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Archaeobotanical Insights into Kañawa (*Chenopodium pallidicaule* Aellen) Domestication: A Rustic Seed Crop of the Andean *Altiplano*

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Abstract: *Kañawa*/*Cañihua* (*Chenopodium pallidicaule* Aellen) is the lesser-known cousin of the domesticated Andean pseudocereal quinoa (*Chenopodium quinoa* Willd.). In 1970, Daniel Gade hypothesized that Andean farmers may have domesticated volunteer wild *kañawa* plants that occupied quinoa or potato fields after observing that they could survive harsh climatic events such as drought or frost. To revisit this question of *kañawa* domestication, this paper provides an overview of the current botanical, genetic, and archaeological knowledge of *kañawa* domestication. It then provides patterns in the presence of wild and domesticated *kañawa* seeds from archaeological sites in the southern Lake Titicaca Basin of Bolivia, spanning the Formative and Tiwanaku periods from approximately 1500 BCE to 1100 CE. This archaeobotanical evidence supports Gade's hypothesis that *kañawa* was a later domesticate, not appearing until after 250 CE. Regional paleoclimatic evidence of frequent climatic fluctuations lends support to the argument that *kañawa* contributed to a diversified food supply, which could provide a buffer against climate risks.

Keywords: *Kañawa*; *Cañahua*; *Cañihua*; pseudocereal domestication; Andes

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1. Introduction

The Andean region of South America is home to a diversity of domesticated pseudocereals (a plant that produces a starchy seed but is not a grass) including one species of amaranth (*Amaranthus caudatus* L.) and two chenopods: quinoa (*Chenopodium quinoa* L.) and *kañawa*/*cañihua* (*Chenopodium pallidicaule* Aellen). *Kañawa*/*cañahua* is the Aymara pronunciation of the crop mostly commonly used in Bolivia, and *cañihua* is the Quechua term most commonly used in Peru. Because this study focuses on the Bolivian altiplano, I utilize the Aymara terms and orthography in this paper. In the Andes, quinoa is the most widely cultivated pseudocereal, thriving across various ecological regimes from the Pacific coast to highlands, from 0 to 4000 m above sea level [1,2]. Amaranth and *kañawa* have more restricted cultivation areas, with amaranth producing best on the warmer coast and highland valleys and *kañawa* being tolerant of the driest, coldest regions of the high Andes (Figure 1) [3–7]. Since the 1990s, quinoa has achieved global recognition as a "superfood" and is now a common ingredient in meals outside of the Andes [1,8]. As the most widely produced and well-known Andean pseudocereal, it has also been the subject of most studies of domestication, diversification, and other agronomic attributes by archaeologists, botanists, and agronomists [1,9]. Amaranth and *kañawa* have received less attention, yet deserve more study as they present nutritional, agronomic, and culinary characteristics that could benefit both producers and consumers [5,10]. Here, I contribute to our understanding of *kañawa* domestication, particularly in the Lake Titicaca basin of the Andean high plain, or *altiplano*. Despite being largely disregarded, confused with, or considered inferior to, quinoa by outsider observers, including the early Spanish colonists [6], *kañawa* has been and continues to be cultivated by smallholder, indigenous farmers across the *altiplano* [11]. It is at risk, however, of genetic loss because of the increase in market demands for quinoa and other crops [12,13]. It is primarily for household consumption but is also increasingly popular in highland cities of La Paz, Bolivia and Puno, Peru. In recognition of its high nutritional value and ability to grow in adverse, arid environments, there are also some efforts to increase its availability outside of the Andean countries [5].

Figure 1. Distribution of *kañawa* in South America (grey area) and location of study area (white box).

This study builds, in particular, on the pioneering observations of geographer Daniel Gade, who documented *kañawa* production in highland Peru in the 1970s and wrote one of the first English-language publications about the crop [14]. In this publication, he not only documented the process of cultivation and its uses, but provided insights into how it became a domesticated crop within the broader system of high, Andean agriculture. He noted that *kañawa* was a "rustic" domesticate, a plant that retained characteristics of wild seed-producing plants, such as shattering and non-uniform maturation. He also hypothesized that *kañawa* was a secondary domesticate, domesticated later in time by Andean quinoa and potato farmers who noticed its resistance to particularly harsh conditions such as frost and drought. In Bruno, Pinto, and Rojas (2018), we considered Gade's first point by examining the morphological attributes of domesticated and wild *kañawa* (known as *illama*) seeds from a contemporary Bolivian seed bank at PROINPA and archaeological sites in the southern Lake Titicaca basin [15]. We found that while there are morphological traits associated with domestication in terms of seed size and testa thickness, there is a greater overlap between wild and domesticated *kañawa* seeds compared to wild and domesticated quinoa. This supported the observation that it is a more "rustic" crop that still possesses some wild characteristics, which I will discuss in more detail below. This detailed seed morphology study enabled identification of *kañawa* species in the archaeological record (morphometric traits summarized in Table 1) [15]. Here, I address the second hypothesis presented by Gade that *kañawa* was a secondary domesticate brought under cultivation for its resilient characteristics through the identification of domesticated seeds from sites dating to the earliest periods of farming and social development in the southern Lake Titicaca Basin. I compare this with recent paleoclimatic evidence from the region. This provides new, direct archaeological evidence about the timing and climatic context of *kañawa* domestication. Before delving into the new archaeological and climatic data, it is important to first contextualize the current understandings of *kañawa* domestication based on agronomic, botanical, genetic, and archaeological information.

Table 1. Summary of quantitative and qualitative attributes for the modern and archaeological domesticated and wild *kañawa* and quinoa. Based on Bruno 2006, Bruno et al., 2018. All seeds were carbonized prior to measurement for comparison to archaeological materials [15,16].

Taxon	Seed Diameter	Testa Thickness	Seed Coat Texture	Margin Configuration	Beak Prominence
Modern *Kañawa* Domesticated	0.90–1.40 mm	4.25–10.60 microns	Canaliculate Smooth center/ Canaliculate at beak	Rounded–Truncate	Prominent to Weak
Modern *Illama* Wild	0.70–1.50 mm	5.10–23.75 microns	Smooth center/ Canaliculate at beak	Rounded to Rounded–Truncate	Prominent
Modern Quinoa Domesticated	1.5–2.9 mm	1.25–3.75 microns	Smooth	Truncate	Weak to very weak
Modern *Quinoa negra* Wild	1.06–2.95 mm	22–55 microns	Reticulate-Alveolate	Biconvex to equatorially banded	Weak

2. Background

2.1. Kañawa Cultivation and Culinary Characteristics

Kañawa differs from quinoa in several ways, and these differences, in part, contributed to its perceived inferiority to outsiders. The *kañawa* plant is smaller (20–80 cm high) than quinoa (80 cm to 3 m high) [17] (Figure 2). Unlike the large, dense seed panicles that grow on the tall stalks of quinoa, *kañawa*'s dry, single seeded fruits grow along the forks of highly branched stems in small, concealed inflorescences. Like quinoa, they are colorful plants in shades of red, yellow, or green. There are three types of growth habits that are described as different landraces by farmers: 'saihu' is erect with few branches, 'lasta' is semi-prostrate and highly branched, and 'pampalasta' is prostate and highly branched [5,13,18]. The first two are recognized as the domesticated varieties (*C. pallidicaule* Aellen), they also have fewer leaves and, in some cases, more seeds. The prostrate type has been identified as the wild species (*C. pallidicaule* Allen var. *pampalasta*), ranging in color from green to dark red, and is referred to by a different name: *illama*.

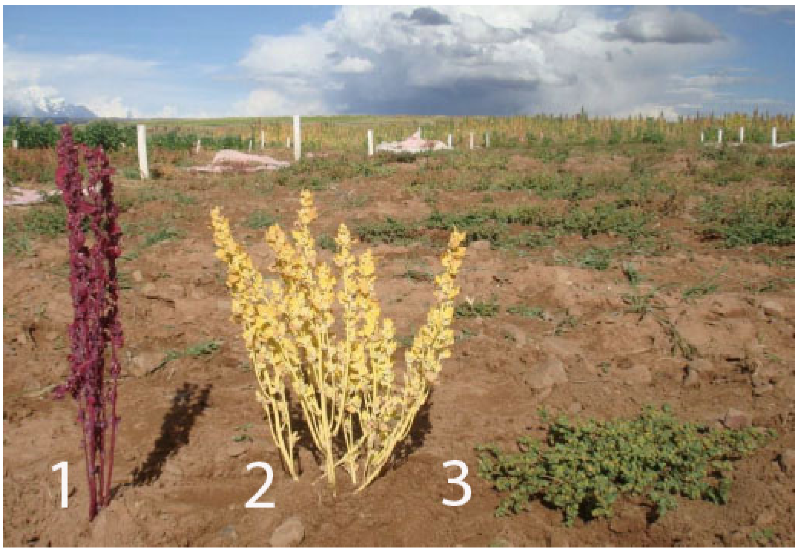

Figure 2. *Kañawa* types grown by PROINPA from left to right: (1) *saihua* domesticated *kañawa* variety, (2) *lasta* domesticated *kañawa* variety, (3) *Pampalasta* or *illama* wild *kañawa* variety (Figure reprinted with permission from Bruno et al. 2018 [15]).

Kañawa has a much more limited area of cultivation compared to quinoa, grown in the highest and driest regions of the Andean altiplano between 3600 and 4500 m above sea level, primarily in Peru and Bolivia, but it has been recorded in some areas of Ecuador [2,5,6,14]. *Kañawa* is an important contributor to the diverse crops cultivated in the high Andes along with quinoa, many varieties of potatoes, and other tubers. Crop rotation and multi-cropping are common risk-reduction strategies employed across the Andes [19–21]. *Kañawa* is normally planted at the start of the rainy season between October and November in a year following a potato harvest, alongside quinoa and other tubers. Like quinoa, it is broadcast-sown in lightly tilled soil.

"Perhaps no other crop is so resistant to the combination of frost, drought, salty soil, and pests or requires such little care in its cultivation", (Gade et al., 1970) [14]. Gade and others note that *kañawa* is a crop that often survives harsh frosts and low rainfall. It requires 500–800 mm of water/rain but can sustain droughts, although too much rain in the early stages of growth can be detrimental. The growing plant can sustain very cold temperatures of as low −10 °C. It is, however, particularly vulnerable to hail. It does not require much tending during the growing season and does not require any fertilization [5]. It is these hearty characteristics, as well as its distinctive flavor, that may have justified the continued management of this plant despite some of the challenges it presents in harvesting.

Kañawa maturation rates vary greatly between 95 and 175 days, which allows for harvesting sometime between March and May [14,22]. According to Serrano Quezada (2012), the plants are harvested when they begin to turn from green to orange, purple, pink, or yellow [11]. Like quinoa, *kañawa* plants are harvested by either pulling the whole plant out of the ground or cutting the stem. The harvesting of *kañawa* is more complicated than quinoa because of characteristics that are common in wild seed plant populations. First, not all plants mature at the same time, so any given field will have mature and immature plants. Secondly, mature plants can shatter during harvest, with 15–35% of the seeds being lost due to shattering [23]. Because of these traits, the yield of *kañawa* harvests is often much less compared to quinoa [5]. Recent studies comparing the effects of planting depth and temperature on maturation rates and seed shattering of different varieties aim to develop improved cultivation procedures and the on-going selection of desirable traits to increase the production of *kañawa* in the future [22].

Descriptions of processing *kañawa* include plants being threshed immediately after being cut or after drying [6,14]. Serrano Quezada notes that the plants are left out in piles for 10–15 days and moved around so that they do not rot [11]. After drying, they are then threshed and winnowed. I was fortunate to witness the processing of *kañawa* during a visit to an Aymara family in the community of Achuta Grande, Bolivia in 2000. After the harvest in late May, the stalks were placed in long piles about 5 m long and 2 m high. They dried for about a month and then armfuls were placed on a large blanket and threshed with sticks. Unlike the forceful pounding motion used to thresh quinoa, a gentler stirring motion was used, as the farmers mentioned that *kañawa* was more delicate that quinoa. Because the seeds are light and small, these farmers preferred to remove the remaining chaff by gently sweeping it away with hand-held *ichu* (*Stipa ichu*) grass brooms, rather than using the wind-blown winnowing described by many others, and commonly used for quinoa. The cleaned seeds were collected into textile bags and stored.

Kañawa is prepared for food in several ways. Gade (1970) and Serrano Quezada (2012) both observed that seeds were first soaked to remove the pericarp and flower, as well as any stones, and then dried and ground into a fine flour [11,14]. In Achuta Grande, the seeds we harvested were not soaked, but toasted in a pan with the pericarp and calyx still attached. They were then ground into flour. That day, we mixed the fine flour in a warm, sweetened herbal tea into a paste called *pitu* in Aymara and *kañihuaco* in Quechua. This is amongst the most common preparations, but the flour can also make small, dense cookies, which can be steamed, *kispiña*, or left out overnight to freeze for *thayacha*. Finally, it can be fermented into a lightly alcoholic beverage known as *chicha*, although this is more commonly made from fermented maize or quinoa.

Vargas (1938) describes several medicinal uses of *kañawa*, including for the treatment of jaundice, foot-and-mouth disease, urinary tract disorders, and altitude sickness [6].

Serrano Quezada (2012) documented that many families use it as a medicine to treat exhaustion, altitude sickness, and fever in humans and animals [11]. It is a very nutritious food composed of 14–19% protein, more than quinoa, which has a protein content between 10–12% [17]. It possesses many essential amino acids, which are similar in composition to casein animal proteins, as well as relatively high levels of Omega 6 fatty acids, flavonoids, antioxidant phenolic compounds, and fiber [10,24]. It has a slightly sweeter taste than quinoa due to the absence of saponins.

Kañawa has several non-food uses as well. The stems and leaves left over after processing the seeds are burned into ash that is mixed with water to create a paste, *illipta*, that is chewed with coca [6,11,14]. They are also sometimes fed to animals as forage. Serrano Quezada's ethnobotanical study found that, in some Bolivian indigenous communities, *kañawa* plants were boiled to make a red color used to dye wool [11]. She also documented the use of domesticated and wild *kañawa* seeds as offerings to mother earth, "Pachamama", for a good harvest.

2.2. Kañawa Domestication: Genetic and Archaeological Antecedents

Gade was the first to synthesize ideas regarding the domestication of *kañawa*. He noted that it "has a strong tendency to volunteer and may have been a weed in quinoa or potato fields before it was a cultivated plant" (Gade et al., 1970 [14]). He also suggested that it may have been noticed for surviving harsh conditions when the cultivated crops failed. This may have motivated farmers to eventually begin to manage it like their other cultivated crops. This would not only have provided another high-protein food source to these communities but would have allowed for high-elevation farming.

Despite publications by Vargas and Gade, *kañawa* was largely ignored by researchers until the 1990s and 2000s, when its cousin, quinoa, began to receive increased international attention. Its potential nutritional value and adaptation to arid environments has led to greater interest in recent years, as scholars in fields of agronomy and genetics consider overlooked crops to help with malnourishment, climate change, and even increasing rates of diabetes in developing countries [5,10]. *Kañawa* genetics emerged out of studies of quinoa aiming to better understand their evolutionary histories and to identify genes of traits that could be improved for agricultural production [25–28]). *Kañawa* (a diploid) has a divergent evolutionary history from quinoa (a tetraploid) in South America, which is more closely related to the Mexican domesticated Huauzontle (*C. berlandieri nuttalliae*) and North American extinct domesticate *C. berlandieri jonesianum*. These studies revealed that quinoa evolved from the hybridization of two ancestral diploid species (A-genome and B-genome), while *kañawa* evolved from only the A-genome diploid species [25,26].

A. Vargas et al. (2011) [28] carried out an analysis of 43 accessions of wild *illama* and domesticated *kañawa*, mostly from Bolivia, to identify genetic markers and quantify genetic diversity within the species. This revealed separate genotypes for wild and cultivated varieties, illustrating that there has been selection under domestication for the crop, despite its "wild" characteristics. They note, however, that no phylogenetic studies have been carried out to determine potential progenitor genotypes between these wild and domesticated populations, something that is needed to answer questions about where and which populations were involved in the domestication process. Interestingly, they found very little genotypic separation amongst groups from different geographic locations, suggesting high levels of interchange amongst the farmers who have cultivated *kañawa* in the past and present.

Little has been published on where *kañawa* might have been domesticated, aside from the general association with the Andean *altiplano*. Taking a Vavilovian approach, some have cited the Lake Titicaca basin as the region of origin due to the high genetic diversity of *kañawa* varieties growing there at present (Catacora 2017 cited in [5]).

The earliest archaeological studies that considered *kañawa* domestication were by archaeobotanists working at sites in Peru and Bolivia in the 1980s and 1990s. These sites contained evidence of the earliest management of wild plant and animal communities by Andean hunter-gatherers. These first, systematic archaeobotanical studies aimed to recover small seeds, such as quinoa and *kañawa,* through water flotation [29–32]. They hypothesized the presence of *kañawa* in the analyzed assemblages based on seed size: the smaller chenopods (mean diameter of 0.5 mm) were interpreted as *kañawa* and the larger chenopods (mean diameter of 1 mm) were interpreted as quinoa. More detailed morphological analysis was needed to verify whether these two sizes represented two species, and to determine if they were, in fact, domesticates.

The development in North America of using Scanning Electron Microscopy (SEM) to identify domesticated traits of *Chenopodium* seeds, which allowed for the identification of the extinct *C. berlandieri jonesianum*, facilitated this approach with the Andean chenopods [33,34]. Characteristics of the testa, or seed coat, including texture and thickness, appeared to be more diagnostic of domestication than seed size alone. Detailed presentation of a suite of morphological traits of wild and domesticated quinoa and *kañawa* have been published elsewhere and are summarized in Table 1 [15,16]. In both quinoa and *kañawa*, the domesticated seeds tend to be larger but also have thinner testa compared to their wild counterparts. There is greater overlap between *kañawa* and *illama* in terms of seed size and testa thickness, again reflecting the retention of more "wild" traits compared to the highly selected-for quinoa domesticate.

The most identifiable qualitative differences between quinoa and *kañawa* are their seed coat textures and shape (margin configuration and beak prominence). Quinoa tends to be completely smooth while *kañawa* has a canaliculate pattern across the entire seed or along the margins. Quinoa seeds also tend to be more truncate in shape with a weak to very weak beak, while *kañawa* is round to truncate with a more prominent beak. The quantitative traits have been useful in differentiating wild versus domesticated seeds in archaeological samples. The qualitative traits are helpful in allowing archaeobotanists to sort out these different types of chenopods as they analyze whole assemblages of macrobotanical plant remains from archaeological sites. This enables the tracking of the presence of both wild *illama* and domesticated *kañawa* through time and across different archaeological contexts.

The timing of *kañawa* domestication is a question that has yet to be answered with direct evidence. A wide range of proposed dates can be found in the non-archaeological literature. Mangelson et al. (2019) claim it was domesticated 7000 years ago while Rodriguez et al. (2020) and Serrano Quezada (2012) state that it was domesticated by the Tiwanaku culture, which existed from AD 500 to 1100, but none of these claims are supported by direct archaeological evidence at present [5,11,26]. Gade's suggestion that it began as a weed in quinoa and tuber fields would place it after the initial period of plant domestication in the highlands. The timing of quinoa domestication appears to be between 5000 and 4000 years ago (3000–2000 BCE) in what is regionally known as the Late Archaic period and into the Early Formative period [9], so *kañawa* would potentially be domesticated after this.

Once domesticated seeds are identified archaeologically, their age can be ascertained through various methods. Associated dates are those obtained on other materials (such as carbon or other carbonized seeds) in the same contexts where the domesticated seeds were recovered. This is a less precise approach, as the seeds are small and could be displaced through taphonomic processes, thus being either older or younger than the dated material. Ideally, researchers would obtain direct AMS radiocarbon dates on identified domesticated seeds. Unfortunately, this can be difficult if only small numbers of seeds are available to date, as researchers may not want to put them through the destructive process. A combination of both approaches is ideal.

With the ability to now identify wild and domesticated *kañawa* in the archaeological record, I turn to examining patterns of their presence through time to address the hypotheses set out by Gade about when, how, and possibly why it was domesticated.

2.3. Chronology and Climate

Archaeologists working at numerous sites across the southern Lake Titicaca basin have developed a cultural chronology based on major developments and changes in human communities in the region (Table 2) [35–38]. This begins with the first, small groups of hunter-gatherers and ranges to the development of large states dependent on agriculture and pastoralism. Paleoenvironmental scientists have also worked to understand the characteristics of the past climate and environment in the lake basin through studies of lake core sediments, diatoms, and geochemistry [39–42]. Fluctuations in temperature and rainfall result in lake-level changes. Collaborations between these specialists have aimed to better understand the interactions between human populations and the changing environment. Here, I summarize the broad patterns that have been identified in both culture and climate to approximately CE 1100 in order to contextualize the processes of *kañawa* domestication and its contributions to the agricultural systems that developed in this region.

Table 2. Summary of archaeological time periods and major human developments in the Southern Lake Titicaca Basin.

Archaeological Period	Human Subsistence and Cultural Trends
Inca 1450–1532 CE	Centralized state from Central Andes. Intensive camelid herding for state; localized agriculture.
Pacajes 1100–1450 CE	Decentralized and autonomous polities; intensive camelid herding; expansive agriculture.
Tiwanaku 500–1100 CE	Centralized state across basin; intensive farming, herding, and fishing for state. Expansion of raised-field agriculture.
Late Formative 200 BCE–500 CE	Regional multi-community polities; intensive dry-land quinoa and tuber farming and camelid herding.
Middle Formative 800–200 BCE	Autonomous villages; extensive quinoa and tuber farming, camelid herding.
Early Formative 1500–800 BCE	Earliest settlements along lake shore, small hamlets; cultivation of early crops, quinoa, and tubers; camelid herding.
Late Archaic 3000–1500 BCE	Mobile hunter–gatherers; intensification of wild chenopod and tuber gathering; camelid hunting and herding.

As early as 8000 BCE, archaic hunter–gatherers interacted with a cold and dry climate, and Lake Titicaca was very low, with the small, southern basin being completely dry [43]. Unfortunately, there is scant evidence for their activities in the southern Lake Basin, but we know from other areas they were collecting and beginning to manage stands of wild chenopods, mostly likely the progenitor of domesticated quinoa, *C. hircinum* [9]. Around 2000 BCE, the climate began to warm, precipitation increased, the lake began to rise, and a productive environment emerged. By 1500 BCE, in what is known as the Early Formative period, human communities began to settle in the lake basin, and we find the first, direct evidence of domesticated quinoa cultivation [44,45]. Human populations grew and established the first villages with ceremonial architecture in the Middle Formative period (800–200 BCE) [36]. Agriculture expanded, with evidence for quinoa and tuber, likely potato (*Solanum tuberosum* L.) and *oca* (*Oxalis tuberosa* Molina) cultivation using more extensive farming practices [46,47]. In the Late Formative period (200 BCE–500 CE), multi-community polities developed with larger population centers and elaborated socio-political networks [48,49]. Based on changes in stone tools and weed assemblages, there is evidence that agriculture intensified through increased tillage of soils, shorter fallow periods, and possible fertilization of fields with camelid dung [46]. Around 500 CE, the first state in the region, Tiwanaku, emerged and became both a powerful religious and economic force in the lake basin [50,51]. The state increased the agricultural production of quinoa and tubers locally through the expansion of raised fields [52,53]. They also increased the presence and use of maize, a crop that did not grow in the basin previously, through cultivation in distant regions with warmer climates and possible experimentation on varieties in the lake basin [54].

Within each of these early periods of human development, the climate fluctuated between warmer/wetter periods with higher lake levels, and cooler/drier periods with lower lake levels [39–42]. Overall, the lake was lower than it is today but gradually increased over the span of time considered here. While none of the cultural changes appear to correlate directly with these climatic shifts, such fluctuations were an important element of the environment in which these human communities developed and thrived. People living during each of these cultural phases experienced at least one major episode of drier, cooler conditions [35]. Learning how to adjust to such changes by shifting land use, practicing a diversity of subsistence practices including fishing, collecting, farming, and herding, as well as raising a diversity of plant and animal species, was a key to their success. I now turn to a description of the materials and methods used to examine archaeological evidence of wild and domesticated *kañawa* across these periods to examine where this crop fit into this dynamic milieu of subsistence activity.

3. Materials and Methods

The materials presented in this study come from excavations at several sites in the southern Lake Titicaca basin of Bolivia (Figure 3). The sites of Chiripa, Kala Uyuni, Sonaji, and Kumi Kipa are located on the Taraco Peninsula and were excavated by the Taraco Archaeological Project directed by Christine Hastorf and Matthew Bandy between 1992 and 2009 [55–58]. These sites are primarily from the Formative period, with some Tiwanaku occupations. Mollu Kontu is an area of the site of Tiwanaku and was excavated by the Proyecto Jacha Marka directed by Nicole Couture, Deborah Blom, and me between 2005 and 2008 [59–62]. Only Tiwanku period contexts were recovered here.

Carbonized macrobotanical remains were obtained from these sites using the same modified-SMAP water flotation systems that processed 10 L soil samples, systematically collected from all excavated contexts [63]. The materials considered here derived from the light fraction of the flotation samples, which were analyzed using light microscopy, following standardized protocols to sort and identify all plant taxa. Several archaeobotanists contributed to this initial analysis, including Christine Hastorf, Bill Whitehead, BrieAnna Langlie, Mabel Ramos, and myself. I carried out the more specific identification of the different chenopod types in these samples: quinoa, *quinoa negra*, *kañawa*, and *illama*. A selection of wild and domesticated *kañawa* seeds were examined with SEM at the Smithsonian Institution and Dickinson College to verify these identifications and have been published [15]. Here, I present the patterns in the presence of these species through time using ubiquity, which is percent presence, and the most common statistic used to present such patterns in macrobotanical analysis [64]. The percentage represents the number of samples that contain each of the species within the total number of samples examined for each period. The number of samples per period is provided.

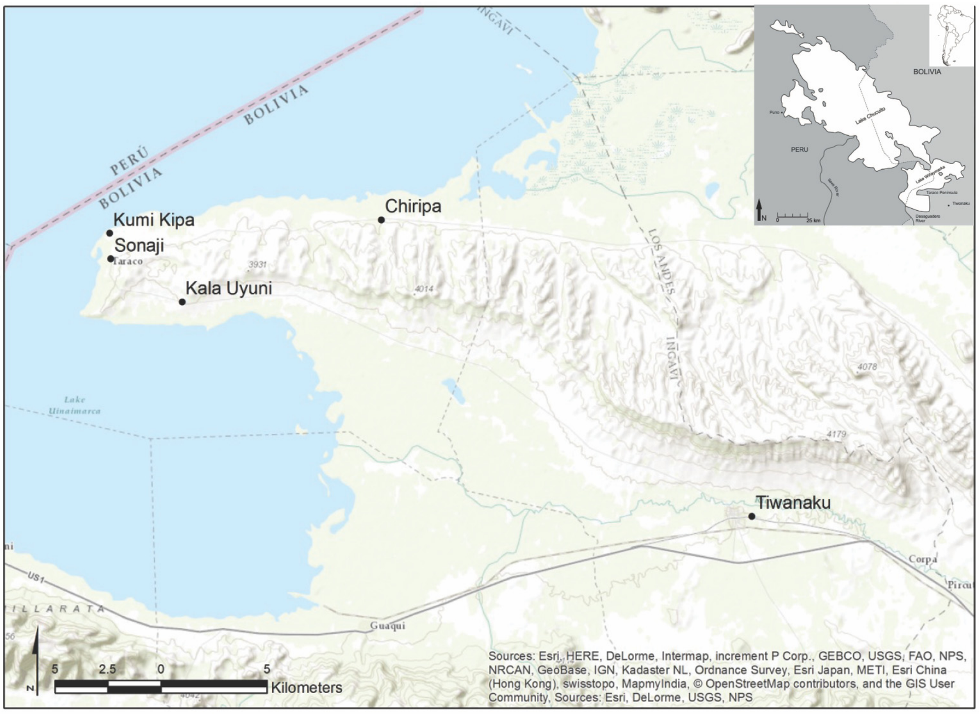

Figure 3. The southern Lake Titicaca Basin, showing the studied archaeological sites on the Taraco Peninsula (Achachi Coa Collu is part of Kala Uyuni) and the site of Tiwanaku where Mollo Kontu is located.

4. Results

4.1. The Appearance of Kañawa

Examining the ubiquity of the major types of chenopods encountered in flotation samples through time from the Taraco Peninsula and Tiwanaku, we find that quinoa is highly ubiquitous across all time periods, and its weedy counterpart *quinoa negra*, is also quite common (Table 3). Wild *kañawa* first appears in samples in the Early Formative period and increases through time. Finally, domesticated *kañawa* seeds do not appear until the Late Formative period, increasing into the Tiwanaku period. They are relatively rare compared to the other types of chenopods.

Table 3. Ubiquity of the four main chenopod types found in sites from the Taraco Peninsula (Chiripa, Kala Uyuni, Sonaji, and Kumi Kipa) and Mollo Kontu at Tiwanaku through time.

	Quinoa	***Quinoa Negra***	***Kañawa***	***Illama***
Early Formative (n = 71)	93%	79%	0%	39%
Middle Formative (n = 87)	93%	77%	0%	79%
Late Formative (n = 149)	98%	85%	2%	93%
Tiwanaku (n = 70)	97%	83%	6%	83%

The relatively high ubiquities of the wild *illama* suggest that this plant was common in the lives of the first farmers on the Taraco peninsula. It appears in similar ubiquities to the wild *quinoa negra* and could have entered the archaeological record indirectly through the burning of camelid dung [65]. Llamas and alpacas graze on these species and their dung is collected as an important source of fuel in the treeless *altiplano*. While this is one explanation for *illama*'s presence in the archaeological record, it occurred in particularly dense concentrations in some specific contexts on the Taraco Peninsula [56]. At the site of Kala Uyuni, in the Middle Formative sector of Achachi Coa Collu, a hilltop overlooking the lake to the south, archaeologists found discrete burning events associated with two sunken courts, ceremonial architecture typical of this period [66]. *Illama* was found in dense quantities in these burning events, suggesting that this plant was specifically chosen to be part of the offerings at this site. Although it was not yet a domesticated crop species, people in the region clearly found it to be significant and used it in these rituals. Serrano Quezada (2012) also mentions a specific case of an older Aymara farmer including *illama* as a burnt offering during the winter solstice for a good harvest in the new year. Additionally, Serrano Quezada documents the collection and use of *illama* as food, ground into flour or *pitu*. Thus, it is also possible that it could have started as a wild plant harvested and consumed even before selection pressures for domestication began [11].

The appearance of domesticated *kañawa* clearly comes later in the sequence. I sent several seeds of domesticated *kañawa* from Mollo Kontu to be directly AMS radiocarbon-dated; unfortunately, the amount was too small to produce a date. The seeds come from several contexts from the earliest phase of occupation that have radiocarbon dates between CE 580–670 and through to the end of occupation there, with a date rang of CE 880–1200 [62]. The number of *kañawa* seeds that we obtained from the Taraco sites (n = 4) is also too small to date and submit to a destructive process. They first appear in contexts based on ceramic styles and radiocarbon dates pertaining to the Late Formative I phase (200 BCE–CE 300) [56]. A few also appear in the Late Formative II (CE 300–500) and Tiwanaku (CE 500–1100) phases. The first few seeds with domesticated traits do not necessarily indicate that whole plants were domesticated but that the early processes leading to the selection of those traits began in the Late Formative period, possibly even before. The increased presence of such seeds in the Tiwanaku period suggests that more plants on the landscape possessed these qualities, indicating the cultivation of domesticated plants. This scenario supports Gade's hypothesis that this was a later domesticate. While *kañawa* was being cultivated by people in Tiwanaku, the credit for domestication should go to their Late Formative ancestors. To date, we do not have any positive identifications of *kañawa* from Late Formative sites in the Tiwanaku valley, and that should be a priority for future research as the crop is much more common in that region at present. Analysis of the ubiquity of *kañawa* from the Taraco sites compared to Mollo Kontu indicates that *kañawa* was much more common at Tiwanaku than on the Taraco Peninsula. *Kañawa* is present in 7% of the samples from Taraco (n = 57) and 37% of the samples from Mollo Kontu (n = 32) during the Tiwanaku period. In fact, *kañawa* is no longer cultivated on the Taraco Peninsula. Farmers state that it does not grow well there because it is warmer and wetter than the valleys further from the lake. Finally, it is worth mentioning that wild *illama* has not be collected on the peninsula and may also be absent. It now primarily grows in the drier regions of the *altiplano*.

4.2. Climate and Kañawa

The final element of Gade's *kañawa* domestication scenario is that it was noticed and eventually cared for because of its resistant qualities to drought and saline conditions. With the data presented here, southern Lake Titicaca basin farmers, at least on the Taraco Peninsula, were successfully growing quinoa and tubers for over a thousand years before *kañawa* was cultivated in high enough quantities to be visible in the archaeological record. Wild *illama* appears to have been common on the landscape and people were accustomed to collecting its seed for special occasions and possibly even food. Over this long period of time, farmers in the region experienced several cycles of warmer/wetter and drier/cooler conditions [35]. Local paleoclimate records indicate that there were several extended periods of much drier and cooler conditions in both the Middle and Late Formative periods, times when *kañawa*'s resilient attributes would have been important, likely filling in gaps in the production of both quinoa and tubers. This new crop would have added to the overall strategy of diversification that residents of the Titicaca Basin had developed and not only included a range of crop species but camelid herding and fishing, as well as some hunting and gathering [35]. While the lake basin continued to fill to even higher levels into the Tiwanaku period, suggesting warmer and wetter conditions during this period, *kañawa* appears to have become an increasingly important crop, adding new flavors and dishes people learned to enjoy, as well as adding an element of food security.

5. Conclusions

Kañawa is quinoa's overlooked cousin, who deserves greater attention. *Kañawa* and its wild counterpart *illama* can now be archaeobotanically differentiated from quinoa with low- and high-powered microscopy. New data presented here confirm that it was domesticated after quinoa by 200 BCE, at which time it became part of the farming systems in the southern Lake Titicaca Basin. More research aimed at identifying these species in the archaeological record is needed to further our understanding of the domestication processes across the Andean *altiplano* in Peru and Bolivia and to refine the chronology through radiocarbon dating. Additional genetic studies of the wild and domesticated varieties can also help to identify progenitors and possibly narrow the region in which domestication began. Greater attention to the deep history of *kañawa* may also promote support for its cultivation in the future. Studies by Andean agronomists of the crop show that its cultivation is in decline, and much of the knowledge of its uses is being lost as older individuals in these communities pass on. Although the global demand for quinoa has had some negative consequences for Andean farmers, it has resulted in the maintenance and deserved valorization of this important crop [8,67,68]. While *kañawa* production may never reach this scale, it is important to work towards sustaining the cultivation of this resilient, flavorful, and healthy Andean crop.

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