# Chapter 4
# Sweet Potato on Rapa Nui: Insights from a Monographic Study of the Genus *Ipomoea*

**Pablo Muñoz-Rodríguez, John R. I. Wood, and Robert W. Scotland**

## 1 Introduction

*Ipomoea batatas* (L.) Lam., the sweet potato, is one of the most important crops worldwide and a staple in many countries. It is cultivated in warm countries for its edible storage roots, and thousands of cultivars and landraces have been recorded worldwide. It is the best-known member of the genus *Ipomoea* L., the morning glories, a group of over 800 species present in all tropical and subtropical regions of the World (Muñoz-Rodríguez et al. 2019).

*Ipomoea batatas* is a species of American origin (de Candolle 1883; Wood et al. 2020). Consequently, its presence in the Pacific region in ancient times has been a matter of discussion for a long time (see, for example, Clarke 1885; de Candolle 1883; von Humboldt 1825). Three possible explanations have been put forward: dispersal by natural means, transportation by indigenous inhabitants from either side of the Pacific in pre-European times, or transportation by Europeans. Currently, the leading theory combines the two latter explanations and is called the "tri-partite hypothesis" (Barrau 1957; Denham 2013; Roullier et al. 2013; Yen 1971). This hypothesis suggests the introduction of three sweet potato lineages from America into the Pacific: two independent introductions by the sixteenth century Spanish and Portuguese travellers and another, earlier introduction of a third lineage. The two European introductions are well documented (e.g. Barrau 1957; Yen 1960, 1974), although there may have been more than just two, considering the frequency of Spanish and Portuguese voyages to the Pacific from the sixteenth to eighteenth centuries (Landín Carrasco 1992).

P. Muñoz-Rodríguez (✉) · J. R. I. Wood · R. W. Scotland
Department of Plant Sciences, University of Oxford, Oxford, UK
e-mail: pablo.munoz@plants.ox.ac.uk; john.wood@plants.ox.ac.uk;
robert.scotland@plants.ox.ac.uk



V. Rull, C. Stevenson (eds.), *The Prehistory of Rapa Nui (Easter Island)*,
Developments in Paleoenvironmental Research 22,
https://doi.org/10.1007/978-3-030-91127-0_4

Regarding the earlier, prehistoric arrival of sweet potato in the region, some authors have suggested it could be the result of long-distance dispersal by natural means. This hypothesis, based on a series of molecular phylogenetic analyses and computer-based modelling studies (Montenegro et al. 2008; Muñoz-Rodríguez et al. 2018; Zhang et al. 2004), has been generally dismissed in favour of a human transportation by indigenous inhabitants (e.g. Denham 2013; Green 2005). This latter theory would imply the existence of contacts between native Americans and Pacific islanders before the appearance of the Europeans. However, support for a human-mediated introduction of sweet potato in the Pacific is fragmentary and consists mainly of indirect evidence, such as that obtained from the analysis of human genetic data (Iaonnidis et al. 2020).

Answering this question—how and when did sweet potato arrive in the Pacific?—demands a critical evaluation of all evidence available. Certain disciplines, such as archaeology and linguistics, have had the predominant role so far. In contrast, the botanical evidence has been often neglected (Yen 1960, p. 368). Our aim is to help fill that gap by assessing the existing evidence from a botanical perspective. In line with the theme of this book, we specifically investigate the presence of sweet potato on Rapa Nui, although our findings may be valid for other territories. This study benefits from the experience we have gained with our monographic study of the morning glories worldwide (Muñoz-Rodríguez et al. 2019; Wood et al. 2020).

It is not our intention to deny the importance of sweet potato for Pacific societies in historic times, a topic extensively discussed by other authors (Coil and Kirch 2005; Handy 1940; Kirch et al. 1995, 2004, 2005; Ladefoged et al. 2005). However, we think it necessary to draw attention to several issues that may complicate the interpretation of existing evidence and lead to erroneous conclusions. First, publications that address the arrival of sweet potato in the Pacific are prolific in detail but, with a few exceptions, are rendered confusing by speculation. For this reason, we restrict our text to the botanical analysis of existing evidence and endeavour to minimise speculation.

Secondly, many authors simply repeat information published elsewhere without criticism; there are relatively few original works. For this reason, we attempt to highlight documents that provide original information, although we also cite some more general studies and reviews for their relevance.

The third and final issue is perhaps the most relevant. In almost all cases, evidence used to support the presence of the sweet potato is ambiguous as it could equally be used to explain the presence of other *Ipomoea* species recorded from the area. We believe a botanical perspective, often overlooked, is necessary for the analysis of the available data and will contribute to understanding the history of the presence of sweet potato in the Pacific.

## 2 Sweet Potato in Rapa Nui Literature

### 2.1 Eighteenth Century: First European Mentions

Jacob Roggeveen commanded the first European visit to Rapa Nui, in 1722. An account of that voyage, *Histoire de l'expedition de trois vaisseaux* ..., was written by Carl Friedrich Behrens, a member of Roggeveen's crew. In his narrative, Behrens explained that different roots were eaten by Rapa Nui inhabitants, but there is no explicit mention of the sweet potato either in the German (Behrens 1738) or in the French (Behrens 1739) versions of the text. The first mention of the roots by Behrens ("red and white roots")[1] could refer to sweet potatoes but also to other root crops, and he explicitly mentions potatoes (*pommes de terre*). In addition, four pages later Behrens explains that these roots taste "almost like bread"—a description that we think does not really fit that of the sweet potato, often described as having a chestnut taste—and that islanders used them *instead of* bread.[2,3] Behrens could be referring to sweet potato but also to yams of the genus *Dioscorea* (Hahn et al. 1987; Martin et al. 1974b), to taro, *Colocasia esculenta* (L.) Schott., or even to manioc, *Manihot esculenta* Crantz (Blixen 1977; Langdon 1998; Mellén Blanco 1986).[4] On the same trip, Roggeveen's logbook reads: "[ ... ] *we found it* [the island] *not only not sandy but on the contrary exceedingly fruitful, producing bananas, potatoes, sugar-cane* [ ... ]" (Corney 1903a, p. 21). Again, Roggeveen's use of the term "potatoes" may refer to sweet potato or may have been used as a general term for several different root crops.

Almost five decades passed before the next European visit to Rapa Nui. In 1770, a fleet commanded by the Spanish Felipe González de Ahedo arrived on the island

[1] *Nous fimes aussi-tot tous les preparatifs pour la descente, mais avvant que de l'exécuter l'Insulaire que nous vions reçû à notre bord deux jours auparavant, vint une seconde fois accompagné de plusieurs autres, nous apporter une grande quantité de poules et* ***de racines aprêtées et accommodées à leur manière*** [ ... ] (p. 126).

[2] *Comme ils virent par-là, que notre dessein étoit de les traiter en amis, ils nous rapporterent un peu après encore cinq cens poules, toutes en vie. Ces poules ressemblent à celles de l'Europe.* ***Ils les avoient accompagnées de racines rouges et blanches, et d'une grande quantité de pommes de terre, dont le goût est à peu près comme celui du pain, aussi ces insulaires s'en servent ils à sa place*** [ ... ] (Behrens 1739, pp. 129–130)

[3] (Skottsberg 1922, p. 62) attributes a specific mention of the sweet potato to Behrens: "Bataten, die wie Brot schmeckten". We were however unable to find this sentence in the 1738 edition of Behrens' text. A later version of Behrens' text, apparently extensively modified by the editor, was published in Leipzig almost two centuries later, in 1923 (Behrens 1923). As precisely shown by Zuzanna Jakubowska, the editor of the 1923 edition incorporated many changes of his own without indicating these, including one or more specific comments about sweet potato absent from the 1738 edition (Jakubowska 2012, p. 26). We refer the reader to the works of Zuzanna Jakubowska for further details on this question.

[4] We refer the reader to the works of Langdon (1998) and Mellén Blanco (1986) for more on the possible presence of manioc, *Cassava esculenta*, and of other crops in the Pacific islands in ancient times.

to map the territory and to claim it for the Spanish Crown. An account of that trip was probably written by officer Juan Hervé (Corney 1903b, p. 113; Mellén Blanco 1998, p. 208) and is readily available in an early-twentieth century translation by Bolton G. Corney (1903b). According to Corney's translation, Hervé recorded that the sailors received from islanders "*plantains, Chili peppers* [sic]*, sweet potatoes and fowls*"[5] (Corney 1903b, p. 121), and islanders had "*several plantations and fields of sugar-cane, sweet potatoes, taro, yams* [...]"[6] along the coast (Corney 1903b, p. 123). By the time González de Ahedo arrived at Rapa Nui, the Spanish had ruled in America for almost two centuries and it seems plausible that they would be able to differentiate between sweet potato (*camote*), manioc (*yuca*), and other roots they came across (Langdon 1998; Mellén Blanco 1986, 1998). To the best of our knowledge, Hervé's text is the first indisputable mention of sweet potato on Rapa Nui.

In 1774, 4 years after González de Ahedo, James Cook arrived on Rapa Nui as part of his second voyage to the Pacific (1772–1775). Cook's crew included naturalist Johann Reinhold Forster and his son, George Forster, both of them authors of relevant accounts. Sweet potato is mentioned several times in *A voyage round the world,*[7] attributed to the son (Forster 1777), and also in a French manuscript recently found in Poland attributed to the father[8] (Jakubowska 2014). Perhaps surprisingly, George Forster did not mention the species in his *Florulae insularum Australium Prodromus* a few years later (Forster 1786), although other important species recorded in the narratives of Cook's voyage are also missing from George Forster's

[5] "[...] *platanos guineos,* ***camotes*** *y gallinas, y los nuestros les dieron sombreros, chamarretas, etc*." [from Mellén Blanco 1998]. It has been noted that Corney's translation of Hervé's text includes some inaccuracies and omissions concerning the names of cultivated plants (Langdon 1998; Mellén Blanco 1986), so it should be read with some caution. Note the Spanish document, for instance, does not mention Chili peppers, as pointed out also by Mellén Blanco (1986) and Langdon (1998, p. 326). The text by Hervé indisputably mentions sweet potatoes (*camotes*).

[6] "[...] *caña dulce, camote, yuca, ñame, calabaza blanca y mates de los que en el Callao sirven para lastrar*", from (Mellén Blanco 1998). Note the translation by Corney has "taro" but the original in Spanish says "yuca", two different crops.

[7] *The potatoes were of a gold-yellow colour, and as sweet as carrots, therefore not equally palatable to us all; however they were extremely nourishing, and very antiscorbutic* (Forster 1777, p. 572). [...] *We now embarked with a small quantity of potatoes, and with ...* (p. 576). [...] *We followed one of the paths which the natives had made, till we came to a cultivated spot, consisting of several fields planted with sweet potatoes, yams, and eddoes, together with a species of night-shade ...* (p. 578). [...] *who brought him* [Captain Cook] *some fowls ready dressed, and some matted baskets full of sweet potatoes, but sometimes deceived him by filling the basket with stones, and only laying a few potatoes at the top* (p. 579). [...] *A field of sweet potatoes was situated close to the well, and a considerable number of people of different ages and sizes, busied themselves in digging them up, and bringing them for sale to our people* (p. 582), etc.

[8] *Soleil il ne laisse cependant pas de devenir extremement fertile par la culture, et comme l'île n'est pas à présent très peuplée, il y a tant de terre en friche, qu'un jeune homme qui a envie e faire menage à part n'a qu'à occuper un terrain, à le defricher avec un instrument de bois dur, de la figure d'un pieu pointu, dont on se sert u lieu de bêche, ses parens & ses amis ne lui refusent pas quelque* ***racines de batates*** *qu'on coupe à chaque bouture pour les multiplier* [...]

*Prodromus* (Skottsberg 1953, p. 61). More importantly, the two aforementioned narratives include up to 15 mentions of the sweet potato in the text, and Johann Forster specifically describes the crop as "profusely cultivated in one of the coasts".

In summary, there is no doubt that the sweet potato was already widely cultivated on the island by the time González de Ahedo and Cook visited Rapa Nui, in 1770 and 1774, respectively. The documents we consulted pertaining to Roggeveen's visit 50 years earlier are compatible with the cultivation of the crop on the island in the early eighteenth century, but do not demonstrate it conclusively.

### 2.2 Nineteenth and Twentieth Centuries: Sweet Potato as a Staple

In the nineteenth century, sweet potato was an important element of the islanders' diets. Eugène Eyraud, the first Westerner to live on Rapa Nui (in 1864 and 1865–1868), seemed to eat sweet potatoes very often[9] (Eyraud 1866). Further, the importance of sweet potato in the island economy is obvious in all subsequent works (e.g. Díaz Vial 1947; Métraux 1957; Yen 1974). Alfred Métraux, for instance, made it clear that sweet potatoes were the main staple on the island in the twentieth century:

> An Easter Islander who wished to give me an idea of the monotony of life on his island once said to me: 'Here, we are born, we eat sweet potatoes, then more sweet potatoes, and then we die'.
>
> (Métraux 1957)

In the early twentieth century, the Chilean scientist Francisco Fuentes cited by their names two varieties cultivated by the islanders ("camote morado" and "camote negro"), and two more varieties in passing[10] (Fuentes 1913, p. 335). The names "camote morado" and "camote negro" are also used for traditional Peruvian and Central American landraces (http://genebank.cipotato.org), but we cannot say whether this indicates a relationship (i.e. they are modern American cultivars recently introduced) or is pure coincidence.

Considering the importance of the crop, it is not surprising that islanders developed and grew several varieties even on a small island the size of Rapa Nui, such as the 4 recorded by Fuentes, although perhaps not as many as the 11 different varieties reported by Douglas Yen (1974). It is interesting that Fuentes did not mention any white-fleshed varieties, whereas by the end of the twentieth century

[9] *On a bientot cuit les éternelles patates: c'est le plat de tous les jours, l'invariable ordinaire des Kanacs, grands et petits.* Note Eyraud refers to the crop as simply *patates*. It has been assumed by previous authors that this refers to sweet potato and not to the Andean potato, *Solanum tuberosum* L.

[10] *Hai* [sic] *otras dos especies o variedades de camotes.*

at least one of two types of sweet potatoes in cultivation on the island had white flesh (Aljaro et al. 1999). The varieties described by Aljaro et al. (1999) may or may not represent different varieties from those recorded by their predecessors. Of course, the island has changed dramatically before and during the two centuries after the first European contact (Horrocks et al. 2013; Métraux 1940; Rull 2020; Yen 1974). It is definitely possible that the original indigenous sweet potato varieties were replaced by other, more productive American varieties in the nineteenth and twentieth centuries.

## 3 The Morning Glories of Rapa Nui

As explained above, *Ipomoea batatas* is the best-known member of the plant genus *Ipomoea*, but it is not the only species recorded in the Pacific nor on Rapa Nui. Several other species have been recorded in the Pacific region (Muñoz-Rodríguez et al., *in prep.*). Most of these species have a widespread distribution; they are found across the Ocean and often both in Asia and in the Americas, and some may be relatively recent introductions to the Pacific region. Several species apart from sweet potato are eaten by humans, and some are also used for their edible storage roots (Muñoz-Rodríguez et al. 2019).

The eighteenth and nineteenth century floristic accounts of the Pacific islands did not record any *Ipomoea* or Convolvulaceae species on Rapa Nui, apart from sweet potato. Neither the first known floristic work to include Rapa Nui, by George Forster (1786) nor Endlicher's (1836) "*Bemerkungen über die Flora der Südseeinseln*", nor Hemsley's (1885) *Report on the present state of knowledge of various insular floras* mentioned any other species of the genus or the family on the island. These works were compiled as a result of long expeditions focused on a much larger area than Rapa Nui, so the fragmentary compilations, considering the nature of those voyages, may not be surprising.

The first more or less complete floristic work focused on Rapa Nui was carried out by Chilean botanist Francisco Fuentes. Fuentes visited the island as a member of Walter Knoche's 1911 scientific expedition and published two reports, one in Spanish (Fuentes 1913) and another one in German—as a chapter in Knoche's *Die Osterinsel*. Knoche's book was first published in Chile in 1925 and has been recently reprinted (Fuentes 2015). Fuentes recorded approximately 135 species of plants native to Rapa Nui and is the first author to record other species of Convolvulaceae from Rapa Nui apart from sweet potato. Fuentes' narratives, however, are contradictory and difficult to interpret. He, for example, cites different Convolvulaceae species in the two documents even though both refer to the same expedition. The one species Fuentes recorded in both works is the pantropical species *Ipomoea pes-caprae* (L.) R.Br. (Fuentes 1913, 2015).[11] *Ipomoea pes-caprae*, the goat's foot morning glory, is a species from sandy coasts in tropical and subtropical regions, and a pioneer on newly formed oceanic islands. This species is easily recognised by its characteristic leaf shape, hence its common name (Devall 1992; Wood et al. 2020). Importantly, the roots, stems, and leaves of this species have been eaten as a famine food in Rapa Nui (Métraux 1940, p. 160; Orliac and Orliac 1996, p. 94) and elsewhere in the Pacific (Neal 1965, p. 709; Chock 1968).

In addition to *Ipomoea batatas* and *I. pes-caprae*, Fuentes (1913) mentioned two other Convolvulaceae species—*Ipomoea kentrocaulos* C.B.Clarke (now a synonym of *Distimake kentrocaulos* (C.B.Clarke) Simões & Staples) and another, unnamed species—but apparently the specimens collected were lost before the preparation of his work and no other information exists. The records by Fuentes remain unconfirmed.

In his work in German, Fuentes does not mention any of the species in the previous paragraph but does include *Ipomoea fastigiata.*[12] This name is now considered a synonym for *I. batatas* (Wood et al. 2020 pp. 394–395), although many authors in the past cited it as a synonym of another sweet potato relative—*I. tiliacea* (Willd.) Choisy. Fuentes succinctly describes *I. fastigiata* as "schwarze Camote" (camote negro, black sweet potato), and a few pages later Knoche (p. 131) records "two types of bulbs, *I. batatas* and *I. fastigiata*".[13] They possibly referred to the "camote negro" sweet potato variety mentioned in Fuentes' 1913 work (see previous section), but it is unclear why he would assign the same entity, observed on the same trip, to different species in different works and with no explanation.[14] Finally, the Chilean botanist also noted that many foreign plant species had been introduced

---

[11] It is curious that Ipomoea pes-caprae was not recorded by the eighteenth-century naturalists such as George Forster, even under the name *Convolulus pes-caprae* or another synonym. It is more difficult to understand that this widespread pantropical species was not mentioned by subsequent authors in the nineteenth century such as Endlicher or Hemsley.

[12] Fuentes did not provide authorship for this name, but here we assume he referred to *Ipomoea fastigiata* (Willd.) Sweet, now a synonym of *Ipomoea batatas* (Wood et al. 2020 pp. 395–396). Apparently, Chapman used the name *Ipomoea fastigiata* to describe a different entity that is now a synonym of *Ipomoea indica* (Burm.) Merr., but Chapman's name has never been used since its publication.

[13] Knoche adds: "Letztere ist im tropischen Amerika heimisch, während die Heimat der ersteren wohl in Hinterasien zu suchen ist." (The latter is native to tropical America, while the home of the former is likely to be found in Western Asia). Previously some authors thought the plants cultivated in America and in Asia belonged to different species, but it was later agreed that they both were, indeed, *Ipomoea batatas*.

[14] We can speculate further about the identity of this species. If by *Ipomoea fastigiata* Fuentes referred to a species of *Ipomoea* other than sweet potato, no such species has been recorded by subsequent authors and may thus have become extinct since then. Alternatively, if this was a form of sweet potato, why would Fuentes record it under a different name? Were these plants growing in the wild and, if so, were they native or escaped from cultivation? We requested information from the Chilean Museo Nacional de Historia Natural, where Fuentes' collections were deposited, but apparently no specimen under this name has been preserved. In the end, this question may never be successfully answered.

to Rapa Nui in previous decades and were now widely cultivated (Fuentes 1913 pp. 324–325, 2015 pp. 121–122), something that has further complicated the identification of truly native elements ever since.

More recently, the *Catálogo* by Rodríguez et al. (2018) recorded *Ipomoea pes-caprae* as native to Rapa Nui but did not mention *I. batatas*, probably because of its cultivated status.

Two other Convolvulaceae species have been recorded from Rapa Nui: *Calystegia sepium* (L.) R.Br. (Skottsberg 1922) and *Jacquemontia paniculata* (Burm.f.) Hallier f. (Zizka 1991). In neither case was a specimen retained nor have the plants been found again so their occurrence in Rapa Nui is doubtful in the extreme.

In conclusion, there have been just a few botanical studies on Rapa Nui, and they are difficult to interpret due to the varying levels of detail and accuracy. Only two species of Convolvulaceae have been recorded with certainty in the territory in the last centuries: *Ipomoea batatas* and *I. pes-caprae*, with the references to other species probably a mistake. The relatively low number of species recorded on the island is not surprising, given its remoteness and small size.

## 4 Sweet Potato in the Archaeological Record

Archaeological remains assigned to sweet potato on Rapa Nui consist mainly of charred specimens, pollen grains, and starch grains (Fig. 4.1). As on other islands, many authors before have discussed the presence of sweet potato on Rapa Nui in ancient times, but most references provide no direct supporting evidence. A chronological review of archaeological records supported by direct biological evidence (remains of plant origin) is provided below, whereas indirect evidence—structures such as walls or pits (e.g. Stevenson et al. 2006), as well as oral traditions and legends (Best 1925; Heyerdahl 1952; Wallin et al. 2005)—is beyond the scope of this chapter and is not discussed.

In 1961, Arne Skjølsvold reported the discovery of charred remains in a fireplace at Anakena, on the north coast of the island (Skjølsvold 1961). Some of those remains were identified as sweet potatoes, although Skjølsvold did not provide an explanation for the identification.[15] $C^{14}$ dating of carbon samples from the lower part of the oven, besides the fireplace where the charred remains were found, resulted in a date of 1526 AD ± 100 years.

Wallin et al. (2005) and Horrocks et al. (2012a,b) cited two publications by Catherine Orliac (Orliac and Orliac 1998a; Orliac 2000) reporting sweet potato tuberous root remains associated with late prehistoric ovens. The 2000 publication is an excellent summary of vegetation changes on the island over 35,000 years,

[15] [The remains] *could be identified as the remains of sugar cane, sweet potatoes, and a small, nut-like fruit* (Skjølsvold 1961, p. 297) [ . . . ] *Charred sweet potatoes were also discovered* (p. 297) [ . . . ]

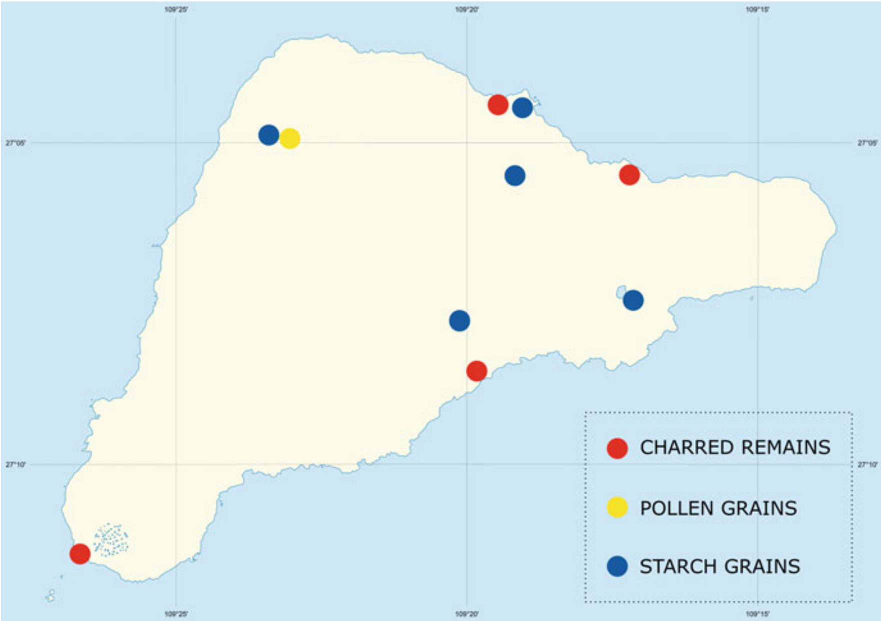


**Fig. 4.1** Location of archaeological remains identified as sweet potato on Rapa Nui. Basemap by Eric Gaba (Sting), derivative work: Xfigpower (pssst) (CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=12178573)

but there is no mention of sweet potato (Orliac 2000).[16] Orliac's 1998 publication is a contribution to an international conference, and the reference to sweet potato is in fact a note to another, earlier report edited by Chaterine Orliac and Michael Orliac with plant remain identifications by Erik Pearthree (Orliac and Orliac 1996). According to this 1996 report, at least 20 specimens from different parts of the island were identified as *Ipomoea* remains (Fig. 4.2). Identification of plant remains in that study was conducted by comparing the remains with charred samples of plants cultivated in Polynesia, including starchy food plants. The author does not explain the specific traits that enabled the identification of *Ipomoea batatas* remains, although an image kindly provided by Catherine Orliac of one of the specimens collected at Orongo resembles sweet potato with little doubt (Fig. 4.2). This is a recent specimen though, being found in an archaeological level dated 030 +/−80 conv. BP, calibration 2-sigma 1675–1775/1800–1945, (Orliac and Orliac 1998b, p. 5) and thus does not help clarify when sweet potato arrived on the island.

In terms of micro-remains, these have been found at Ahu Te Niu and La Perouse (Horrocks and Wozniak 2008); Rano Raraku (Horrocks et al. 2012a); and

[16] The author mentions the existence of hundreds of plant remains, most of them charcoal fragments of a few millimeters, but does not mention sweet potato.

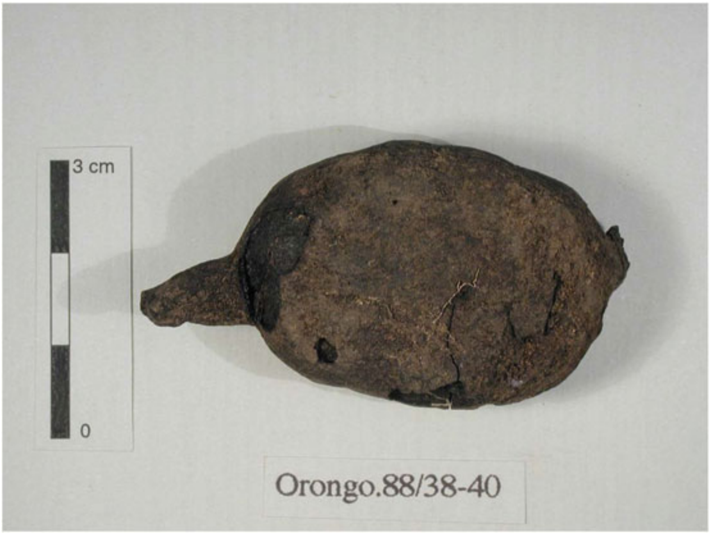


**Fig. 4.2** Charred root from Orongo site (SW Rapa Nui) identified as sweet potato from Orongo site. Photograph by Catherine Orliac

Kaovaokiri, Vaitea Atroke Hau, and also Rano Raraku (Horrocks et al. 2017) (Fig. 4.1). We found no mention of *Ipomoea* remains in studies at Rano Aroi (Flenley 1979; Flenley et al. 1991; Flenley and King 1984; Horrocks et al. 2015; Margalef et al. 2013; Margalef Marrasé 2014; Peteet et al. 2003; Rull et al. 2015) or Rano Kau (Flenley 1979; Flenley et al. 1991; Flenley and King 1984; Horrocks et al. 2013).

Publications by Horrocks and collaborators are remarkable in that they provide detailed descriptions of their findings, explain the basis for the identification of the material and discuss the possibility that some of the remains belong to wild plants, which is certainly possible. Their first study described sweet potato starch grains from Ahu Te Niu and two other sites, 200 and 900 m to the east of Te Niu, respectively (Fig. 4.1) (Horrocks and Wozniak 2008). The starch grains are described as large (up to 25 $\mu$m in diameter), ovate to sub-triangular and a vacuole at the central hilum (Horrocks and Wozniak 2008, p. 134), and appeared in all samples studied except the two oldest ones. According to the authors, individual sweet potato starch grains would constitute the second most abundant type of grain after those of *Dioscorea alata*, which predominate in the samples.

In the study at Rano Raraku, Horrocks et al. (2012a) found pollen fragments (see Figs. 6a and 7a in Horrocks et al.'s paper) and starch grains in two cores, one from a lake sediment and the other from dryland soil. Based on a previous review (Cummings 1998), the authors argue that the pollen grains of *I. batatas* and *I. pes-caprae* can be differentiated, thus classifying their finding as *I. batatas*. Cummings (1998, p. 102) explains that the *I. batatas* pollen can be distinguished by the "densely packed rods that form the shape of a coarse reticulum around each pore", a feature not observed in *I. pes-caprae*.

## 5 Analysis of Archaeological Remains from a Botanical Perspective

Botanical knowledge, often missing in sweet potato studies, may help interpret archaeological remains associated with sweet potato. To conclude this chapter, we would like to discuss in more detail the archaeological remains identified as *Ipomoea batatas* on Rapa Nui from a botanical perspective. Generally speaking, how *Ipomoea* archaeological remains are identified is an important issue. Except in some exceptional, detailed studies, authors do not mention the criteria they used to identify their findings as sweet potato (e.g. Skjølsvold 1961), which makes discussion impossible. Further, it is difficult to know with what degree of confidence the authors were able to differentiate between cultivated sweet potato and other *Ipomoea* or Convolvulaceae species. In fact, the similarity of both macro- and micro-remains with those from other closely related taxa (see, for example, photographs in McCormick 1916; Sengupta 1972; Wilkin 1996; Eserman et al. 2018) generates doubts not only among us, but also among other authors.[17,18] Consequently, some remains identified as sweet potato have later been re-identified as wood charcoal or as belonging to other species (Coil and Kirch 2005; Patterson and Lanning 1964, 1966).

To the best of our knowledge, only two studies have reported sweet potato macro-remains on Rapa Nui (Orliac and Orliac 1996; Skjølsvold 1961). The discovery by Skjølsvold is difficult to assess, since, as explained earlier, the author did not provide any information or pictures to allow further investigation. Another problem affecting these remains is that only a single radiocarbon date was provided (1526 AD $\pm$ 100 years). According to Wallin et al. (2005), a single radiocarbon date does not represent the timespan in which a place was occupied nor allows us to link this to the date when the sweet potatoes were burnt. The identification of the remains reported by Skjølsvold, even if correct, may be of limited value without a broader context. On the other hand, the remains reported by Orliac and colleagues are more compelling. They report up to 20 specimens from three different locations on the island. Nonetheless, the authors did not explain the basis for the identification of sweet potato remains and there are no images available except Fig. 4.2, which is of a rather modern specimen. Although most remains in the study by Orliac and colleagues will probably belong to sweet potato, it is important that future studies report the basis on which sweet potato identification was made in archaeological specimens.

[17] "*On the whole, there are insufficient modern reference studies of these plants to produce solid evaluations of the degree to which tuber anatomy or microfossil characteristics can truly allow an archaeobotanical separation of sweet potato from other related, naturally occurring plants*". (Ladefoged et al. 2005, p. 363).

[18] "*Similarly, starch grains and xylem of sweet potato are not easily differentiated from those of the single indigenous species (*Ipomoea cairica*)*" (Horrocks et al. 2004, p. 153).

### 5.1 Pollen Grains

In the most comprehensive study of *Ipomoea* pollen morphology to date, Paul Wilkin (1996) reported overlapping pollen grain diameters for *Ipomoea batatas* and for *I. pes-caprae*, 76.7–123.8 μm and 86.4–112.2 μm, respectively. Before Wilkin, Jones and Kobayashi (1969) reported a pollen size in *I. pes-caprae* of 88 ± 2 μm, and Martin et al. (1974a) reported much bigger sweet potato pollen grains (186 μm)—surprisingly big compared to the other studies. More recently, Adi Susanto et al. (2013) reported sweet potato pollen grains very variable in size, 68 to 187 μm, and Srisuwan et al. (2019) measured two sweet potato varieties with pollen sizes 97.9 ± 14.8 μm and 90.9 ± 4.1 μm, respectively. Some of these authors do not explain the method they used to prepare the pollen, but this can dramatically affect the measurement of pollen size. This may be the case in the study by Martin et al. (1974a). However, assuming the results are accurate in the rest of the studies, it is clear that the size of pollen grains in *Ipomoea batatas* and in *I. pes-caprae* overlap.

In terms of morphology, studies show that exine thickness and the overall morphology of the pollen grain are also very similar between species of *Ipomoea* (Jayeola and Oladunjoye 2012; Sengupta 1972; Wilkin 1996), although some authors have attempted to classify the species into different categories based on this (Sengupta 1972; Wilkin 1996). The pollen grains of *I. batatas* and *I. pes-caprae* photographed by Wilkin are in fact very similar in structure and shape, at least in the SEM photographs provided (Plates 3.8 and 3.11, pages 85 and 88, respectively). Both photographs show a pattern of four supratectal processes (spines) per pore, perhaps more regular in *I. batatas*, with processes in both species somehow elongated at the apex. We have not seen optical microscope pictures of *I. pes-caprae* pollen, but photographs of other *Ipomoea* species taken with an optical microscope are also difficult to distinguish from *I. batatas*.

*Ipomoea* pollen remains have only been reported from Rapa Nui by Horrocks et al. (2012a). These remains are not entire pollen grains but degraded fragments of exine and, although the authors claim *I. batatas* and *I. pes-caprae* pollen can be differentiated, we are sceptical. In the first place, because the finding consists not of entire well-preserved pollen grains but of fragments damaged by acetolysis (see Fig. 7a in Horrocks et al.'s paper). Secondly, our own palynological observations (Wood et al. 2020) show a continuous variation in pollen morphology between species, and the differences do not correlate with phylogeny (see phylogenies in Muñoz-Rodríguez et al. 2019). Broadly speaking, the pollen in *Ipomoea* Clade A (the clade including *Ipomoea batatas*) usually has fewer spines than in other clades, and pollen in clade C (the clade including *I. pes-caprae*) often shows a regular pattern of 4–6 spines around pores, but neither of these patterns is always present (Wood et al. 2020 pp. 48–51). Further, we do not think those structures can be distinguished in the images provided by Horrocks et al. (2012a).

In our experience, pollen morphology is of little use in *Ipomoea* taxonomy. Whereas pollen grains can be identified more or less easily as belonging to the genus *Ipomoea*, it is very difficult, if not impossible, to assign a pollen grain to a specific species or even to a clade with absolute certainty. We remain sceptical about pollen identification at the infrageneric level, and especially if the evidence consists of fragments of pollen grains and not entire grains. Further, the appearance of pollen grains may change depending on whether certain structures remain intact or not after acetolysis (Wood et al. 2020), something that occurred in the study by Horrocks et al. (2012a). In summary, even though the pollen remains found by Horrocks and collaborators may be assigned, more or less confidently, to *Ipomoea*, we do not think it is possible to assign them to a particular species based on their size, and it is certainly very difficult to provide an identification based on their morphology.

### *5.2 Starch Grains*

As far as we are aware, only a few experimental studies of starch granules have been conducted in other *Ipomoea* species besides *Ipomoea batatas*. Apart from a succinct note by Anselme Payen (1826), the first study we are aware of was published in 1854 by Léon Soubeiran. The French chemist studied starch grains from the roots of three Convolvulaceae species: *I. batatas*, *Ipomoea jalapa* (L.) Pursh, and *Operculina turpethum* (L.) Silva Manso.[19] Soubeiran noted the variable size of starch grains in all three of them, as well as the morphological resemblance between the two *Ipomoea* species, also in their central hilum (Soubeiran 1854).

Seventy years later, a meticulous study on starch grains by Edward T. Reichert (1913 pp. 884–885) included *I. batatas*, *I. jalapa* (L.) Pursh, *I. imperati* (Vahl) Griseb.[20] and *I. purga* (Wender.) Hayne, as well as other Convolvulaceae species such as *Calystegia soldanella* (L.) R.Br. and *Convolvulus lineatus* L. Reichert also found that starch grains overlap in size, not only between species of *Ipomoea* but also with other species of Convolvulaceae, and their morphology is similar in different species of *Ipomoea*.

One more study was conducted before the end of the twentieth century and in this case comparing *Ipomoea batatas* and its closest wild relative, *I. trifida* (Kunth) G.Don. Asante et al. (1993) found a bigger average size of starch grains in the cultivated plant, but the size ranges between both species overlap (Table 2 in Asante et al. 1993), thus large grains produced by *I. trifida* plants were bigger than small grains produced by the cultivated *I. batatas*. Asante and collaborators also found that the amylose content was similar or even more extensive in *I. trifida*.

Starch grains are the sweet potato remains most frequently reported from Rapa Nui, yet their identification presents similar challenges to those of pollen grains. Horrocks and Wozniak (2008) acknowledge that *Ipomoea batatas* starch grains are difficult to differentiate from those of *I. pes-caprae*. However, they argue that the starch grains found at Te Niu could belong to *Ipomoea batatas* because *I. pes-*

[19] Cited as *Ipomoea turpethum* (L.) R.Br., now a synonym.

[20] Cited as *Convolvulus imperati* Vahl, now a synonym.

*caprae* does not produce storage roots. Although this is true, starch grains can also be found in other plant structures such as stems or leaves (Preiss and Levi 1979), so it is possible that starch grains came from leaves or stems, as well as from non-tuberous roots. Regarding *Ipomoea*, Horrocks (2004) observed that starch grains from *I. cairica* stems are similar to those from *I. batatas* roots. Unfortunately, we are not aware of any study of starch grains in *I. pes-caprae*, which may help identify the remains found by Horrocks and Wozniak in Rapa Nui.

In addition to their similar morphology, starch grain size varies significantly not only between species of *Ipomoea*, but also within species and even within the same plant. Importantly, it is not known how domestication and starch grain formation impact grain shape. In addition, Perry (2002) found that starch grain size and date of deposition do not correlate. Finally, a pilot study using techniques of image analysis found that sweet potato starch grains were often misclassified as other crops by the algorithm—even though no other species of *Ipomoea* or Convolvulaceae were included in the analysis (Wilson et al. 2010). In conclusion, researchers must be cautious in the identification of a sample, or the inference of its cultivated or wild status, based on the size or the morphology of starch grains, as this may lead to erroneous conclusions. Micro-remains may be of some use in identifying certain specimens as belonging to the genus, but assigning the remains to one or another species, based on their size and/or morphology, may prove difficult if not impossible.

In summary, the utility of most archaeological remains to enable differentiation between cultivated sweet potato, non-cultivated sweet potato, and other species of *Ipomoea* is unsatisfactory. External factors such as the geographical location of the deposited remains or their association with human utensils or structures may help assign the remains to sweet potato (see, for example, Horrocks et al. 2012b p. 154). However, researchers taking this approach must be cautious, especially as sweet potato was not the only morning glory species used by humans. Many remains, especially in the Americas but also in the Pacific, will indeed correspond to sweet potato, but other remains may correspond to different morning glory species, and it is currently impossible to assign any remains to any specific species based on biological evidence only. As pointed out by Wilson et al. (2010), the accurate classification of starch grains—and, we would add, of most archaeological remains—, as well as discrimination between domesticated and wild plants, would also require a better understanding of how those processes affect grain shape.

## 6 Sweet Potato Arrival in Rapa Nui

It is probable that sweet potato was already present in Rapa Nui when Europeans first visited the island. Mentions by Roggeveen and Behrens after the first visit to the island may be open to interpretation, as they do not mention sweet potato explicitly (see footnote 3). However, the crop was already widely cultivated when Felipe González de Ahedo and Cook visited the island. Considering the extent of cultivation reported in the last third of the eighteenth century, together with the various archaeological remains, it seems highly probable (and the rest of this discussion assumes) that the crop was present on the island in pre-European times. In that scenario, we may then ask, when and how did sweet potato arrive on the island? Was the species introduced by Pacific islanders or did it arrive on Rapa Nui by natural means?

Computer-based models published to date do not infer a dispersal of the sweet potato from America to Rapa Nui by natural means. This, on the other hand, does not preclude its dispersal to a different place in the Pacific with subsequent arrival in Rapa Nui. In addition to the molecular phylogenetic analyses and modelling studies mentioned in the introduction, anatomical studies by Guppy (1906) showed that the seeds of some sweet potato varieties have an aerial space that would be compatible with the ability to float. Importantly, a recent study showed that sweet potato seeds are able to germinate after 120 days submerged in sea water, the seed dispersal period estimated from the Americas to Polynesia (Pereira et al. 2020). In addition, long-distance dispersal by natural means is the most plausible explanation for the distribution of over 25 other species of *Ipomoea* in the Pacific, including the Rapa Nui native species *Ipomoea pes-caprae* (Devall and Thien 1989; Miryeganeh et al. 2014; Muñoz-Rodríguez et al. 2018, 2019). It has already been shown that the seeds of *Ipomoea pes-caprae* are able to float and can germinate after 6 months in the ocean so explaining its worldwide distribution (Guppy 1906; Miryeganeh et al. 2014).

If sweet potato dispersed into the Pacific by natural means, it remains unknown where in Polynesia the plant could have landed. We are only aware of one modelling study that explored this question (Montenegro et al. 2008). Montenegro and colleagues show a number of possible landing places for drifting sweet potato seeds, and Rapa Nui is not included among them (see Fig. 4.2 in Montenegro et al.'s paper). However, for reasons not explained by the authors, the model by Montenegro and collaborators only allowed sweet potato floating seeds to depart from coastal Ecuador, whereas the estimated natural distribution of the species in the Americas is much broader (Wood et al. 2020). The restricted departure points of sweet potato seeds from coastal America in that study resulted in no expected contacts with Rapa Nui, but a broader departure region could provide quite different results. In addition, we are not aware of any study that modelled the possibility of an arrival in Rapa Nui by natural dispersal from other Polynesian islands, which would also be interesting. Future studies may provide further evidence of where in the Pacific sweet potato could have arrived in a scenario of long-distance dispersal by natural means, or, alternatively, reject the possibility of its arrival in Rapa Nui by natural means.

The alternative to long-distance dispersal is that sweet potato was transported onto Rapa Nui by humans. People could have arrived from elsewhere in Polynesia or directly from the American continent, as postulated by several authors (Heyerdahl 1952; Heyerdahl and Ferdon Jr. 1961, p. 522). Despite the passionate defence of the latter possibility by Heyerdahl and other authors, all alleged evidence supporting a transfer of the crop from the American continent to Polynesia and Rapa Nui is weak at best (Muñoz-Rodríguez 2019). It seems indisputable, not only from oral traditions but also from other lines of evidence, that contacts between inhabitants from different Pacific islands in ancient times existed (Best 1925; Buck 1938; Cox and Banack 1991; Hornell 1946). Therefore, if the sweet potato was present anywhere else in the Pacific in ancient times (regardless of whether it got there by human transport or natural means), Polynesians could be responsible for its dispersal throughout the region and its introduction to Rapa Nui.

To date, all archaeological remains from Rapa Nui assigned to sweet potato have been dated to 625–513 cal BP (c. 1300–1400 AD; Horrocks et al. 2012b) or more recent times. *Ipomoea* remains have not been reported in studies from earlier dates. However, studies only report pollen grains, and only one pollen remain has been reported from the island (Horrocks et al. 2012a). The lack of *Ipomoea* pollen remains may be due simply to its absence from the area or perhaps to animal pollination of *Ipomoea* species. Further, many studies were focused on the Rano Raraku, Rano Aroi, and Rano Kao craters areas, where no sweet potato remains, apart from those reported by Horrocks et al. (2012a) have been found.

It is now thought that only coastal areas of Rapa Nui were cultivated during the first centuries of human presence on the island, whereas inland territories including the three volcanoes would have remained forested for a longer time (Horrocks et al. 2017; Ladefoged et al. 2013). This may also explain the lack of sweet potato archaeological remains from all except Rano Raraku (if it truly is sweet potato but see previous section). Further, the presence of yams but not sweet potato in the pre-1300 sample studied by Horrocks and Wozniak (2008) is compatible, as hypothesised by the authors, with the proposal that sweet potato cultivation started at around 1200–1300 AD, and therefore later than yam cultivation, as postulated in other studies based on changes in the agricultural system (Wallin et al. 2005).

In summary, the limited evidence currently available is most compatible with a human-mediated introduction of sweet potato to Rapa Nui at around 1300 AD, possibly not by the first colonisers but in a later arrival (Wallin et al. 2005). This possibility, of course, assumes that remains identified as sweet potato truly are of sweet potato and did not originate from other species. Data currently available, including indirect evidence, is compatible with the remains being sweet potato, but we cannot dismiss the possibility that at least some of them were other species. On the other hand, the absence of *Ipomoea* remains in the oldest soil samples available, mostly from non-coastal locations, does not exclude the presence of *Ipomoea batatas*, *I. pes-caprae* or other species of Convolvulaceae nearer the coast in more ancient times, either as a result of long-distance dispersal or human introduction. Even in the case of a human-mediated introduction, it could have occurred pre-1300 AD. Future analyses that demonstrate the existence (or the lack of) sweet potato remains in coastal locations in ancient times may further inform the question of how sweet potato arrived on Rapa Nui.

**Acknowledgements** We thank Catherine Orliac for sharing with us several important documents that we had been unable to find, as well as for providing the photograph of a sweet potato storage root in Fig. 4.2. Thanks are also due to Stephen Harris, Corinna Hartinger, and Benedikt Kuhnhaeuser for their help with the translation of several historic texts.

## References

Adi Susanto F, Sri Sulasmi E, Rahayuningsih SA (2013) Pollen morphology and sucrose giving on stigma relation with incompatibility of sweet potato (*Ipomoea batatas* (L.) L.). J Trop Life Sci 3:207–211

Aljaro UA, Herrera FL, Herrera BR (1999) La horticultura Rapa Nui. Tierra Adentro 28:20–22

Asante SA, Yamada T, Hisamatsu M, Shiotani I (1993) Studies on the properties of starch of diploid *Ipomoea trifida* (H. B. K.) Don. strains. Starch - Stärke 45:299–306

Barrau J (1957) L'énigme de la patate douce en Oceanie. Études d'Outre-Mer 40

Behrens KF (1738) Der wohlversiichte Süd-Länder y das ist: ausführliche Reise-Beschreibung um die Welt. Georg Monath, Leipzig, Germany

Behrens KF (1739) Histoire de l'expédition de trois vaisseaux: envoyés par la Compagnie des Indes Occidentales des Provinces-Unies, aux terres australes en MDCCXXI. aux depens de la compagnie, La Haye

Behrens KF (1923) Der wohlversuchte Südländer, Reise um die Welt 1721/22. In: Alle Reisen und Abenteuer, n. 7. Brockhaus-Verlag, Leipzig

Best E (1925) The Maori canoe. A.R, Shearer, Wellington, N.Z

Blixen O (1977) La expedición española de 1770 a la Isla de Pascua. Moana 1

Buck PH (1938) Vikings of the sunrise. Frederic A, Stokes, New York

Chock AK (1968) Hawaiian ethnobotanical studies I. Native food and beverage plants. Econ Bot 22:221–238

Clarke CB (1885) Convolvulaceae. In: Hooker JD (ed) The flora of British India. L. Reeve, London, pp 179–228

Coil JH, Kirch PV (2005) An Ipomoean landscape: archaeology and the sweet potato in Kahikinui, Maui, Hawaiian Islands. In: Ballard C, Brown P, Bourke RM, Harwood T (eds) The sweet potato in Oceania: a reappraisal. University of Sydney, Sidney, pp 71–84

Corney BG (1903a) Extract from the official log of the voyage of Mynheer Jacob Roggeveen, in the ships Den Arend, Thienhoven and De Afrikaansche Galey, in 1721–2 in so far as it relates to the discovery of Rapa Nui. In: The voyage of Captain Don Felipe González to Rapa Nui 1770–1, 2, 21. Hakluyt Society, Cambridge

Corney BG (1903b) The voyage of Captain Don Felipe González to Easter Island 1770–1. Hakluyt Society, Cambridge

Cox PA, Banack SA (1991) Islands, plants, and Polynesians: an introduction to Polynesian ethnobotany: proceedings of a symposium. Dioscorides Press, Portland, Or

Cummings LS (1998) A review of recent pollen and phytolith studies from various contexts on Rapa Nui. In: Stevenson CM, Lee G, Morin FJ (eds) Easter island in pacific context, proceedings of the fourth international conference on Easter Island and East Polynesia. The Easter Island Foundation, Los Osos, CA, pp 100–106

de Candolle A (1883) Origine des plantes cultivées, 1st edn. Germer Baillière, Paris

Denham T (2013) Ancient and historic dispersals of sweet potato in Oceania. Proc Natl Acad Sci U S A 110:1982–1983

Devall MS (1992) The biological flora of coastal dunes and wetlands. 2. Ipomoea pes-caprae (L.) Roth. J Coast Res 8:442–456

Devall MS, Thien LB (1989) Factors influencing the reproductive success of *Ipomoea pes-caprae* (Convolvulaceae) around the Gulf of Mexico. Am J Bot 76:1821–1831

Díaz Vial C (1947) Asociación de suelos de la Isla de Pascua. Agric Técnica Chile 9:115–135

Endlicher S (1836) Bemerkungen über die flora der Südseeinseln. Erste Order Botanische Artheilung

Eserman LA, Jarret RL, Leebens-Mack JH (2018) Parallel evolution of storage roots in morning glories (Convolvulaceae). BMC Plant Biol 18

Eyraud E (1866) Lettres au T.R.P, Congrégation du sacré-cœur de Jésus et de Marie. In: Annales Association de la Propagation de la foi 38: 52–61 & 124–138

Flenley JR (1979) Stratigraphic evidence of environmental change on Easter Island. Asian Perspect 22:33–40

Flenley JR, King SM (1984) Late Quaternary pollen records from Easter Island. Nature 307:47–50

Flenley JR, King ASM, Jackson J, Chew C, Teller JT, Prentice ME (1991) The Late Quaternary vegetational and climatic history of Easter Island. J Quat Sci 6:85–115

Forster G (1777) A voyage round the world in His Britannic Majesty's sloop, Resolution, commanded by Capt. James Cook, during the years 1772, 3, 4 and 5. White, Robson, Elmsly & Robinson, London

Forster G (1786) Florulae insularum Australium prodromus. Joann Christian Dietrich, Gottingae

Fuentes F (1913) Reseña botánica sobre la Isla de Pascua, vol 5. Boletín del Museo Nacional de Historia Natural, Chilele, pp 320–337

Fuentes F (2015) Die Pflanzenwelt der Osterinsel. In: Knoche W (ed) Walter Knoche: die Osterinsel: die chilenische Osterinsel-Expedition von 1911, Quellen und Forschungen zur Südsee. Reihe A. Harrassowitz Verlag, Wiesbaden, pp 121–145

Green RC (2005) Sweet potato transfers in Polynesian prehistory. In: The sweet potato in Oceania: a reappraisal, Ethnology Monographs, 43–62. University of Sidney, Sidney

Guppy HB (1906) Observations of a naturalist in the Pacific between 1896 and 1899. MacMillan and Co., Limited, London

Hahn SK, Osiru DSO, Akoroda MO, Otoo JA (1987) Yam production and its future prospects. Outlook Agric 16:105–110

Handy ESC (1940) The Hawaiian planter. His plants, methods and areas of cultivation. Bishop Museum, Honolulu, Hawaii

Hemsley WB (1885) Report on the present state of knowledge of various insular floras. Report on the scientific results of the voyage of H.M.S. Challenger during the years 1873–1876. Longmans & Co., London

Heyerdahl Y (1952) American Indians in the Pacific. The theory behind the Kon-Tiki expedition, 1st edn. George Allen & Unwin Ltd.

Heyerdahl T, Ferdon EN Jr (eds) (1961) Reports of the Norwegian archaeological expedition to Easter island and the East Pacific. Rand McNally & Company, Chicago, US

Hornell J (1946) How did the sweet potato reach Oceania? J Linn Soc Lond Bot 53:41–62

Horrocks M (2004) Polynesian plant subsistence in prehistoric New Zealand: a summary of the microfossil evidence. New Zealand J Bot 42:321–334

Horrocks M, Baisden T, Flenley J, Feek D, Love C, Haoa-Cardinali S, González Nualart L, Gorman TE (2017) Pollen, phytolith and starch analyses of dryland soils from Easter Island (Rapa Nui) show widespread vegetation clearance and Polynesian-introduced crops. Palynology 41:339–350

Horrocks M, Baisden WT, Flenley J, Feek D, Nualart LG, Haoa-Cardinali S, Gorman TE (2012a) Fossil plant remains at Rano Raraku, Easter Islands's statue quarry: evidence for past elevated lake level and ancient Polynesian agriculture. J Paleo 48:767–783

Horrocks M, Baisden WT, Nieuwoudt MK, Flenley J, Feek D, González Nualart L, Haoa-Cardinali S, Edmunds Gorman T (2012b) Microfossils of Polynesian cultigens in lake sediment cores from Rano Kau, Easter Island. J Paleo 47:185–204

Horrocks M, Marra M, Baisden WT, Flenley J, Feek D, González Nualart L, Haoa-Cardinali S, Edmunds Gorman T (2013) Pollen, phytoliths, arthropods and high-resolution 14C sampling from Rano Kau, Easter Island: evidence for late Quaternary environments, ant (Formicidae) distributions and human activity. J Paleo 50:417–432

Horrocks M, Baisden WT, Harper MA, Marra M, Flenley J, Feek D, Haoa-Cardinali S et al (2015) A plant microfossil record of Late Quaternary environments and human activity from Rano Aroi and surroundings, Easter Island. J Paleo 54:279–303

Horrocks M, Shane PA, Barber IG, D'Costa DM, Nichol SL (2004) Microbotanical remains reveal Polynesian agriculture and mixed cropping in early New Zealand. Rev Palaeobot Palynol 131:147–157

Horrocks M, Wozniak JA (2008) Plant microfossil analysis reveals disturbed forest and a mixed-crop, dryland production system at Te Niu, Easter Island. J Archaeol Sci 35:126–142

Iaonnidis AG et al (2020) Native American gene flow into Polynesia predating Easter Island settlement. Nature 583:572–577

Jakubowska Z (2012) Behrens' narrative of the discovery of Rapa Nui: two editions, two personalities, two realities. Rapa Nui J 26:21–30

Jakubowska Z (2014) The Forsters back in the spotlight: unknown manuscript on Rapa Nui discovered in Poland. Rapa Nui J 28:68–87

Jayeola AA, Oladunjoye OR (2012) Systematic studies in some Ipomoea Linn. species using pollen and flower morphology. Ann West Univ Timisoara Biol 15:177–187

Jones A, Kobayashi M (1969) Interspecific hybrids of *Ipomoea pes-caprae* and *I. crassicaulis*. Bot Gaz 130:264–266

Kirch P, Coil J, Hartshorn A, Jeraj M, Vitousek P, Chadwick O (2005) Intensive dryland farming on the leeward slopes of Haleakala, Maui, Hawaiian Islands: archaeological, archaeobotanical, and geochemical perspectives. World Archaeol 37:240–258

Kirch PV, Hartshorn AS, Chadwick OA, Vitousek PM, Sherrod DR, Coil J, Holm L, Sharp WD (2004) Environment, agriculture, and settlement patterns in a marginal Polynesian landscape. Proc Natl Acad Sci U S A 101:9936–9941

Kirch PV, Steadman DW, Butler VL, Hather J, Weisler MI (1995) Prehistory and human ecology in Eastern Polynesia: excavations at Tangatatau rockshelter, Mangaia, Cook Islands. Archaeol Ocean 30:47–65

Ladefoged TN, Flaws A, Stevenson CM (2013) The distribution of rock gardens on Rapa Nui (Easter Island) as determined from satellite imagery. J Archaeol Sci 40:1203–1212

Ladefoged TN, Graves MW, Coil JH (2005) The introduction of sweet potato in Polynesia: early remains in Hawai'i. J Polynesian Soc 114:359–374

Landín Carrasco A (ed) (1992) Descubrimientos españoles en el Mar del Sur. Editorial Naval, Madrid, España

Langdon R (1998) Manioc, a long concealed key to the enigma of Easter Island. Geogr J 154:324–336

Margalef O, Cañellas-Boltà N, Pla-Rabes S, Giralt S, Pueyo JJ, Joosten H, Rull V et al (2013) A 70,000 year multiproxy record of climatic and environmental change from Rano Aroi peatland (Rapa Nui). Global Planet Change 108:72–84

Margalef Marrasé O (2014) The last 70 kyr of Rano Aroi (Rapa Nui, 27°S) peat record: New insights for the Central Pacific paleoclimatology. PhD Thesis. Universitat de Barcelona, Barcelona, Spain

Martin FW, Ruberté RM, Jones A (1974a) A wild *Ipomoea* species closely related to the sweet potato. Econ Bot 28:287–292

Martin FW, Telek L, Ruberté RM (1974b) Yellow pigments of *Dioscorea bulbifera*. J Agric Food Chem 22:335–337

McCormick FA (1916) Notes on the anatomy of the young tuber of *Ipomoea* batatas Lam. Bot Gaz 61:388–398

Mellén Blanco F (1986) Manuscritos y documentos españoles para la historia de la Isla de Pascua: la expedición del capitán D. Felipe González de Haedo a la Isla de David, Biblioteca CEHOPU, Spain

Mellén Blanco F (1998) El marino santoñés Felipe González Haedo y el descubrimiento de la Isla de Pascua. Monte Buciero, vol vol. 2, pp 201–216

Métraux A (1940) Ethnology of Easter Island. Bishop Museum Press, Honolulu, Hawaii

Métraux A (1957) Easter Island. A stone-age civilization of the Pacific, 3. impr edn. Andre Deutsch Limited, London

Miryeganeh M, Takayama K, Tateishi Y, Kajita T (2014) Long-distance dispersal by sea-drifted seeds has maintained the global distribution of *Ipomoea pes-caprae* subsp. *brasiliensis* (Convolvulaceae) T. Wang [ed.]. PLoS ONE 9:e91836

Montenegro Á, Avis C, Weaver A (2008) Modelling the prehistoric arrival of the sweet potato in Polynesia. J Archaeol Sci 35:355–367

Muñoz-Rodríguez P (2019) Systematic studies of the sweet potato and its wild relatives. PhD thesis. University of Oxford, Oxford

Muñoz-Rodríguez P, Carruthers T, Wood JRI, Williams BRM, Weitemier K, Kronmiller B, Ellis D et al (2018) Reconciling conflicting phylogenies in the origin of sweet potato and dispersal to Polynesia. Curr Biol 28:1246–1256.e12

Muñoz-Rodríguez P, Carruthers T, Wood JRI, Williams BRM, Weitemier K, Kronmiller B, Ellis D et al (2019) A taxonomic monograph of *Ipomoea* integrated across phylogenetic scales. Nat Plants 5:1136–1144

Neal MC (1965) In gardens of Hawaii. Bishop Museum Press, Honolulu, Hawaii

Orliac C (2000) The woody vegetation of Rapa Nui between the early 14th and the mid-17th centuries AD. In: Stevenson CM, Ayres WS (eds) Rapa Nui archaeology, research on Early Rapanui Culture. Easter Island Foundation, Los Osos, CA, pp 211–220

Orliac C, Orliac M (1996) Arbres et arbustes de l'Île de Pâques. Composition et évolution de la flore depuis l'arrivée des Polynésiens. In: Rapport intermédiaire. Ministère des Affaires Etrangères/CNRS/Consejo de Monumentos/Conaf

Orliac C, Orliac M (1998a) The disappearance of Easter Island's forest: over-exploitation or climatic catastrophe? In: Stevenson CM, Lee G, Morin FJ (eds) Easter island in pacific context, proceedings of the fourth international conference on Easter island and East Polynesia. The Easter Island Foundation, Los Osos, CA, pp 129–134

Orliac C, Orliac M (1998b) Composition et Évolution de la flore de l'Ile de Pâques du 14 ème au 17 ème siecle. In: Raport noviembre 1998. CNRS/Ministère des Affaires Etrangères

Patterson TC, Lanning EP (1964) Changing settlement patterns on the central Peruvian coast. Ñawpa Pacha: J Andean Arch 2:113–123

Patterson TC, Lanning EP (1966) Correction to Ñawpa Pacha 2. Ñawpa Pacha: J Andean Arch 4:155

Payen A (1826) Extrait d'une note lue à la Société Philomatique, le 7 janvier. J Chimie Méd Pharm Toxicol 12:237–239

Pereira D, Nunes AHF, Pessenda LCR, Oliveira GCX (2020) Seawater resistance in sweet potato (*Ipomoea batatas*) seeds: a key factor for natural dispersal from the Americas to Oceania. Front Biogeogr 12:e46169

Perry L (2002) Starch granule size and the domestication of manioc (Manihot Esculenta) and sweet potato (Ipomoea Batatas). Econ Bot 56:335–349

Peteet D, Beck W, Ortiz J, O'Connell S, Kurdyla D, Mann D (2003) Rapid Vegetational and Sediment Change from Rano Aroi Crater, Easter Island. In: Loret J, Tanacredi JT (eds) Rapa Nui. Springer, US, Boston, MA, pp 81–92

Preiss J, Levi C (1979) Metabolism of starch in leaves. In: Gibbs M, Latzko E (eds) Photosynthesis II. Springer, Berlin Heidelberg, Berlin, Heidelberg, pp 282–312

Reichert ET (1913) The differentiation and specificity of starches in relation to genera, species, etc.; stereochemistry applied to protoplasmic processes and products, and as strictly scientific basis for the classification of plants and animals. The Carnegie Institution of Washington, Washington, DC

Rodriguez R, Marticorena C, Alarcòn D, Baeza C, Cavieres L, Finot VL, Fuentes N, Kiessling A, Mihoc M, Pauchard A, et al. 2018. Catàlogo de las plantas vasculares de Chile. *Gayana. Botànica* 75: 1–430

Roullier C, Benoit L, McKey DB, Lebot V (2013) Historical collections reveal patterns of diffusion of sweet potato in Oceania obscured by modern plant movements and recombination. Proc Natl Acad Sci U S A 110:2205–2210

Rull V (2020) Paleoecological research on Easter Island: climatic and ecological change, 1st edn. Elsevier, Waltham

Rull V, Cañellas-Boltà N, Margalef O, Sáez A, Pla-Rabes S, Giralt S (2015) Late Holocene vegetation dynamics and deforestation in Rano Aroi: implications for Easter Island's ecological and cultural history. Quat Sci Rev 126:219–226

Sengupta S (1972) On the pollen morphology of Convolvulaceae with special reference to taxonomy. Rev Palaeobot Palynol 13:157–212

Skjølsvold A (1961) Report 9. Site E-2, a circular stone dwelling, Anakena. In: Heyerdahl T, Ferdon EN Jr (eds) Reports of the Norwegian archaeological expedition to Rapa Nui and the East Pacific, monographs of the School of American Research and the Museum of New Mexico. Rand McNally & Company, Chicago, US, pp 295–303

Skottsberg C (1922) The Phanerogams of Easter Island. In: Skottsberg C (ed) The natural history of Juan Fernandez and Easter Island. Almqvist & Wiksells Boktryckeri, Uppsala, pp 61–84

Skottsberg C (1953) The natural history of Juan Fernandez and Easter Island. Almqvist & Wiksells Boktryckeri, Uppsala

Soubeiran MJL (1854) Études micrographiques sur quelques fécules. J Pharm Chimie 25:89–105

Srisuwan S, Sihachakr D, Martín J, Vallès J, Ressayre A, Brown SC, Siljak-Yakovlev S (2019) Change in nuclear DNA content and pollen size with polyploidisation in the sweet potato (*Ipomoea batatas*, *Convolvulaceae*) complex J. Arroyo [ed.]. Plant Biol 21:237–247

Stevenson CM, Jackson TL, Mieth A, Bork H-R, Ladefoged TN (2006) Prehistoric and early historic agriculture at Maunga Orito, Rapa Nui (Easter Island), Chile. Antiquity 80:919–936

von Humboldt A (1825) Essai politique sur le royaume de la Nouvelle-Espagne, 12th edn. Chez Antoine-Augustin Renouard, Paris

Wallin P, Stevenson C, Ladefoged TN (2005) Sweet potato production on Rapa Nui. The Sweet Potato in Oceania: a reappraisal, Ethnology Monographs. University of Sidney, Sidney

Wilkin P (1996) A revision of the infrageneric classification of the genus *Ipomoea* L. and the related genera in the tribe Ipomoeeae (Convolvulaceae). Doctoral Thesis. University of Reading, Reading, UK

Wilson J, Hardy K, Allen R, Copeland L, Wrangham R, Collins M (2010) Automated classification of starch granules using supervised pattern recognition of morphological properties. J Archaeol Sci 37:594–604

Wood JRI, Muñoz-Rodríguez P, Williams BRM, Scotland RW (2020) A foundation monograph of *Ipomoea* (Convolvulaceae) in the New World. PhytoKeys 143:1–823

Yen DE (1960) The sweet potato in the Pacific: the propagation of the plant in relation to its distribution. J Polynesian Soc 69:368–375

Yen DE (1971) Construction of the hypothesis for distribution of the sweet potato. Man across the sea. Problems of Pre-Columbian Contacts. The University of Texas Printing Division, Austin

Yen DE (1974) The sweet potato and Oceania. An essay in Ethnobotany. Bishop Museum Press, Honolulu, Hawaii

Zhang D, Rossel G, Kriegner A, Hijmans R (2004) AFLP assessment of diversity in sweet potato from Latin America and the Pacific region: its implications on the dispersal of the crop. Genet Resour Crop Evol 51:115–120

Zizka G (1991) Flowering plants of Easter Island. Palmengarten, Stadt Frankfurt am Main, Frankfurt