

ANDEAN TUBER AND ROOT CROPS: ORIGIN AND VARIABILITY

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The human occupancy of the Andean highlands is more than 10,000 years old. If the common theory is accepted that man came to America through the Bering strait and dispersed southwards, then the Andean highlands offered to early man a series of habitats that were somewhat similar to the northern part of Asia. The cool, barren punas were excellent hunting grounds. The auchenids: guanaco, llama, vicuna and alpaca, supplied him with abundant meat and furs. The open country covered with grass, in the belt between the 3000-4000 m., with clear streams and many caves, was probably the first area in which man settled permanently in the Andes. The remains of El Inga in Ecuador and the caves of Lauricocha in Peru, show that hunting was the predominant activity of the Andean man 8000-6000 years ago.

In the high Andes the frost-free period determine the growing season. Only few plants, grasses like *Stipa*, could grow continuously. The majority of the species have developed extensive subterranean organs, storage roots or tubers, which are permanent; during the frost-free season they put up few leaves and flowers, the latter comparatively large. All the aerial parts are eventually destroyed by frost, which marks the end of the growing period. In the tuber plants, the underground organs continue to grow for some period after the aerial parts have died; they are ready to sprout again as soon as the frost disappears in the next growing season. This process is so efficient, as a means of survival, that many plants in the Andean habitat usually do not set seeds and depend on tubers for their propagation.

Sauer (10) has pointed out how easy it is for primitive man to start using tubers as food. In the Andes two factors may have contributed to domestication. First, it is possible that in the original systems of cooking meat, using hot stones ("pachamanca") with earth piled around, some tubers could be casually cooked, and eventually eaten. In this form tubers and roots were consumed for a long time before the invention of pottery. A second factor is that the Andean tubers and roots present very attractive forms and coloration; primitive man may have collected them for such characters, and then tried them as food.

ANDEAN ROOTS AND TUBERS

Vavilov (11) has given a long list of cultigens which he supposed originate in the Andes. Many of them, we know now, are introductions from other areas, assembled by expeditions and interchange, particularly during the expansion of the Inca Empire. This vast political unit covered from north to south an area longer than from Norway to Spain. However, all the tubers listed by Vavilov are undoubtedly of Andean origin. The most important are the potatoes; but there are others, like oca or cubia, *Oxalis tuberosa*; ulluco or melloco, *Ullucos tuberosus*; mashua or isano, *Tropaeolum tuberosum*, which are of local importance. Besides there are: maca, *Lepidium meyenii*, a root or rather a tuberous hypocotil now a

relict crop; and among the true roots, arracacha, *Arracacia xanthorrhiza*; yacon, *Polymnia sonchifolia*; jicama, *Pachyrrhizus ahipa*.

In some Andean plants the fleshy and edible tissues extend from the roots to the lower part of the aerial stems, which in turn are of the same colour and structure and also edible. Such happens commonly in the yacon and the mauka, *Mirabilis expansa*, the latter recently discovered in cultivation by Ing. Julio Rea, first in Bolivia and later in Ecuador.

From Venezuela to northern Argentina, the Andean tuber and root crops grow at different altitudinal levels: oca, ulluco, mashua, maca and some potatoes above 3000 ft.; arracacha and yacon from 2000 to 4800 ft.

In the vast area occupied by these crops it is difficult to delimit specific centers of origin. For potatoes, oca, ulluco and mashua, the highest concentration of present variability is located between Peru and Bolivia. It is also in this area, where more wild *Solanum* are concentrated. Wild ullucus are still found in these two countries. No true wild oca has ever been found. In reference to mashua the picture is more complicated, as several species of edible *Tropaelum* have been reported from Colombia to Patagonia, and this group needs a careful revision to determine the different species. The facts mentioned above support the hypothesis of Cook (4), Bukasov (1) and others on the altiplano origin of these crops, which seems more likely than the new idea expressed by Sauer (10), which supposes that most of the Andean crops were domesticated in northern South America.

THE ANDEAN POTATOES

In the Andes there are several species of potatoes that are cultivated regularly; others which are collected occasionally and many wild species of tuberous *Solanum* without any economic use. The classification of the Andean potatoes is, in spite of the efforts of taxonomists and geneticists, still quite confusing. There are several factors that contribute to this situation. The cultivated potato shows different levels of ploidy: 2x, 3x, 4x and 5x; they grow in very different habitats, from 3000 ft. to the highest level of vegetation; it is possible that through hybridization and introgression, wild genes may be introduced in this complex. The taxonomy is still a matter of controversy. Bukasov (2) considers as species 5 diploids: *S. stenotomun*, *S. goniocalyx*, *S. ajanhuiri*, *S. phureja*, *S. rybinii*; several triploids; *S. chaucha*, *S. tenuifilamentum*, *S. mammilliferum*, *S. chocclo*, *S. cuencanum*; two tetraploids: *S. tuberosum*, *S. andigenum*; one pentaploid: *S. curtilobum*.

According to Dodds (6) there is one species, *S. tuberosum*, divided in five groups: *stenotomun*, *phureja*, *chaucha*, *andigena* and *tuberosum*; a triploid hybrid: *S. X juzepczukii*, and a pentaploid hybrid: *S. X curtilobum*.

Hawkes (8) recognizes 3 triploid species: *S. ajanhuri*, *S. phureja*, *S. stenotomun*; a tetraploid: *S. tuberosum*; two triploid hybrids: *S. X chaucha*, *S. X juzepczukii*; one pentaploid hybrid: *S. X curtilobum*.

MINOR TUBERS

The oca or ibia, *Oxalis tuberosa*, is the second tuber of importance in the Andes: it is cultivated from Venezuela to northern Argentina. Outside this region

it is found only in Mexico, New Zealand and occasionally in southern Europe. Ocas are short, compact fleshy plants, formed by several stems that sprout from the mother tuber. The leaves, as in other species of *Oxalis*, are formed by a long petiole with the blade divided in three parts like clover. The yellow flowers show a marked heterostily; they drop a few days after anthesis and very seldom set seed.

The tubers are cylindrical or ellipsoidal, very fleshy, with long, shallow "eyes." Their colour ranges from yellow to purple, uniform or more intense around the buds. Unlike the potatoes, the skin is soft. Many varieties are quite sweet and eaten raw, but most of the tubers are cooked or prepared in chuno.

Ocas are extremely variable. In the Andean Zone collection there are around 150 introductions. They originate mainly from bud mutations.

Ulluco or melloco, *Ullucus tuberosus*, belongs to the Basellaceae. The cultivated types are short and compact, while the wild plants have long, climbing stems. The leaves, cordate and thick, are bright green, often with yellowish areas in the margins. Aerial tubers are found sometimes in the axils of the leaves. The star-like flowers of opaque-yellow colour, grow in racemes; the fruits are capsules containing one seed.

The tubers are cylindrical, ellipsoidal or spherical, with shallow eyes. The most common types are golden yellow, which turn green when exposed to light. In these clones chimaeras are common, appearing as spots, limes or relatively large areas of deep purple. There are also cultivars with white, green, coral, pink, brown or purple tubers. Some varieties may be confused with potatoes, as they have a dark colour and a velvety surface. The skin is soft, and the flesh yellow and mucilaginous. Ullucus are always cooked; they are consumed in large quantities in the cities, and appear in plastic containers in the best supermarkets.

There is an ample variation in this species, concentrated in the Peruvian-Bolivian area.

The third among the lesser tubers is the anu, isano or mashua, *Tropaelum tuberosum*. This plant resembles the common nasturtium, although it is more compact and has smaller flowers. The stems are green or reddish, and the leaves show a considerable variation in form; they are peltate, with 3 to 5 lobes. The flowers, like in nasturtium, have long peduncles. The red calyx forms a spur, in some cases two. The orange petals are of different size and shape. The mashua commonly set seeds.

The tubers are long, generally deeply furrowed, each furrow corresponding to an eye. The coloration varies from transparent white to almost black. Some very attractive types have tubers with a deep yellow background with some areas covered by fine points or lines of brown or purple.

The mashua tubers are always cooked; they taste like turnips. In some Indian communities, where potatoes or other tubers do not grow, mashuas are a primary article in the diet. This species may grow at higher altitudes than the other tubers, due to its resistance to cold. Mashuas are also frozen after cooked, and in this way they are more agreeable and nutritious.

Several hundred clones of mashua are known. It has been proposed to separate them in two species: one would correspond to the Colombian types,

characterized by long, deeply furrowed tubers, white with pink extremes, with numerous rootlets; the second to the Peruvian-Bolivian types, with yellow tubers, often with dots and lines, and without rootlets. The characteristics mentioned do not seem, however, to justify the specific separation.

ROOT AND CORM CROPS

In the Andean area several root and corm crops have been domesticated. Others like the achira, *Canna edulia*, although of very ancient use, may have been introduced from the lower regions (7).

Maca, *Lepidium meyenii*, is a turnip like plant which grows at the highest elevations (3500-4000 ft.), above the level at which the common potatoes and the other tubers are planted. The plant exhibits the typical habit of the puna plants: a rosette of dissected leaves, attached to the ground, and a thick hypocotyl, the edible part, rich in starch and sugars. Macas are propagated by seed; its culture is disappearing rapidly (9).

Arracacha, *Arracacia xanthorrhiza*, is the only Umbellifer domesticated in the New World. It has been introduced to Central America, West Indies, the highlands of Africa and Ceylon, where it grows well above 600 m. It is also produced commercially in the subtropical area around Sao Paulo. The arracacha is a vigorous plant, up to 2 ft. high, with dark green or purple foliage. The edible part are the roots, and in some cases the underground stem. The roots are starchy, highly aromatic, and are eaten cooked in different ways. According to Bukasov (1), "The natives rightly appreciate the flavor of arracacha which is superior to potato, as the insipid taste of the potato, is supplanted in the arracacha by the aroma of the umbelliferae, in a moderate degree (different from celery), which makes arracacha not a condiment but a food, which can be used in a pure state".

The fusiform roots, up to 15 inches long and 3 inches wide, are white or purplish outside. The inside is white or yellow, often with purple areas. The transversal section shows a ring of purple dots and mucilage channels, separating the cortex from the central core.

The center of variability of arracacha lies in central and eastern Colombia. In cultivation it extends to southern Bolivia. Although there are several wild species of *Arracacia* from Colombia to Peru, there is no information on the relationship of the cultivated arracacha and these wild species, neither is it found anywhere in native state.

Yacon, *Polymnia sonchifolia*, is a typical Andean Cultivar. It grows from Venezuela to northern Argentina, from 3000 to 7500 ft. Nothing is known about its origin; Bukasov (1) says it grows wild in Colombia.

The edible parts in the yacon are the roots and the fleshy part of the lower sections of the stem. Both have a soft, purplish bark. The flesh is transparent yellow, and contains insulin-like sugar. The fusiform roots are harvested, stored in a dry dark place. They are eaten fresh and have a typical sweet taste. Starch is completely absent. Cobo (4) says that in the colonial times, the roots were taken in the long trips by boat to Spain, and they lasted for months in good conditions.

The yacon is propagated vegetatively by sprouts. The plant produces several aerial stems, with abundant foliage; as leaves and stems contain between 12 to 16% of protein, the yacon could be used, like the topinambur, as a forage plant.

Jicama or aricama, *Pachyrrhizus ahipa*, is the Andean counterpart of the Mexican jicama, *P. erosus*. It is restricted to Bolivia and northern Argentina, while *P. tuberosus* according to Clausen (3) is the species found in the highlands of Ecuador.

The jicamas have one or several vines arising from a subterranean, fleshy root. The leaves are divided in three leaflets, often of different shape in the same plant. The seeds have been used as an insecticide.

The watery sweet roots are the edible part. They are eaten fresh, and are consumed in great quantities in Bolivia and Ecuador. In Peru they are unknown at present, although jicama was an important crop in the pre-Spanish period.

COMMON CHARACTERISTICS OF THE ANDEAN TUBER CROPS

1. The tuber crops originated at high altitudes — potatoes, oca, ulluco, mashua — offer a great similarity in morphological and physiological characteristics. By convergent evolution, tubers of certain cultivars of oca, potatoes and ulluco, are practically not distinguishable to the common observer. They are similar in size, shape and superficial texture. Areas with red or purple pigments are found in all of them, varying from a solid patch covering a good part of the tuber, to tiny lines or dots. The presence of red-purple pigments is a common feature in many Andean plants.
2. In the Andean tubers, vegetative propagation is the rule; potatoes and mashuas regularly set a good number of seed.
3. The growth process is quite similar in the tuber species mentioned above. It is determined by a short growing season from 6 to 7 months, between the frost periods; by high day and low night temperatures, and high insolation. Measurements of the weight of vegetative parts, under experimental conditions, in Andigena potato, ulluco, mashua and oca, show roughly similar curves. In all of them there is a marked increase in the first two months, then a resting period of very short duration, followed by a final increase in growth, far more important than the first.
4. The start of tuberization corresponds in these species approximately with the blooming period, and the tubers continue increasing in size after the frost has killed the tops of the plants.
5. The uses of the Andean tubers are quite similar. They are eaten primarily cooked, as vegetables. Freezing and drying to convert the fleshy tubers in a dry mass ("chuno") is practiced with potatoes, ocas and mashuas.

R E F E R E N C E S

1. Bukasov, S.I. (1963): Las plantas cultivadas de Mexico, Guatemala y Colombia. Lima, Instituto Interamericano de Ciencias Agrícolas. **Publication Miscelanea No. 20.** 261 p. (mimeografiado).
2. ——— (1966): Die kulturarten der Kartoffel und ihre wildwachsenden Vorfahren. **Zeitschrift für Pflanzenzüchtung** 55(2): 139—164.
3. Clausen, R.T. (1944): A botanical study of the yam beans (*Pachyrhizus*). **Cornell University Memoir No. 264.** 36 p.
4. Cobo, B. (1956): Historia del Nuevo Mundo. Madrid. **Biblioteca de Autores Espanoles**, 2 vols.
5. Cook, O.F. (1925): Peru as a center of domestication. **Journal of Heredity** 26 : 33—46; 95—110.
6. Dodds, K.S. (1962): Classification of cultivated potatoes. In D.S. Correll. The potato and its wild relatives. p. 517—539. **Renner, Tex.**
7. Gade, D.W. (1966): Achira, the edible canna. Its cultivation and uses in the Peruvian Andes. **Economic Botany** 20 : 407—415.
8. Hawkes, J.G. (1963): A revision of the tuber-bearing Solanums. **Scottish Breeding Station Record** 1963 : 154—159.
9. Leon, J.—Plantas alimenticias andinas. **Instituto Interamericano de Ciencias Agrícolas Boletín Técnico No. 6.** 112 p.
10. Sauer, C. (1965): Cultural factors in plant domestication in the New World. **Euphytica** 14 : 301—306.
11. Vavilov, N.I. (1951): The origin, variation, immunity and breeding of cultivated plants. **Chronica Botanica** 13 : 1—364.