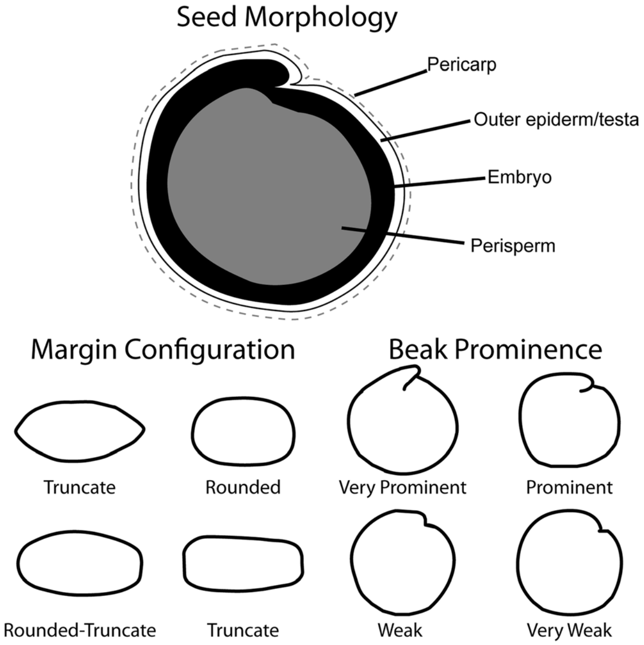

**Fig. 3.** *Chenopodium* seed morphology, margin configuration variation, and beak prominence variation.

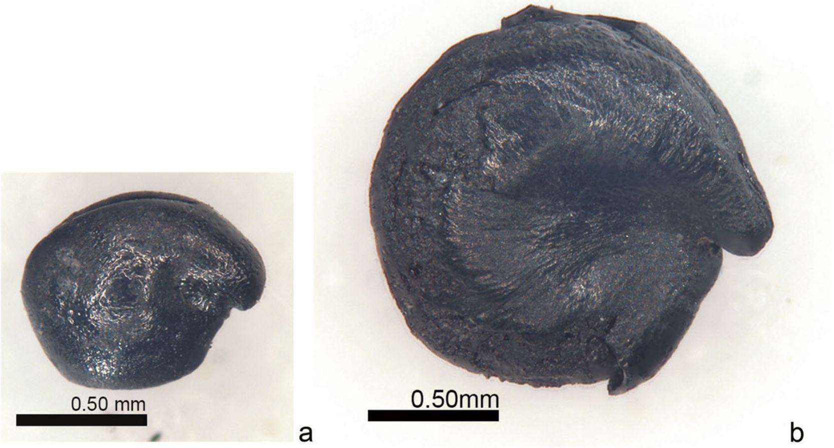

**Fig. 4.** **a** Archeological "unknown Amaranthaceae" or *illama* seed showing shiny surface. Also note canaliculate texture across the seed but particularly at the beak. **b** Archeological domesticated kañawa seed, also with a canalicate seed coat texture.

*Chenopodium* seeds. They occurred in 94% of the 213 samples analyzed and comprised 20.3% of all identified species (Bruno 2008:218). She designated them as the "unknown Amaranthaceae" type (sensu APG 1998) and hypothesized that it could be *illama* but did not have the comparative collections to test it. As part of her dissertation fieldwork, Bruno conducted an extensive plant collection on the Taraco Peninsula but did not encounter any *illama*. Today, Taraco farmers grow quinoa, but they do not grow kañawa. It is, however, regularly grown in the Tiwanaku valley to the southwest (Fig. 1).

The lack of modern *illama* specimens led Bruno to contact the La Paz, Bolivia office of the PROINPA Foundation. As part of its work in protecting genetic resources and agrobiodiversity, PROINPA managed the Banco Nacional de Germoplasma de Granos Andinos (BNGA) until 2010. It currently maintains working collections of quinoa and kañawa, including a variety of cultived, wild, and weedy varieties that were gathered from communities across the Bolivian *altiplano* but particularly in the southern Lake Titicaca basin (Rojas et al. 2010) (Fig. 1). In collaboration with agricultural engineers Licenciado Wilfredo Rojas and Licenciado Milton Pinto, Bruno was able to sample seeds of *illama* from the PROINPA working collection to study their morphology.

Here, we present new information on the morphological characteristics of modern *kañawa* and *illama*. We then turn to an analysis of archeological specimens from the Taraco Peninsula and Tiwanaku that have been identified as either unknown Amaranthaceae (following Bruno 2008) or domesticated *kañawa* based on morphological similarities with the modern populations. We find that there are some morphological differences among the modern and wild populations, but argue that the unknown Amaranthaceae are wild *kañawa* or *illama*. We then turn to a discussion about the unique seed morphology of these chenopods, what they may reveal about the domestication of *kañawa*, and its designation as a "rustic" crop.

## Methods: Identifying Wild and Domesticated Kañawa Based on Seed Morphology

There are now several generations of international archeobotanists working on chenopod morphology throughout the Americas and a standard protocol has been developed for describing the most diagnostic morphological characteristics of seeds using both quantitative and qualitative measures that reflect basic taxonomic differences as well as traits selected for under domestication (for details on the traits and summarizes of this research, we recommend Fritz et al. 2017 and Planella et al. 2014).

Bruno conducted the SEM analysis of both modern and archeological specimens. At Washington University in St. Louis (2000–2006), she measured seed diameter under a Leica Wild M3 stereomicroscope with an ocular micrometer. High-resolution images of each testa and some examples of the seed coat texture were captured using Hitachi scanning electron microscope and printed on photographic paper. The testa thickness then was measured directly from the photographs (see Bruno 2001). At the Smithsonian Institution's National Museum of Natural History (2009), she measured seed diameter using an Olympus SZX12 Microscope/Digital Camera system and measured on screen with ImagePro Plus software. High-resolution images of each testa and seed coat texture were viewed with a Phillips XL-30 ESEM and measured on screen with Scandium Imagining System Software. At Dickinson College (2015), seed diameter was observed using a Nikon SMZ 645/DS-Fi1 Digital Camera and measured on screen with ImagePro Plus software. High-resolution images of the testa and seed coat texture were taken with a JEOL JSM 5900 SEM and measured with ImagePro Plus software. In all cases, the qualitative attributes were assessed using a combination of microscopes.

The modern domesticated kañawa seeds ($N = 42$) come from collections made by Christine Hastorf and Maria Bruno during ethnnobotanical and archeological projects carried out in the Tiwanaku valley in the late 1990s and early 2000s. The modern *illama* seeds ($N = 105$) come from the PROINPA collection and derive from various locations in the Bolivian *altiplano* (Fig. 1). All of the modern seeds were carbonized using a muffle furnace to make them comparable to the carbonized archeological specimens. Not all of the attributes could be measured on each seed, so sample size varies in the analysis. Additionally, pericarp rarely preserves on the carbonized archeological specimens, so this attribute was not considered. For the modern specimens, after carbonization, most of the pericarp was gently removed by rolling the seeds so as to access the characteristics of the seed coat, particularly texture.

The archeological specimens derive from flotation samples from three sites: Chiripa and Kala Uyuni, on the Taraco Peninsula, Bolivia, and the sector of Mollo Kontu, at the site of Tiwanaku (Fig. 1). Using a stereomicroscope, Bruno examined the basic traits: relative seed size and testa thickness, seed coat texture, and margin configuration to make an initial identification of seeds a *kañawa* or "unknown Amaranthaceae." For the SEM analysis, we selected 42 seeds identified as archeological *kañawa* and 45 seeds identified as "unknown Amaranthaceae," which we hypothesize to be archeological *illama* and refer to as such below. A summary of all attributes is provided in Table 1. The data were analyzed using JMP13. Student's *t* test and chi-squared likelihood ratios were utilized to determine statistical significance of difference among the various populations.

## Morphological Attributes of Modern Kañawa and Illama

### SEED DIAMETER

The modern *kañawa* seeds ($N = 42$) range in diameter from 0.9 to 1.40 mm with a mean of 1.12 mm (SD = 0.13). The modern *illama* ($N = 103$) seeds range in size from 0.77 to 1.56 mm with a mean of 1.00 mm (SD = 0.15 mm). Although there is overlap in the ranges of seed diameter, their means are statistically significantly different ($t = -4.363$, df = 179, $p = < 0.001$) with the domesticated form being slightly larger than the wild one.

### TESTA THICKNESS

Modern *kañawa* seeds ($N = 42$) have testa thicknesses ranging from 4.25 to 10.60 μm with a mean of 6.67 μm (SD = 1.42). Testa thickness of *illama* seeds ($N = 100$) ranges from 5.10 to 23.75 μm with a mean of 13.41 μm (SD = 4.25 mm). Again, there is some overlap in testa thickness between the wild and domesticated forms, but the difference in mean testa thickness is statistically significant ($t = 5.63$, df = 176, $p = < 0.001$).

### TESTA/DIAMETER RATIO

To take into account the thickness of the testa in relation to the entire seed diameter, it is possible to examine a ratio of the two (Bruno 2006). A lower number reflects a smaller percentage of the total diameter that is the seed coat (Table 1) (Fig. 6). *Kañawa* ranges from – 2.15 to – 1.68 with a mean of – 1.93 (SD = 0.10) and *illama* ranges from – 1.99 to – 1.29 with a mean of – 1.59 (SD = 0.17). Although there is overlap, this difference is statistically significant ($t = 9.866$, df = 260, $p = < 0.001$).

### SEED COAT TEXTURE

Both the *kañawa* and *illama* seeds have a canaliculate texture, although they do display some

TABLE 1. SUMMARY OF QUANTITATIVE AND QUALITATIVE ATTRIBUTES FOR THE MODERN AND ARCHEOLOGICAL *KAÑAWA* AND *ILLAMA* SEEDS EXAMINED IN STUDY. ALL SPECIMENS ARE CARBONIZED.

| Taxon | Seed diameter (mm) | Testa thickness (microns) | Log testa/diameter ratio | Seed coat texture | Margin configuration | Beak prominence |
|---|---|---|---|---|---|---|
| Modern *Kañawa* | $N$ = 42 | $N$ = 42 | $N$ = 42 | $N$ = 42 | $N$ = 42 | $N$ = 21 |
| | $x$ = 1.12 | $x$ = 6.67 | $x$ = – 1.93 | 90% canaliculate | 100% rounded-truncate | 0% very prominent |
| | SD = 0.13 | SD = 1.42 | SD = 0.10 | 10% smooth center/canaliculate at beak | | 48% prominent |
| | Min = 0.90 | Min = 4.25 | Min = – 2.15 | | | 43% weak |
| | Max = 1.40 | Max = 10.60 | Max = – 1.68 | | | 9% very weak |
| Modern *Illama* | $N$ = 103 | $N$ = 100 | $N$ = 99 | $N$ = 102 | N = 105 | $N$ = 104 |
| | $x$ = 1.00 | $x$ = 13.41 | $x$ = – 1.59 | 72% canaliculate | 73% rounded-truncate | 0% very prominent |
| | SD = 0.15 | SD = 4.25 | SD = 0.17 | 28% smooth center/canaliculate at beak | 13% rounded | 83% prominent |
| | Min = 0.77 | Min = 5.10 | Min = – 1.99 | | 13% truncate | 16% weak |
| | Max = 1.56 | Max = 23.75 | Max = – 1.29 | | | 0% very weak |
| | | | | | | 1% N/A |
| Archeological *kañawa* | $N$ = 42 | $N$ = 42 | $N$ = 42 | $N$ = 42 | $N$ = 40 | $N$ = 42 |
| | $x$ = 0.89 | $x$ = 9.13 | $x$ = – 1.57 | 88% canaliculate | 40% rounded-truncate | 14% very prominent |
| | SD = 0.19 | SD = 3.40 | SD = 0.16 | 12% smooth center/canaliculate at beak | 5% rounded | 69% prominent |
| | Min = 0.68 | Min = 1.52 | Min = – 2.00 | | 50% truncate | 17% weak |
| | Max = 1.42 | Max = 19.46 | Max = – 1.27 | | 5% N/A | 0% very weak |
| Archeological unknown Amaranthacea *illama* | $N$ = 45 | $N$ = 45 | $N$ = 45 | $N$ = 45 | $N$ = 45 | $N$ = 8 |
| | $x$ = 0.88 | $x$ = 12.18 | $x$ = – 1.72 | 4% canaliculate | 4% rounded-truncate | 12% very prominent |
| | SD = 0.15 | SD = 4.17 | SD = 0.24 | 96% shiny/smooth center/canaliculate at beak | 93% rounded | 38% prominent |
| | Min = 0.60 | Min = 5.5044 | Min = –2.62 | | 2% truncate | 50% weak |
| | Max = 1.25 | Max = 27.00 | Max = – 1.45 | | | 0% very weak |

variation. In 90% of the *kañawa* seeds, the entire seed coat is canaliculate (Fig. 6a), while the remainder has a smooth texture in the center and is canaliculate near the beak. Among the *illama* seeds, 72% are entirely canaliculated and 28% are canaliculate near the beak but smooth in the center (Fig. 6b). Thus, while both types display canaliculate patterning on the seed coat, domesticated seeds have it across the whole seed while wild seeds often have it only at the beak and margins ($\chi^2 = 8.04$; df = 2, $p < 0.018$).

### MARGIN CONFIGURATION

The shape of the seed in cross-section is known as margin configuration (Fig. 3). This attribute becomes difficult to assess when the seeds are carbonized as the perisperm often expands causing the seed to "puff" and look more rounded in cross-section. All of the *kañawa* seeds, even with slight puffing, have a truncate configuration. The *illama* have more variation with some truncate (13%) or rounded (13%) but predominately (73%) rounded-truncate. While both domesticated and wild forms tend to be truncate-rounded, there is a statistically significant chance that the wild *illama* seeds will be more rounded than the domesticated seeds ($\chi^2 = 219.56$; df = 9, $p < 0.001$).

### BEAK PROMINENCE

This is an attribute that has recently been described for Andean chenopods (Langlie et al. 2011), and Bruno did not begin recording it until her work at NMNH in 2009 (Fig. 3). For this reason, not all of the modern kañawa specimens have this attribute recorded. The *kañawa* seeds ($N = 21$) are mostly prominent (48%) or weak (43%), with just a few exhibiting very weak beaks (9%). For *illama*, the majority (83%) of the seeds have prominent beaks, while less have (17%) have weak beaks (Fig. 6), and one could not be determined due to damage. The prominent beak type is the most common across the wild and domesticated types but there does seem to be trend towards a weak beak in the domesticated seeds ($\chi^2 = 15.26$; df = 2, $p < 0.001$).

### DIFFERENTIATING MODERN KAÑAWA AND ILLAMA SEEDS

This analysis reveals that although there are several similarities in seed morphology between *kañawa* and *illama* seeds, there are also several statistically significant differences that would allow an archeobotanist to differentiate them. Like other chenopods, the domesticated *kañawa* tends to be larger in diameter and have a thinner testa than the wild counterpart *illama*. The domesticated *kañawa* seeds tend to have seed coats that are entirely canaliculate, their margins more truncate, and there is a slight tendency towards a weaker beak. In contrast, the wild *illama* seeds can be identified by their rounder margins, smoother surfaces with strong canaliculate patterning near the beak, and more prominent beaks. With these parameters, we can now turn to the archeological samples.

## Morphological Attributes of Archeological Kañawa and Illama

### SEED DIAMETER

The diameter of the archeological *kañawa* seeds ($N = 42$) ranges from 0.68 to 1.42 mm with an average of 0.89 mm (SD = 0.19). The archeological *illama* seeds ($N = 45$) range from 0.60 to 1.25 mm with a mean of 0.88 mm (SD = 0.15 mm). Although there is a slight tendency for larger seeds in the domesticated seeds, the average diameter between the two is nearly identical and they are not statistically significantly ($t = -0.725$, df = 92, $p = 0.4702$).

### TESTA THICKNESS

The testa thickness of the archeological *kañawa* seeds ($N = 42$) ranges from 1.52 to 19.46 µm with an average of 9.13 µm (SD = 3.40). The testa thickness of the archeological *illama* seeds ($N = 45$) ranges from 5.50 to 27.00 µm with a mean of 12.18 mm (SD = 4.17 µm). While there is overlap in these two groups, the domesticated seeds have a slightly thinner mean testa thickness, the difference of which is statistically significant ($t = 3.52$, df = 92, $p = 0.0007$).

### TESTA/DIAMETER RATIO

For the testa/diameter ratio the archeological *kañawa* seeds range from − 2.00 to − 1.27 with a mean of − 1.57 (SD = 0.16) and the archeological *illama* seeds range from − 2.62 to − 1.45 with a mean of − 1.72 (SD = 0.24). Although slight, the difference is statistically significant ($t = 3.815$, df = 260, $p = 0.0002$) showing that the domesticated form has a relatively larger seed and thinner seed coat compared to the wild one (Fig. 5).

### Seed Coat Texture

The majority of the archeological *kañawa* seeds (88%) are entirely canaliculate and 12% have a smooth center and are canaliculate at the beak (Fig. 6c). The majority (96%) of the archeological *illama* seeds have a shiny, smooth surface in the center with canaliculate patterning along the seed margins and near the beak (Fig. 6d). A few of the archeological *illama* seeds (4%) have the canaliculate patterning across the whole seed. These differences are statistically significant ($\chi^2 = 72.65$; df = 1, $p < 0.001$) indicating that it is more likely for the domesticated form to be entirely canaliculate and the wild form smooth in the center and canaliculate at the margins.

### Margin Configuration

Fifty-three percent of the archeological *kañawa* seeds have a truncate shape with 43% rounded-truncate and only 4% rounded. Nearly all of the archeological *illama* seeds have some degree of "puffing" resulting in the majority (93%) being described as rounded in shape (Fig. 3). Those that are less puffed are either rounded-truncate (4%) or truncate (2%). The domesticated *kañawa* seeds are also susceptible to puffing, but it seems less common than in the wild seeds. These differences are statistically significant ($\chi^2 = 80.35$, df = 2, $p < 0.001$).

### Beak Prominence

The majority (70%) of the archeological *kañawa* seeds have a prominent beak, 14% are very prominent, and 17% are weak (Fig. 6c). Most of the archeological *illama* seeds were examined prior to 2009, and therefore, beak prominence was only observed for 8 seeds. Half had a weak beak with 38% prominent and 12% very prominent (Fig. 6d). While it appears that the domesticated form has a tendency for a prominent beak and the wild a weak beak, the low sample size does not make them amenable to statistical analysis.

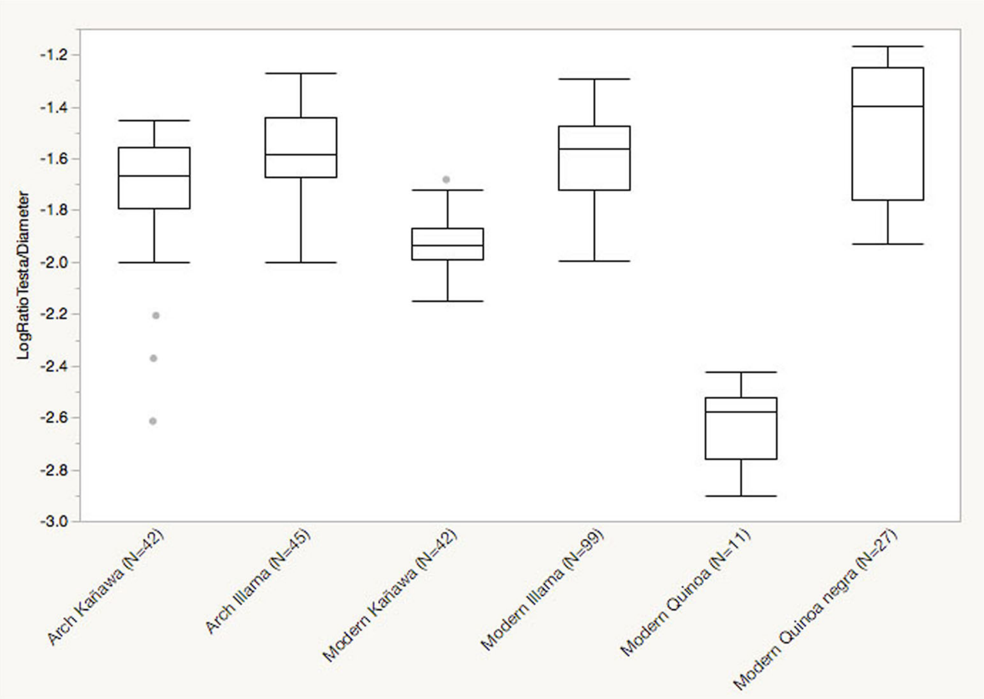

**Fig. 5.** Box plot of log ratio testa/diameter of archeological and modern specimens of domesticated *kañawa*, wild *illama*, domesticated *quinoa*, and wild *quinoa negra* (one-way ANOVA, $F = 85.647$, DF = 5, $p = < 0.001$).

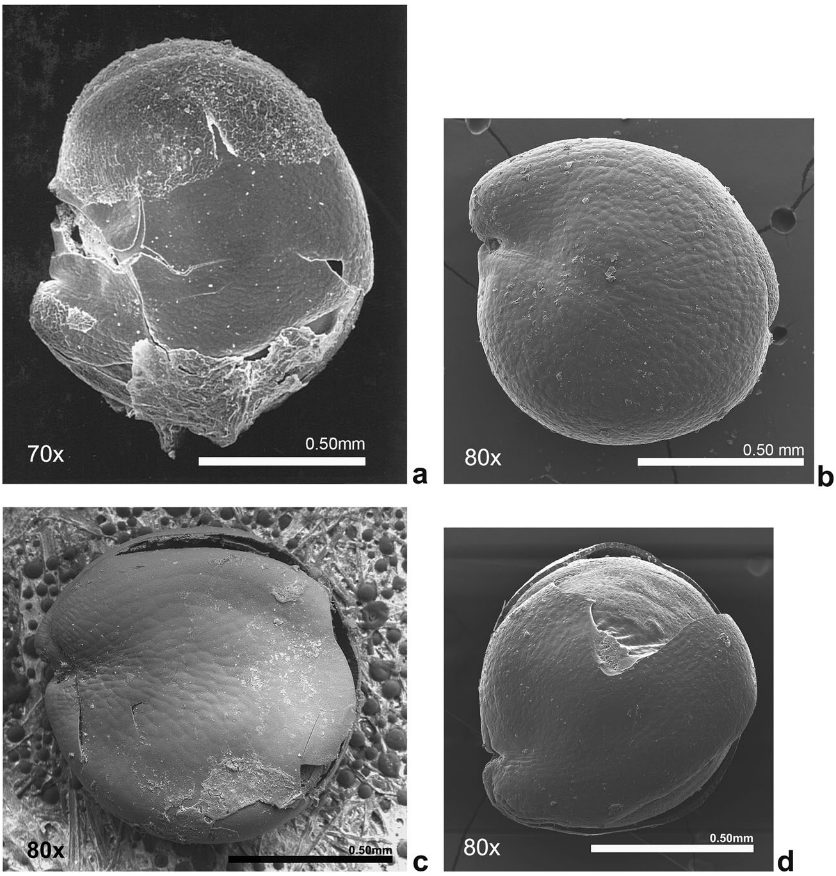

**Fig. 6.** SEM images of **a** modern kañawa seed with canaliculate texture (some of its papery pericarp also preserves) and a weak beak, **b** a modern *illama* seed with a canaliculate texture, particularly strong along the margin and beak, and a prominent beak, **c** an archeological kañawa seed with canaliculate texture and a weak beak, **d** an archeological *illama* (unknown Amaranthaceae) seed with a canaliculate texture along the margin and beak, smooth in the center, and a prominent beak.

## IDENTIFYING AND DIFFERENTIATING ARCHEOLOGICAL KAÑAWA AND ILLAMA SEEDS

In order to test our hypothesis that we have identified both the domesticated species of *kañawa* and its wild counterpart *illama*, we compare them to the modern populations. For the quantitative traits, we can compare relative testa thickness and seed diameter with the ratio (Table 1). Figure 5 illustrates that there is a great deal of overlap in size (diameter) and testa thickness among the four *kañawa* populations, yet there are some differences. The modern domesticated *kañawa* seeds tend to have the largest diameters and thinnest testas. Although the majority of the archeological domesticated *kañawa* seeds are not as large or thin as the modern specimens, they are more so than either the modern or archeological *illama* populations. Most important to our identification of the "unknown Amaranthaceae" as *illama* is that the archeological and modern seeds have a nearly identical testa/diameter ratio with no significant difference in their means ($t = -0.729$, df = 260, $p = 0.4662$).

The qualitative trait that appears to be most diagnostic for identifying the *kañawa* group as a whole is the presence of some degree of canaliculate seed coat patterning, as Bruno (2006) observed previously. We find that both the archeological and modern domesticated *kañawa* specimens tend to have the patterning across the whole seed. While there is a higher percentage of a smooth center and a canaliculate beak in the modern *illama* (24%) seeds, this pattern is much more common in the archeological wild population (96%). This could potentially reflect a difference in ecotypes, perhaps the original Taraco/Tiwanaku *illama* populations had this trait and those in the surrounding areas represented in the modern populations did not. It could also be a trait that was lost through time as humans selected for the domesticated *kañawa* variety and continued introgression between wild and domesticated populations resulted in the fully canaliculate trait becoming more frequent in all *kañawa* populations. We do not have the ability to answer this issue here, but we hope that continued study into the archeological and modern populations can help to clarify it.

There is a great deal more variance in margin configuration among the four populations, and this is likely due to differences in processes of carbonization. Although we did carbonize the modern samples, we did so slowly so as not to cause much distortion in the seeds. The archeological seeds were exposed to a range of different burning conditions often resulting in puffing, particularly with the archeological *illama* seeds. Despite this variation, both the modern and archeological *kañawa* seeds tend to have more truncate margins whereas the modern and archeological *illama* seed tend to be more rounded.

## Conclusions

As Bruno (2006) argues, the diversity of chenopods in the Andes requires that archeobotanists examine a suite of attributes in order to identify particular species. With this study, we now have more robust guidelines with which to identify archeological specimens of the second major cultigen of *Chenopodium* in the Andes, *kañawa* and its wild counterpart, *illama*, at least in the Lake Titicaca Basin. The diversity of Andean chenopods certainly leaves open the possibility that the traits described here may overlap with un-studied wild chenopod populations elsewhere in the Andes. We hope that this study encourages further research.

In summarizing these findings, we find it useful to review the difference between the *kañawa* group (*Chenopodium pallidicaule*) and its cousin *Chenopodium quinoa* (Fig. 5; Bruno 2006), which are the most common species in archeological assemblages. First, the *kañawa* group tends to have a smaller seed diameter (around 1 mm or less) than *quinoa* (> 1 mm), an attribute recognized by the first archeobotanists mentioned in the introduction. Testa thickness varies but both domesticated forms of *kañawa* and *quinoa* have thinner testa thicknesses than their wild counterparts *quinoa negra* and *illama*. *Quinoa* is more extreme on both ends, with the cultigens having both the thinnest (0–10 μm) seed coats and the wild form having the thickest (20–40 μm). While the means are statistically significantly different between domesticated *kañawa* and wild *illama* their ranges overlap much more than in the wild and domesticated *quinoa*. The texture and margin configuration of the two species are also distinctive. The *kañawa* populations all possess a canaliculate seed coat texture. Domesticated *quinoa* has a very smooth surface while *quinoa negra* seeds have a reticulate texture. The margin configuration of both domesticated *kañawa* and *quinoa* are truncate whereas group wild *kañawa* is rounded and wild *quinoa negra* biconvex.

This comparison illustrates that there are greater morphological differences between the wild and domesticated *quinoa* species than the domesticated and wild *kañawa* species. While this might make differentiating *kañawa* and *illama* in the archeological record more challenging, it adds new information to our understanding of the character of this understudied crop. In many respects, these findings support characterizations of *kañawa* as a "rustic" or weed-like cultigen. Traits such as a small size and relatively thick seed coat likely contribute to the crops' ability to resist adverse conditions and still produce when other crops, including its cousin *quinoa*, are destroyed by frosts and drought. Yet, despite these similarities, the morphological differences in domesticated *kañawa* and wild *illama* seed populations reflect the selective pressures of humans as they recognized the usefulness of this species to produce food under a variety of conditions as well as add new flavors and textures to their culinary traditions. The differences between the modern and archeological domesticated *kañawa* populations further reflect hundreds of years of selective pressure by Andean farmers. With this study, archeobotanists can move forward in documenting the presence of *kañawa* and *illama* in the archeological record, obtaining information on the timing, locations, and processes of domestication and diversification, and begin to unravel the history of a unique crop that has been overlooked for far too long.

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