Collecting Andean root and tuber crops (excluding potatoes) in Ecuador

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R. Castillo[1] and M. Hermann[2]
[1]*Estacion Experimental 'Santa Catalina', INIAP, 14 km, carretera Panamericana al Sur de Quito, Casilla Postal 340, Quito, Ecuador:*
[2]*CIP, Apartado 5969, Lima, Peru.*

Introduction

The Andean region has long been recognized as a major centre of crop diversity. In pre-Columbian times, Andean civilizations domesticated some 70 crops, many of which are hardly known outside the region. Beside the potato, these include another eight species with edible underground parts, sometimes referred to as Andean root and tuber crops (ARTs) (Table 32.1). They are widely used by farmers throughout the Andes as subsistence crops, with the surplus production going to rural and urban markets. Ulluco (*Ullucus tuberosus*) and arracacha (*Arracacia xanthorrhiza*) in particular are sold in considerable quantities in markets in Andean countries.

Probably some 40 to 50 million people include ARTs in their diet. They are well adapted to the Andean environment, productive under low-input conditions and highly nutritious. Some ART species and varieties may have potential as novel sources of sugars, as raw material for the production of starch (e.g. achira, *Canna edulis*) and in the food-processing industry (e.g. arracacha). The underground parts and foliage of several species have been successfully tested as animal feeds. High yields can be achieved at comparatively low cost, giving ARTs potential in livestock production. Mashua (*Tropaeolum tuberosum*), for instance, produces on average $60\,t\,ha^{-1}$ of tubers combining high levels of protein with high carbohydrate content.

Despite all this, the importance of ARTs has sharply declined since colonial times, a process which continues to the present day. When the Spaniards arrived in America, Old World crops such as wheat, barley, broad beans and a large number of vegetables and fruits were introduced and new dietary patterns were taken up by the indigenous population. Today, reasons for the underuse of ARTs include social prejudice against

Table 32.1. Andean root and tuber crops.

Botanical name	Common name[1]	Family	Edible part	Altitudinal range[2] (m)
Ullucus tuberosus	Melloco (ulluco, papalisa)	Basellaceae	Tuber	2060–(3050)–3700
Oxalis tuberosa	Oca (apilla, ibia)	Oxalidaceae	Tuber	2130–(3100)–3900
Tropaeolum tuberosum	Mashua (isañu)	Tropaeolaceae	Tuber	2560–(3240)–3900
Arracacia xanthorrhiza	Zanahoria blanca (arracacha, virraca)	Umbelliferae	Roots	1450–(2510)–3600
Canna edulis	Achira (chiri)	Cannaceae	Rhizome	2200–2800
Polymnia sonchifolia	Jícama (yacón, aricoma)	Compositae	Roots	2040–(2620)–2920
Mirabilis expansa	Miso (chago, mauca)	Nyctaginaceae	Roots	2470–(2610)–2800
Lepidium meyenii[3]	(Maca)	Cruciferae	Hypocotyl-root	3800–4500

[1] Common name in Ecuador. In brackets are given other names used in the Andes.
[2] Range in Ecuador. The average altitude is given in brackets. Data taken from INIAP's collection (Hermann, 1988).
[3] Only known in cultivation around Lake Junín, Central Peru.

their consumption, ignorance of their dietary value and the preference of urban populations for processed food, especially as incomes rise. Moreover, subsidies have eroded the competitiveness of ARTs. This has resulted in genetic erosion in almost all ART species. For example, oca (*Oxalis tuberosa*), once an important subsistence crop in Ecuador, can no longer be found in many areas. In other areas, varieties that were still available in farmers' fields and markets a generation ago have disappeared. Reasons for this include: market demands for a limited number of clones with characteristics desired by urban consumers, changes in diet and phytosanitary problems such as the oca weevil in Peru.

There is probably still time to conserve much of the variation historically available in these crops, but it may soon be too late. Unfortunately, national programmes in the Andean countries cannot give as much attention to ARTs as is necessary. With only modest resources, they struggle to cope with the basic tasks of sustaining work on staples such as potato, maize and beans.

The current status of collections

About 20 years ago concern over genetic erosion in ARTs led a few Andean scientists to start assembling germplasm. Much of this material has been collected with support from the Centro Internacional de la Papa (CIP), the International Board for Plant Genetic Resources (IBPGR) and the International Development Research Centre (IDRC), Canada. As a result, several local and regional collections have been established in Ecuador, Peru and Bolivia. Table 32.2 summarizes current germplasm holdings. This material is predominantly maintained in field collections. The Instituto Nacional de Investigaciones Agropecuarias (INIAP) of Ecuador maintains all accessions both in the field and *in vitro* (Castillo, 1989) and some of the Peruvian and all the Bolivian accessions are duplicated *in vitro* at CIP's field station in Quito for security reasons.

The holdings of the national programme of Peru account for 78% of the total. The diversity of ARTs which can be found in the country is certainly high, but the number of accessions held there is at least partly a consequence of the extensive exchange of material without proper documentation. Research undertaken jointly by the national programme, IBPGR and CIP has shown that duplication within this collection may be as high as 80% (Hermann and del Río, 1989; del Río and Hermann, 1991).

Bolivia, which has perhaps as much diversity as southern Peru, is currently holding only 98 ART accessions, the result of a single recent collecting missions by the Instituto Nacional de Tecnología Agropecuaria (IBTA) jointly undertaken with CIP. Bolivian institutions have lost a major part of their collections (well over 1000 accessions) over recent years. Fortunately, some 150 Bolivian ulluco accessions have been maintained in Finland at the University of Turku, from which duplicates will be repatriated. There are no reported collections from

Table 32.2. Numbers of clonally maintained accessions of Andean roots and tubers maintained by national programmes[1] (1990).

	Ecuador	Peru	Bolivia	Chile	Total
Ullucus tuberosus	210	515	14		739
Oxalis tuberosa	139	1184	47	4	1374
Tropaeolum tuberosum	54	259	18		331
Arracacia xanthorrhiza	78	123	6		207
Canna edulis			7		7
Polymnia sonchifolia	21	39	6		66
Mirabilis expansa	10				10
Lepidium meyenii		38			38
Total	512	2158	98	4	2772

[1]Ecuador: Instituto Nacional de Investigaciones Agropecuarias (INIAP). Peru: Centro de Investigaciones de Cultivos Andinos (CICA) of the Universidad Nacional San Antonio Abad del Cusco; Universidad Nacional de San Cristobal de Huamanga, Ayacucho; Instituto Nacional de Investigaciones Agrarias y Agroindustriales (INIAA), Baños del Inca, Cajamarca. Bolivia: Instituto Nacional de Tecnología Agropecuaria (IBTA), Cochabamba.

Colombia and Argentina and only very few from Chile. Though their diversity of ARTs is rather limited, these countries are nevertheless a high collecting priority in view of the unique traits that can be expected in such material. For example, in Chile oca has in the past been grown as far south as the island of Chiloé (latitude 43°S) and such germplasm is probably long-day adapted, in contrast to oca from the Andes (10°N to 24°S), which requires short days (<13 hours) to form tubers. Also, certain ullucos from Colombia can produce tubers after only four months, which is much less than the seven to eight months taken by material from the Central Andes (Peru and Bolivia).

Collecting missions in Ecuador

As in other parts of the Andes, ARTs in Ecuador are closely associated with native people, who still cultivate a wide variety of species, typically intercropped on small plots of land. For example, oca and mashua are generally intercropped with *Ullucus tuberosus*, the latter being economically the most important species and often grown in monoculture. Initially, collecting missions concentrated on areas with large native populations, such as the provinces of Cotopaxi and Chimborazo in central Ecuador. As evidence for the replacement of ARTs by barley, broad beans, forages and potatoes mounted, the emphasis was shifted to areas where the threat of genetic erosion was estimated to be highest (INIAP, 1985).

Figure 32.1 shows where INIAP has collected ARTs between 1982 and 1988. This material is maintained clonally at INIAP's experimental station south of Quito. Each dot in Fig. 32.1 represents a locality where ART samples have been collected; commonly, several samples are collected at each site. Ecuador comprises a minor part of the Andes and its geography does not pose the formidable barriers which are common in the central Andes, such as deep valleys, 'cordilleras' and sparsely populated plains. Consequently, most of the Ecuadorean highlands (above 2600 m) and valleys descending to the lowlands are comparatively easy to reach. The map shows that INIAP's germplasm is fairly representative of the Ecuadorean highlands in terms of geographic coverage. Some areas, however, still need to be visited, particularly the less accessible eastern highlands as well as some valleys to the west and south which can only be reached by foot or on horseback.

Eighty-one per cent of INIAP's holdings was collected in farmers' fields or stores. Only 9% was collected in markets. The rest is wild material, somaclonal variants and clones selected for breeding purposes. Basic passport data, such as locality, altitude, latitude and longitude, local name, etc., are available for all Ecuadorean ART germplasm in the INIAP collection (Castillo, 1991).

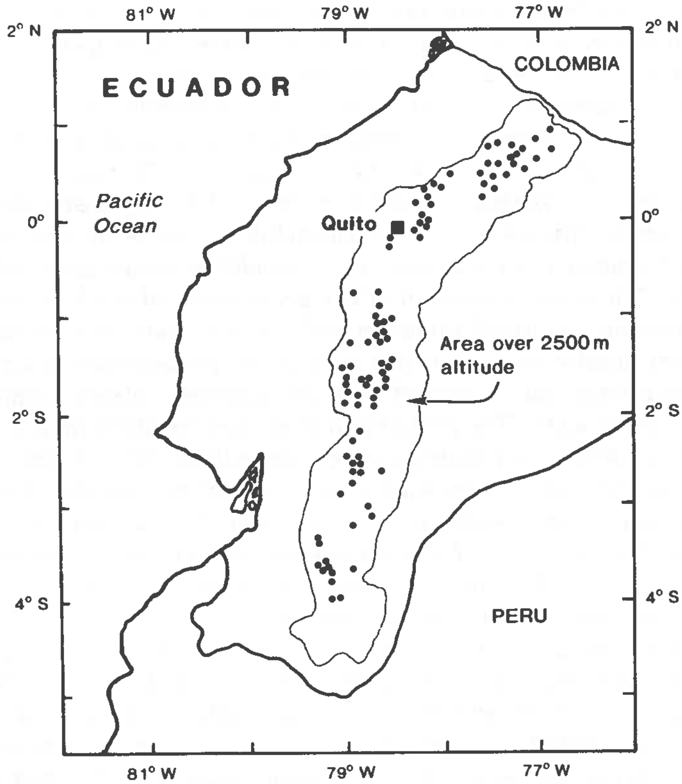

Fig. 32.1. Collection sites of Andean root and tuber crops in the Ecuadorean highlands (Hermann, 1988).

Collecting techniques

With the exception of maca (*Lepidium meyenii*), a biennial propagated by orthodox seeds, all other ARTs are vegetatively propagated perennials. Generally, the edible plant part serves as the propagule, but in the case of *Arracacia xanthorrhiza* and *Polymnia sonchifolia* other parts must be used as propagating material.

All vegetatively propagated ARTs have retained the ability to set functional flowers, but they rarely set viable seed. For example, most accessions of melloco flower abundantly, but seed set under field conditions is extremely rare. Germination in melloco is slow and the factors controlling it are as yet not well understood (Lempiäinen, 1989). In other cases, special procedures, such as scarification, particular germinating substrates and disinfection, are known to be required for germination (Muñoz and Castillo, 1991).

Consequently, only vegetative plant parts, if possible those the farmer uses for planting, are usually collected. In the case of oca, ulluco and mashua, the mature tubers are most appropriate. At ambient temperatures (10–12°C at 3000 m) they can be stored for up to six months. However, mature tubers are available only during a short period, i.e. between harvesting and planting (July–October), so shoot cuttings or immature tubers are sometimes collected. The former must be placed in a rooting substrate within a few days, and the latter tend to be easily bruised and are susceptible to bacterial and fungal decay.

Arracacha is propagated by cormel-like structures, called 'colinos' locally. These are composed of the basal parts of the leaf sheaths, which are inserted on a thick underground vertical stem, or rootstock. 'Colinos' are very similar to the cormels used in the propagation of taro (*Colocasia esculenta*) and can be stored in paper bags at ambient temperatures for up to two months. The roots cannot be used as planting material as they begin to decay very quickly after harvesting, like cassava roots.

Miso (*Mirabilis expansa*) is most easily propagated from stem cuttings, but sexual seeds can also be used. The collecting of achira and jícama (*Polymnia sonchifolia*) does not present major problems. Achira reproduces by rhizomes and jícama by a rootstock which can be taken from the plant at any time of the year.

Traditionally, farmers tend to grow a variety of clones of each species intercropped in the same field. In collecting, the tubers found in a field or store are sorted into morphologically distinct groups and an accession number is assigned to each group. Great care is taken to avoid clonal mixtures under one accession number. The participation of farmers is vital in this, though occasionally their indigenous classification systems do not take into consideration small but genetically determined differences. Occasionally gene-bank curators must split up accessions as such mixtures become apparent during subsequent grow-outs. However, preliminary isozyme studies have shown that material considered and vegetatively maintained as one accession in the germplasm collections of ARTs consists with very few exceptions of just one clone (Hermann, 1988).

The importance of passport data

A meticulous description of the locality may seem superfluous to the local collector, but germplasm may be very widely duplicated and exchanged and such data will be necessary to workers not familiar with the collecting region. The study of the ecogeographic distribution of variation is impossible without accurate passport data, including at least locality and altitude. Passport data will also be needed to re-collect a lost accession. There is some flexibility possible in recording data in the field, however. In one locality a more detailed description of the environment may be required, whereas in another place the mode of use or the agronomic features of germplasm may deserve more detailed comment. Unfortunately, even basic passport data are not available for a major part. of the collections of ARTs. Ideally, herbarium samples should accompany each accession, but again very little herbarium material of ARTs has been collected during germplasm collecting missions in the past. This is a source of particular regret when germplasm collections are lost.

Farmers can provide much information on clones which they may have been growing and observing for decades. An attempt is usually made when collecting ARTs to tap local knowledge on such topics as disease susceptibility, agronomic characteristics, mode of use and market acceptance. Unfortunately, farmers are normally busy people and do not always like being questioned. Certainly, technical jargon and leading questions must be avoided when talking with them. Native farmers in Peru and Bolivia apply folk classification systems to ARTs. These are not 'natural' systems but do provide meaningful descriptions which can complement technical accounts of variation. For example, 'huahuaquepe' is a popular class of melloco in Peru. It gives a strong yellow colour to meals and has rather large tubers much appreciated by consumers. The name is a Quechua word meaning 'carrying a child', an apparent reference to the tendency of this ulluco to form small tuberlets in the eyes of larger tubers, especially on light soils. Unfortunately, the knowledge that forms the basis of such classifications is in many places disappearing along with the crops themselves.

After the collecting mission: conservation and use

All samples are quickly planted in the field for multiplication. When enough planting material is available, the collection is characterized and evaluated under field conditions. Planting is repeated every year. For each accession, plots of about 12 m^2 are required. Harvested material is stored at INIAP for three months in a traditional store at an ambient temperature of 10–12°C.

Such a system of periodic replantings is particularly vulnerable to phytosanitary and climatic problems (Hawkes, 1970). Today, most of INIAP's collections of *Ullucus*, *Tropaeolum* and *Oxalis* are being conserved *in vitro* (Castillo *et al.*, unpublished). The *in vitro* media for these species are based on the standard Murashige and Skoog (1962) medium supplemented with 10 ppm gibberellic acid and 3% sucrose. Good results have been obtained by adding 0.5% activated charcoal to the medium for *Oxalis*. Different concentrations of mannitol and sorbitol have been used in the culture medium to retard the growth of germplasm maintained *in vitro*. The best results have been obtained for *Ullucus* with 4% mannitol and for *Tropaeolum* and *Oxalis* with 6% and 4% sorbitol, respectively. With these additions, and at a temperature of 8°C, Andean tubers can be kept for up to two years before a new micropropagation is necessary (Muñoz, 1988; Tapia, 1991). Tissue culture work is under way with the other species and preliminary results with *Arracacia* are promising (Cevallos, 1991).

Evaluation has led to the identification of elite lines of ARTs with respect to yield, disease resistance and precocity. The Andean Crops Breeding Programme of INIAP is now using 20 elite lines of melloco, for example. Selection and further evaluation are carried out in order to produce new varieties suitable not only for the Andes but also for other tropical highlands.

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