Botanical Perspectives on Coca*

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INTRODUCTION

The coca leaf has played an important role in the lives of South American Indians for thousands of years. Its use as a masticatory persists today in many parts of the Andes and in the Amazon basin, where it serves as a mild stimulant and medicine among Indians and rural inhabitants. In addition to small quantities of the alkaloid cocaine, coca leaves contain several minor alkaloids, essential oils and relatively high amounts of vitamins and minerals (Holmstedt et al. 1979, 1977; Duke et al. 1975; Willaman & Schubert 1961).

The basic method of coca use is quite uniform throughout its area, although some minor variations exist. The whole, dried leaves are placed in the mouth, usually one at a time. They are moistened with saliva and gradually worked into a quid about the size of a walnut. The leaves are not actually "chewed"; rather, the quid of softened leaves is sucked and moved about with the tongue to extract the green juices. Some form of alkaline substance such as lime is always added to the quid, a practice which is also observed with the use of betel nut and tobacco. The quid is kept in the mouth for about 45 minutes and then is spat out. Coca chewers are often recognized by a bulge in one or both cheeks caused by the quid of leaves. This bulge is frequently represented in pre-Columbian art and may be considered indicative of coca chewing. The details of coca chewing and its pharmacological effects are summarized in several recent publications (Antonil 1978; Grinspoon & Bakalar 1976; Andrews & Solomon 1975; Burchard 1975).

The antiquity of the use and cultivation of coca is only now coming to light. The oldest direct evidence for coca chewing has been found on the coast of Ecuador in the Valdivia culture. Lathrap (1976) points out ceramic lime pots and figurines of coca chewers which date coca chewing to about 3000 B.C. He also suggests that domesticated coca was grown on the eastern and western slopes of the Ecuadorian Andes at this early date.

BOTANICAL STUDIES ON COCA

In spite of its being one of the oldest cultivated plants of South America, until very recently little attention has been paid to the origin and evolution of the coca plant. Anthropologists have long been aware of the importance of coca in South American cultures. For reasons which I will outline below, botanists have neglected the study of coca, which in turn has hindered anthropological and archeological work.

As in the study of any cultivated plant, a thorough knowledge of the basic botany is needed before more sophisticated interdisciplinary studies can be carried out. In the case of coca, there have been no coordinated studies on the part of botanists and anthropologists to unravel the early history of the plant.

"Coca" in the broad sense refers to species of the

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genus *Erythroxylum*[1] of the family Erythroxylaceae. Coca should not be confused with *cocoa* or *cacao*, the chocolate plant (*Theobroma cacao* L.), or with the Spanish word *coco* which in Latin America refers to the coconut (*Cocos nucifera* L.) and in Jamaica refers to rootcrops of the genus *Xanthosoma*, also called "coco-yams."

Erythroxylum is a pantropical genus including perhaps as many as 250 species, most of which are natives of the American tropics. All species of the genus are shrubs or small- to medium-sized trees. They grow usually in the understory of primary and secondary forests, or in open thickets. The numerous wild species occur mostly below 1000 meters elevation, although the cultivated species may be grown as high as 2000 meters. None of the species tolerate frosts. In South America species are widely distributed in both wet and dry tropical areas and are especially well adapted to regions with a pronounced dry season. By far the greatest concentration of species lies in central and southeastern Brazil, with secondary centers in the eastern Andes, the Amazon basin and the Guiana region. Drolet (1974) has stated that all species of *Erythroxylum* are recorded from the eastern *montaña* zones of Colombia, Ecuador and Peru, and that the highest density of species is found in eastern Colombia. Neither of these statements has any factual basis.

Many of the species of *Erythroxylum* are difficult to distinguish owing to their small, inconspicuous flowers, a lack of well defined taxonomic characters and the great variability observed in certain characters. One of the greatest obstacles to identifying the American species is their sheer number.

The difficulty in working with this group of plants has discouraged many botanists, and only one comprehensive work on *Erythroxylum* has appeared in this century. This was a world-wide monograph published in Engler's *Das Pflanzenreich* in 1907 by O.E. Schulz, a German botanist working in Berlin. Taxonomic work on the genus suffered a major setback with the destruction, during World War II, of the Berlin herbarium which housed many of the type specimens on which Schulz based his work. Although Schulz' monograph has many shortcomings and is now out of date, it is an invaluable compendium which remains the basic reference point for subsequent systematic studies on *Erythroxylum*. A few minor works on the genus have appeared in recent years but these consist mainly of descriptions of new species or regional accounts adapted from Schulz' original work (D'Arcy & Schanen 1975; Gentner 1972; Machado 1972; Macbride 1949).

My own studies on *Erythroxylum* have focused on the South American members of the genus with special emphasis on the Andean and cultivated species. I have spent more than three years in Colombia, Ecuador and Peru, collecting and studying the plants in the field. This work has provided an opportunity to observe the ecology of many of the wild species as well as the cultivation and use of the cultivated ones. I have also been able to study several key species and varieties under uniform, controlled conditions. This work is especially useful for interpreting morphological differences induced by local variations in climate and soils. Breeding experiments among various wild and cultivated species have been conducted in order to test genetic affinities and crossability relationships. I have examined several thousand herbarium specimens of *Erythroxylum* from all parts of the Neotropics, in order to interpret the morphological variation within the species.

The cultivated cocas belong to two closely related species of *Erythroxylum*: *E. coca* Lam. and *E. novogranatense* (Morris) Hieron. Some workers in the past, including botanists, chemists and anthropologists, chose to recognize only one species, *E. coca*, and to consider *E. novogranatense* as its variety (Martin 1970; Hegnauer & Fikenscher 1960; Mortimer 1901; Burck 1892, 1890; Morris 1889). However, the consensus of most botanists who have studied the plants in the field as well as in the herbarium is that there are two distinct species (Machado 1972; Payens 1958; Schulz 1907; Rusby 1900; Hieronymus 1895). The characters which are employed to separate the species take into account morphology, anatomy, chemistry, ecology, geographical distribution and breeding relationships. A detailed account of these characters will be the subject of a later paper.

The genus *Erythroxylum* is the only natural source of the alkaloid cocaine and related compounds. Only the two main cultivated species contain sufficiently large amounts of cocaine to warrant mastication as a stimulant or extraction for pharmaceutical use. Minute quantities of cocaine have been detected to date in 17 wild species of the genus, including several Old World species (Aynilian et al. 1974; Rivier & Plowman unpublished data). There seems to be little or no discernible relationship between the occurrence of cocaine and morphological affinities. Some of the species most similar to *E. coca* and *E. novogranatense* contain no cocaine (Holmstedt et al. 1977). Almost nothing is known about the distribution of the minor coca alkaloids in the genus, although twelve different such compounds have been reported for the cultivated cocas (Willaman & Schubert 1961).

There have been several reports of other Andean

species of *Erythroxylum* being cultivated for coca leaf chewing. During his travels in the Province of Popayán, Colombia, in 1801, Humboldt claimed to have found several species in use, including *E. bondense* H.B.K. (Mortimer 1901). More recently, Uscátegui (1954) and Espinosa (1975) have stated that *E. bondense* is cultivated and used similarly to *E. novogranatense* in Colombia. This wild species has been found in several areas in the Andes and may occasionally be employed in medicinal teas. However, I have found no convincing evidence that it is ever cultivated or chewed like coca. Recent analyses indicate that it contains no cocaine (Holmstedt et al. 1977). Uscátegui implied the *E. popayanense* H.B.K. is also cultivated in Colombia. Since this species has not been rediscovered since Humboldt's original collections, this surely represents a misidentification of the plant. Unless such reports of additional cultivated species can be documented with voucher specimens and field work, the identity of the plants remains open to question.

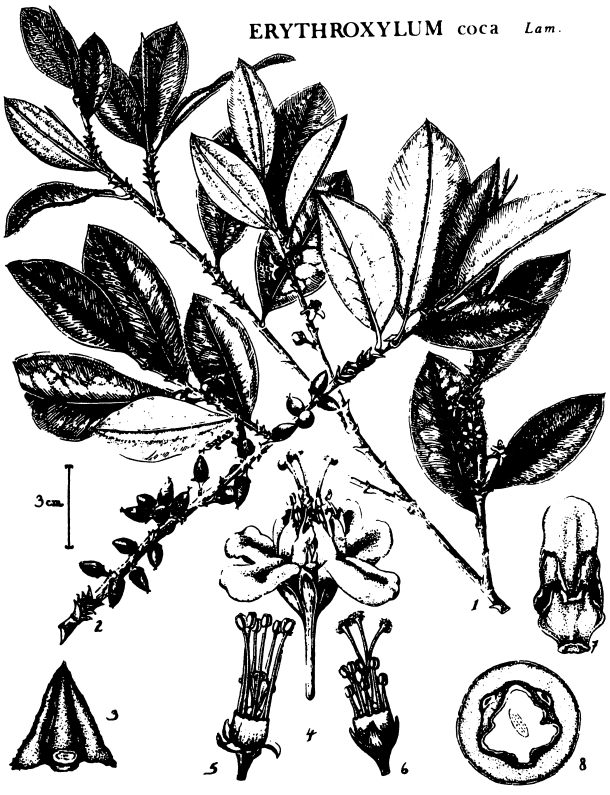


Figure 1 — *Erythroxylum coca*. 1,flowering branch; 2, fruiting branch; 3, stipule; 4, long-styled flower; 5, short-styled flower, petals removed; 6, long-styled flower, petals removed; 7, petal, adaxial view showing appendage; 8, cross-section of fruit. Drawing by L.T. Bates.

HUÁNUCO OR BOLIVIAN COCA: *ERYTHROXYLUM COCA*

The most important commercial species of coca is *Erythroxylum coca*. This plant was first described scientifically by the French botanist Lamarck in 1786 from specimens collected in Peru by Joseph de Jussieu in 1749. Lamarck named the species for the Peruvian common name of the plant "coca."

As in times past *E. coca* is one of the most important cash crops in eastern Peru and Bolivia, and its role in the local economy cannot be underestimated. It is this species from which most of the world's cocaine supply is extracted. The value of the leaves has skyrocketed in recent years commensurate with the huge increase in illicit cocaine consumption.

Estimates of the amount of coca leaves produced vary widely. In 1978, annual production in Peru alone was estimated at 30,000,000 kg of dried leaves, over 95 percent of which was derived from *E. coca* (Anonymous 1978). Three years earlier estimates ranged from 10,000,000 kg (official) to 20,000,000 kg (unofficial). In Bolivia the crop in 1974 was thought to be about 12,000,000 kg (South 1977). Current estimates for the Bolivian crop range from 11,000,000 kg to 35,000,000 kg.

Erythroxylum coca is native to the Andean *montaña*, a region of the eastern Andes between about 500 and 1500 meters elevation, consisting of wet, tropical montane forests. This includes not only the eastern flanks of the cordillera but also the numerous intermontane tropical valleys which tongue into the high mountains. In Peru, coca is grown throughout this zone which stretches the entire length of the country. The principal centers of cultivation today are in the Department of Huánuco, mainly around the city of Tingo María, and in the Department of Cusco in the Valley of La Convención. In Bolivia there are also two main centers: the Yungas region just east of La Paz and the Chapare district of Cochabamba Province.

Although we have no authenticated archeological specimens of coca from the eastern Andes, it is certain that its cultivation in the *montaña* dates back several millennia. In historic times this species is known from Ecuador south to Bolivia. It is difficult today to pinpoint the exact geographic origin of *E. coca*, but the tropical valleys of the Peruvian Andes lie near the center of geographical distribution, and this region may well have been the original area. The fact that *E. coca* is conspicuously absent from the tropical mountains of

Figure 2 — Plantation of *Erythroxylum coca* at Naranjillo, near Tingo María, Department Huánuco, Peru. Photograph by T. Plowman.

Colombia and Venezuela also implies a more southern origin.

Erythroxylum coca was the first type of cultivated coca to be collected and studied by Europeans. In the formerly extensive pharmaceutical trade in coca, it was called "Huánuco" or "Bolivian" coca, after the main areas of cultivation. True *E. coca* is little known outside South America and only rarely is cultivated in botanical gardens and conservatories.

The plant grows as a small to medium-sized shrub, usually planted in rows in large, hillside plantations. The leaves are characteristically large and thick, broadly elliptic in shape, more or less pointed at the apex and dark green in color. On the underside of the leaves are found two lines parallel to the midrib which are often said to be characteristic of the species. However, these lines are present to a degree in all the cultivated species and in several wild species of *Erythroxylum* as well.

Like many plants which have been cultivated for thousands of years, *Erythroxylum coca* is now rarely found in a truly wild state. Several early botanists (Rusby 1900; Poeppig 1836) reported "wild" coca in their travels, but this was always found growing near areas of coca cultivation. Even today, scattered individuals are frequently encountered in secondary woods and thickets around coca plantations. The small, shiny, bright red fruits are readily dispersed by birds, which accounts for the appearance of spontaneous *E. coca* in areas now removed from coca cultivation. I found some cases of reputedly "wild" coca to be mere remnants of old, abandoned plantations.

Throughout the *montaña* feral plants of *E. coca* often persist in secondary growth and may subsequently continue to grow in the understory of secondary forests. These plants mature and reproduce as small, scattered populations, but no extensive wild populations have been found away from areas of cultivation. At present, it appears that cultivated populations of *E. coca* exist in a genetic equilibrium with feral individuals and that gene exchange occurs freely between them. The ease with which this plant escapes from cultivation and thrives in the Peruvian *montaña* lends further support to my belief

Figure 3 – Habit of cultivated plant of *Erythroxylum coca*, Río Mishollo, Department San Martín, Peru (*Plowman & Kennedy 5792*). Photograph by T. Plowman.

that this is its natural habitat and center of origin.

Cultivated plants of *E. coca* differ only slightly from spontaneous individuals found nearby. There is little evidence that artificial selection has played an important role in the domestication of the species, in contrast to the often drastic genetic and morphological changes which have taken place in the evolution of other cultivated plants (Pickersgill & Heiser 1976). Exploitation of the leaf for its alkaloids has little affected the original form of the species, its genetic integrity or its capability of reproducing outside cultivation. Selection for greater alkaloid production may have occurred, but this would be coincidentally advantageous to the plant in discouraging insect predation of the leaves.

The fruit of *Erythroxylum coca*, as in all species of the genus, is a small, red drupe with a thin, fleshy mesocarp. The seed, enclosed in a hard, bony endocarp or "stone," has a very short period of viability (one to two weeks) and is easily killed if allowed to dry out. The seed is adapted to the continuously moist, forest conditions found in the *montaña*, where a dormancy period or impermeable seed coat are not necessary for survival. The high perishability of the seed is an

Figure 4 – Habit and habitat of feral *Erythroxylum coca* growing as a slender tree (man holding trunk of plant), Cerro San Cristóbal, Department Huánuco, Peru (*Plowman 5795*). Photograph by T. Plowman.

Figure 5 — Habitat of feral *Erythroxylum coca* growing as an understory shrub (man holding branch of plant), Tocache Nuevo, Department San Martín (*Plowman & Schunke 7535*). Photograph by T. Plowman.

important deterrent to the natural or human dispersal of the cultivated cocas to drier and less hospitable habitats.

Many minor morphological and chemical variants are found in *Erythroxylum coca* throughout the Peruvian and Bolivian Andes. Usually these cultivated forms are designated with local names and often represent environmentally induced variants, such as plants grown in the shade, on open, exposed ridges or in valley bottoms. Other variants appear to be genetic in origin, producing differences in habit, leaf size and shape, fruit size and shape and alkaloid content. This great variation reflects the long history of coca cultivation in a wide variety of microhabitats and in partial isolation in a large number of Andean valleys.

About twenty-five wild species of *Erythroxylum* also occur in the *montaña* zone, some of which are similar to and close relatives of *E. coca*. The Huallaga Valley in Peru is especially rich in species which occupy the same habitat as *E. coca* and often grow alongside the cultivated plants in adjacent woods. These wild species, like *E. coca*, are clearly well adapted to the wet, not excessively hot climate and well drained, iron-rich soils which characterize the *montaña*. In spite of their proximity, I have found no evidence of hybridization between *E. coca* and any of the wild species in the area.

A distinct form of *Erythroxylum coca* is cultivated on a small scale by several Indian tribes in the Amazon basin, in parts of Colombia, Peru and Brazil. This form differs from Andean *E. coca* in having a weak, spindly habit and thicker apically rounded leaves with a much lower cocaine content (Holmstedt et al. 1979, 1977). There are also differences in floral structure. In addition, this form of coca is prepared by a unique method: the leaves are first toasted to dryness over a fire and pulverized to a fine powder, to which are added the ashes of leaves of a species of *Cecropia* or *Pourouma* (Moraceae). This powder is then made into a quid with saliva and carried in the cheeks and gums, not unlike the Andean method (Holmstedt et al. 1979; Prance 1972; Schultes 1957; Spruce 1908; Spix & Martius 1831).

Figure 6 – Ripe fruits of *Erythroxylum coca* produced on cultivated plant grown under glass. Photograph by T. Plowman.

Some authors (Gutiérrez-Noriega & Von Hagen 1951, 1950) have stated that *Erythroxylum coca* arose in the Amazon jungles where indigenous tribes discovered its stimulating effects. They believe that the plants and the custom of coca chewing were later carried to the Andes. However, the converse opinion, first stated by Spix and Martius in 1831, seems a more likely explanation.

Compared to its montane counterpart, the Amazonian form of *E. coca* does not grow well in the tropical lowlands, possibly because of the poorly drained soils and intense heat. The plant is short lived, tends to become weak and diseased and is less productive in both amount of foliage produced and its cocaine content. It is common practice to propagate Amazon coca by cuttings rather than by seed, which is the usual practice in the *montaña*. As a result, entire plantings may result from a single clone, evidenced by the occurrence in any one planting of only one stylar form in this heterostylous species. Consequently, Amazon coca rarely produces viable seeds. Lastly, this form does not readily persist in competition with the secondary vegetation which grows up after a plantation is abandoned. It appears that this lowland form of *E. coca* is a specialized cultigen, derived originally from plants domesticated in the Andean foothills.

COLOMBIAN COCA: *ERYTHROXYLUM NOVOGRANATENSE*

The second cultivated species of coca, *Erythroxylum novogranatense*, was originally identified as *E. coca* (Bentley & Trimen 1880; Triana & Planchon 1862) and later described as a variety of *E. coca* (Morris 1889). It was first recognized as a distinct species by the German botanist Hieronymus in 1895. The species name "novogranatense" refers to the geographic origin of the plant, Nueva Grenada, the old colonial name for Colombia. This is the form of coca commonly grown in Colombia today and which formerly was widespread in parts of Central America and Venezuela. I will refer to this plant as "Colombian" coca to distinguish it from "Trujillo" coca, a closely related variety of *E. novogranatense* discussed later.

In pre-Columbian times *Erythroxylum novogranatense* was extensively cultivated throughout the Caribbean coast of northern South America, in adjacent parts of Central America and in the interior mountains of Colombia. One of the earliest descriptions of coca chewing was made by Amérigo Vespuccio in 1499 in the Paria Peninsula of Venezuela (Patiño 1967) and certainly refers to this species. Throughout the coast and the interior of Colombia, this plant was called *bayo* (sometimes written *jallo*). The name *coca* was not

Figure 7 – Plantation of *Erythroxylum coca* grown in the Amazon lowlands, Brillo Nuevo, Río Ampiyacu, Department Loreto, Peru (*Plowman, Schultes & Tovar 6750*). Photograph by R.E. Schultes.

known until the Spanish introduced it from Peru after the Conquest. The name *bayo* is still used for Colombian coca by tribes in the Sierra Nevada de Santa Marta. Several wild species of *Erythroxylum* growing along the north coast of South America are also called *bayo* today by the local inhabitants.

Although no archeological remains of Colombian coca are preserved, there is abundant evidence for the ancient use of coca in this part of South America. In the Muisca and Quimbaya cultures many gold artifacts have been recovered which represent coca chewing paraphernalia including lime pots, lime sticks and figurines of coca chewers. An excellent collection of these artifacts is housed at the Museo de Oro in Bogotá.

Ceramic coca toasting pans have been found in archeological sites of the Tairona culture which are almost identical to pans used today in the Sierra Nevada de Santa Marta (Reichel-Dolmatoff 1953). At San Agustín in southern Colombia, coca chewing is strongly suggested by the stylized cheek bulges depicted on several large stone anthropomorphic figures (Uscátegui 1954). San Agustín has long been an important center of coca production and distribution, and *E. novogranatense* is still commonly cultivated there despite government suppression.

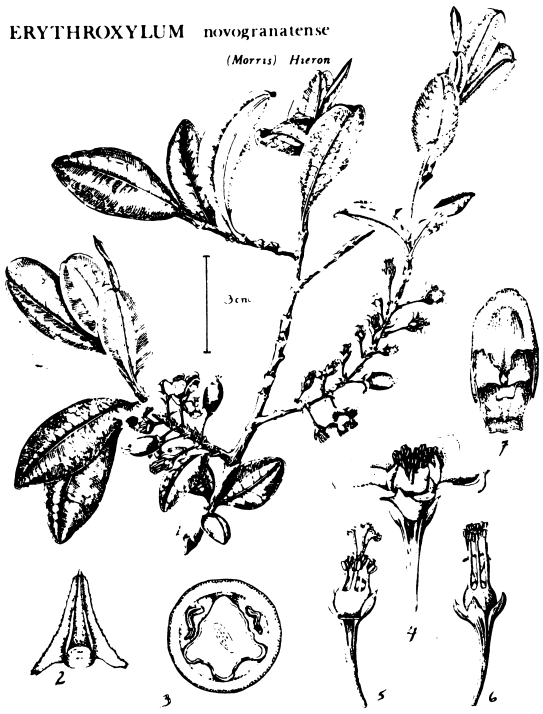


Figure 8 — *Erythroxylum novogranatense*, Colombian Coca. 1, branch with flowers and fruits; 2, stipule; 3, cross-section of fruit; 4, short-styled flower; 5, long-styled flower, petals and portion of calyx removed; 6, short-styled flower, petals removed; 7, petal, adaxial view showing appendage. Drawing by L.T. Bates.

At present, *E. novogranatense* is much restricted in its area of distribution. It is almost unknown in most of Venezuela and only occasionally cultivated as an ornamental in parts of Central America. In Colombia, plantations of *E. novogranatense* exist only in the Sierra Nevada de Santa Marta in the north, and in the rugged mountains of the Departments of Cauca and Huila. In these areas, coca chewing is still practiced by a number of Indian tribes which have managed to resist acculturation and assimilation by the Colombians. These tribes grow coca mostly in small plots for their own use.

In contrast to the situation in Peru and Bolivia, there is no open commerce in coca leaves in Colombia, since both the growing and chewing of coca is prohibited by the government. Since about 1970, an illicit cocaine business has developed in southern Colombia based on locally grown Colombian coca. A detailed account of many aspects of coca cultivation and use in this area, particularly among the Paez Indians, has recently been published (Antonil 1978). This excellent interdisciplinary study focuses on the current conflict between the traditional use of coca and commercial exploitation of the plant for cocaine.

Colombian coca has been widely cultivated throughout the Old World tropics since the end of the nineteenth century. It was distributed to botanical gardens and agricultural centers in many parts of the former British Empire for use in horticulture and in acclimatization trials. The first plants, of uncertain South American origin, were sent out from the Royal Botanic Gardens at Kew under the name "E. coca." This contributed appreciably to the confusion over the identity of cultivated coca plants. Descendants of these original plants are still grown as ornamentals in such far ranging places as India, Sri Lanka, Indonesia, Hong Kong, Jamaica and Zaïre, as well as in European and North American conservatories.

In Java, a profitable but relatively short-lived cocaine industry developed at the turn of the century based on *E. novogranatense*. Enterprising Dutch farmers using modern agricultural techniques were able to produce up to two percent total alkaloids in the dried leaves. This was the first attempt by Europeans to cultivate coca on a commercial scale, but the industry collapsed when the price of coca leaves rapidly declined in the 1920s (Payens 1958).

Erythroxylum novogranatense is similar in many ways to *E. coca* but usually can be distinguished by its smaller, narrower, thinner, bright yellowish-green leaves which are usually rounded at the apex. The general habit

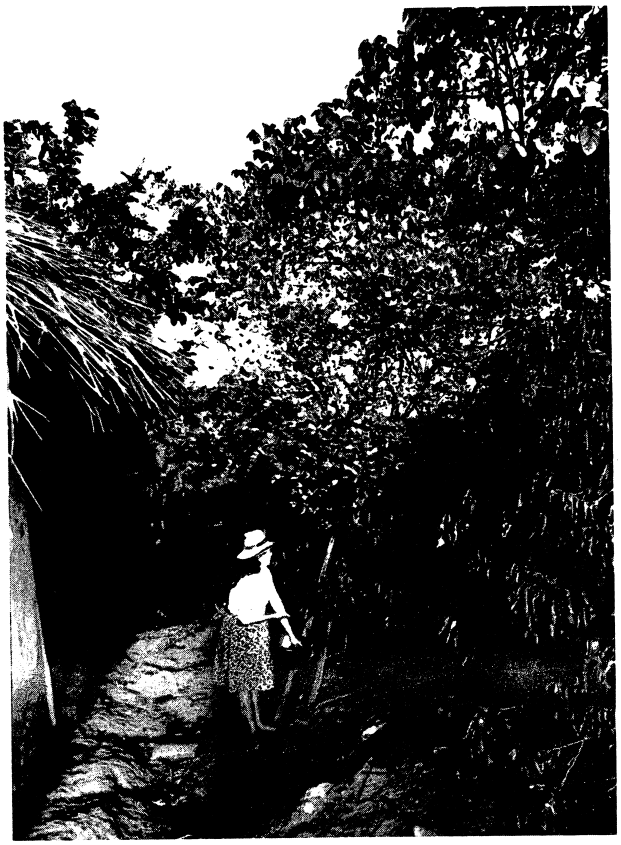


Figure 9 – Tree-like individual of Colombian Coca, *Erythroxylum novogranatense* cultivated as a dooryard plant near Neiva, Department Huila, Colombia (*Plowman & Davis 4152*). Photograph by T. Plowman.

of the plant also differs. In *E. coca* the leaves are usually deciduous after the current season's growth; *E. novogranatense* characteristically holds its leaves on the branches. This habit gives Colombian coca a larger, bushier, more robust appearance. As with most species of *Erythroxylum*, these two species can be positively identified only by considering a number of technical characters together, since no single morphological character is sufficiently diagnostic to separate them.

An important but overlooked difference between these two species lies in their ecological preferences. In contrast to *E. coca* which thrives in the moist, relatively cool climate of the *montaña*, *E. novogranatense* occurs naturally in hot, often seasonally dry habitats. These habitats are typically found in the upper Cauca and Magdalena river valleys of Colombia and all along the northern coast of South America. Colombian coca is very resistant to prolonged periods of drought, a feature which is highly regarded by local farmers (Antonil 1978).

Unlike *E. coca.*, *E. novogranatense* is not found in semi-wild or feral populations. Although scattered plants are found frequently throughout the mountains of Colombia, these are always near dwellings or former habitations. Coca is commonly grown in Colombia as an ornamental dooryard plant and for its medicinal value in treating stomach aches, toothaches and other ailments. But I have not found any plants which might be considered part of natural populations in forested areas. This does not preclude the possibility that *E. novogranatense* may once have formed part of the natural vegetation, but there is no present evidence for it.

Besides being tolerant of drought conditions, *E. novogranatense* adapts readily to a diversity of environmental conditions. This is affirmed by its successful cultivation in different soils and climatic areas in many tropical countries. It grows in both lowland and mountainous situations and even survives subtropical conditions at Miami, Florida.

In terms of alkaloid production, *E. novogranatense* is comparable to *E. coca* in showing considerable variation (Holmstedt et al. 1977). There may be consistent differences between these species in the minor alkaloids, but only very preliminary data are available (Espinel Ovalle & Guzmán Parra 1971; Hegnauer & Fikenscher 1960). *E. novogranatense* does differ markedly from *E. coca* in producing high amounts of methyl salicylate in the leaves (Hegnauer 1966, 1964; Reens 1919). This odor is readily noticed when the leaves of Colombian coca are dried. *E. coca*, on the other hand, has a uniquely different odor which has been variously described as "grassy," or like hay, China tea or even vanilla (Mortimer 1901). Wintergreen oil may also be a minor component of the odor of *E. coca* leaves but it is not detectable by smell. A modern survey of the volatile oils of all the cultivated cocas is much needed to clarify the distribution and taxonomic significance of these substances.

TRUJILLO COCA: *ERYTHROXYLUM NOVOGRANATENSE* VAR. *TRUXILLENSE*

One distinct variety is recognized within *Erythroxylum novogranatense*: var. *truxillense* (Rusby) Machado.[2] This plant is known in the trade as "Trujillo" coca, for the city of Trujillo in northern Peru from which it is exported. In the former pharmaceutical trade, this variety was also referred to as "Peruvian" coca, an obviously confusing term which should be avoided.

Trujillo coca was originally described by Rusby in 1900 as a distinct species, *E. truxillense*, when the

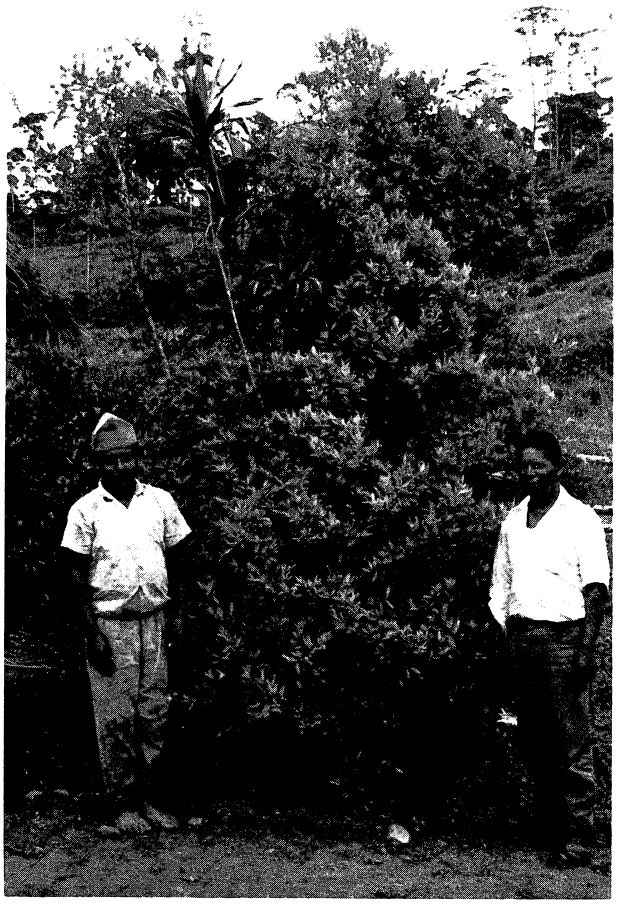
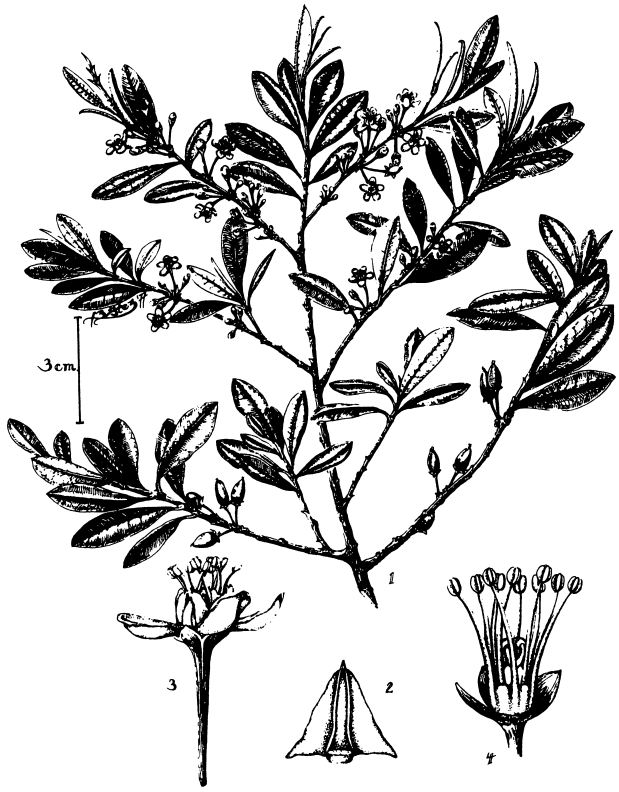


Figure 10 — Bushy habit of *Erythroxylum novogranatense* grown for medicinal purposes at Mocoa, Comisaría del Putumayo, Colombia (*Plowman 2020*). Photograph by T. Plowman.



ERYTHROXYLUM novogranatense *var.* truxillense *(Rusby) E. Machado*

Figure 11 — *Erythroxylum novogranatense* var. *truxillense* Trujillo Coca. 1, branch with flowers and fruits; 2, stipule; 3, short-styled flower; 4, short-styled flower, petals and portion of calyx removed. Drawing by L.T. Bates.

plant's identity was the object of some debate among pharmacognosists (Holmes 1910, 1901, 1892; Rusby 1901, 1900). Trujillo coca was much desired by the pharmaceutical industry because of its superior flavor and shipping properties. Several hundred tons a year are still exported from Trujillo to New York for preparation of extracts used in the manufacture of Coca-Cola®.

Today Trujillo coca is cultivated on the desert coast of Peru near Trujillo and in the adjacent Andean foothills. Numerous plantations also exist in the dry, upper Marañon valley which parallels the Peruvian coast. The latter is a very inaccessible area and little is known of the extent of coca cultivation there.

Before the Spanish conquest, Trujillo coca was cultivated on a large scale in many if not all the coastal valleys of Peru (Rostworowski 1973). All archeological coca leaves from coastal Peru that I have examined belong to this variety, including material from Vista Alegre in the Rimac Valley, from the Yauca Valley, from Nazca and from Arica in northernmost Chile. Earlier workers have identified archeological leaves as either *E. coca*, *E. novogranatense* or merely as *Erythroxylum* sp. (Cohen 1979; Towle 1961). Rochebrune (1879) recorded the presence of leaves of both *E. coca* and *E. rigidulum* DC. at Ancón. The latter name is a synonym of *E. carthagenense* Jacq., a species known only from the Caribbean coast of South America. This identification is therefore questionable, as noted earlier by Towle (1961). These identifications must be reconfirmed and all available samples of archeological coca should now be reexamined in light of better knowledge of the differences between the species.

The earliest specimens of archeological coca leaves consist of chewed quids recovered from the Ancón-Chillón region north of Lima, dated at ca. 1750 B.C. (Patterson 1971). Another early record comes from a

pre-Ceramic site at Asia, a town 125 km south of Lima. The site has been radiocarbon dated at 1314 B.C. (± 100). Both coca and gourd lime pots were found here by Engel (1963). Lanning (1967) suggested that coca from Asia was traded from the *montaña*, even though no other evidence of trans-Andean contact was found (Rostworowski 1973). Although leaves of *E. coca* imported from the *montaña* may turn up in coastal sites, it is more likely that these leaves pertain to Trujillo coca produced on the coast. Again, it will be necessary to study the original material.

Many later sites on the Peruvian coast have yielded coca leaves and fruits, as well as coca chewing paraphernalia. Ceramic representations of coca chewers are especially abundant in the Mochica culture which was centered near the modern city of Trujillo.

It is significant that in Incan times, two kinds of coca were distinguished in Peru. Rostworowski (1973) provides us with this important evidence from two early chroniclers, Marúa and González Holguín. *E. coca* from the Andes (*montaña*) was known as *mamox* coca (also written *mamosh, mamas* or *mumus*) and was recognized by its large leaves. A second kind of coca was called *tupa* coca (also written *ttupa* or *thupa*). This coca came from "los llanos," as the Peruvian coast was then known, and differed in its small leaves and better flavor. It was much esteemed and presumably used by the Inca royalty: the word "tupa" means "noble" in Quechua, the Incan language. There can be no doubt that *tupa* is Trujillo coca. Even today this name persists for the plant in the area around Trujillo (Ferreyra 1976).

Trujillo coca is morphologically similar to the Colombian variety of *E. novogranatense* (var. *novogranatense*). It differs slightly in both floral and vegetative characters, and shows considerable morphological variation in different parts of its range. Trujillo coca may be distinguished from Colombian coca in having smaller, narrower but slightly thicker leaves, which at maturity are a richer green in color. In habit, it is a large, much branched shrub similar to its Colombian counterpart.

Like Colombian coca and even to a greater extent,

Figure 12 – Plantation of Trujillo Coca, *Erythroxylum novogranatense* var. *truxillense*, showing the use of a leguminous shade tree, *Inga feuillei*, Simbal, Department La Libertad, Peru (*Plowman 5600*). Photograph by T. Plowman.

Trujillo coca shows tolerance to drought, which explains its successful cultivation under desert conditions. It always requires some irrigation from the rivers originating in the Andes, but it is reputed to withstand prolonged droughts better than any other crop on the coast.

That Trujillo coca is physiologically adapted to desert conditions is supported by evidence from transplant experiments. A Peruvian agronomist, Ing. Rodolfo Collantes (1976), made large plantings of Trujillo coca near Tingo María in the Peruvian *montaña*. Within a few years, these plants had all become weak and diseased and most of them died. Similarly, plants of *E. coca* planted near Trujillo and in Lima did not survive, even when well watered and protected from the intense sun.

Trujillo coca is never found growing outside of cultivation, since it depends upon at least some irrigation for continued survival in the desert. The seeds are particularly subject to death by desiccation. Special care must be taken to keep them moist and shaded in seedbeds for germination. Of all the cultivated cocas, Trujillo coca is most dependent on human intervention for its continuing existence and may be designated as a true cultigen.

ECUADOR: A MISSING LINK

E. coca and both varieties of *E. novogranatense* are presently allopatric in their distributions, that is, none occur together in the same areas. There is, therefore, no opportunity for natural hybridization to take place, although this may not have been true in the past. At present, Trujillo coca in the Marañon Valley grows in relatively close proximity to plantations of *E. coca* in the Huallaga Valley. They are isolated by the strong ecological differences between these areas and by high mountains which function as a barrier to gene exchange. However, there may be areas in the still largely unexplored region of northern Peru where intermediate habitats are found and where these two plants might co-exist. Hybrids between them would be expected in this area.

Ecuador, lying in the key position between Colombia and Peru, represents a conspicuous gap in the distribution of cultivated coca. We know that coca cultivation and coca chewing are very ancient in Ecuador where, as mentioned earlier, the oldest evidence of coca chewing has been found. Numerous artifacts documenting coca chewing have been discovered in several Ecuadorian archeological phases representing all three major developmental periods (Lathrap 1976; Drolet 1974; Naranjo 1974; Meggers 1966).

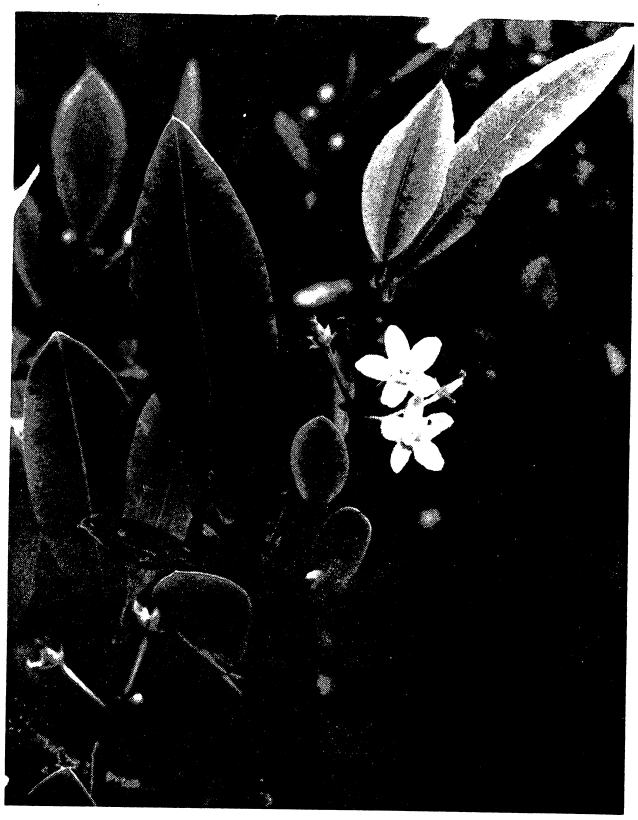


Figure 13 — *Erythroxylum novogranatense* var. *truxillense*, Trujillo Coca. Flowering branch of plant cultivated at Collambay, Department La Libertad, Peru (*Plowman 5606*). Photograph by T. Plowman.

The disappearance of the use of coca in Ecuador has still not been fully explained. Coca chewing persisted up until the colonial era, and its eradication apparently resulted from persecution of the habit by governmental and ecclesiastical officials who found no economic advantage in the plant as did their counterparts in Peru (León 1952).

It is likely that a diversity of coca varieties was once grown in this ecologically varied country, but most of these have probably become extinct. Specimens of *E. coca* have been collected at Sanagüín on the moist, western slopes of the Andes in Cañar Province. Coca cultivation apparently has a long history at this remote locality (Cordero 1911). No specimens of *E. coca* have been collected in the eastern *montaña* of Ecuador. An interesting form of *E. novogranatense* has recently been discovered in northwesternmost Ecuador along the Colombian border, where clandestine coca chewing continues among some Indian groups. To my knowledge,

no coca has been discovered or collected in any other parts of the country.

Presumably, both species of cultivated coca will be found in other parts of Ecuador upon further searching. It is possible that areas exist where both species now grow together and where they possibly hybridized in the past. Intensive field work is needed on both sides of the Ecuadorian Andes and in the arid regions along the coast in order to document what remnant populations might still exist. Such collections could provide the necessary data for unraveling the early history of coca in this important and centrally located country.

THE ORIGIN OF COCA

Although we still have very limited data on many aspects of coca and its use, I would like to offer some thoughts on the putative origins and early evolution of the plant. All the cultivated forms of coca are more closely related to each other than to any other species of *Erythroxylum*. This suggests that they arose from a common genetic stock. Their present differences have resulted from evolutionary divergence from the original precursor, influenced by artificial selection and gradual adaptation by humans to new environments and geographical areas.

Based on morphology, relationships to wild species, breeding systems and ecological parameters, *E. coca* may be considered the most primitive of the cultivated cocas. From this species, which still behaves like a wild plant, an early form of *E. novogranatense* could have been derived by human selection for chemical traits and for drought resistance in more xeric environments. *E. novogranatense* later diverged into two distinct varieties which are geographically and to some extent genetically isolated from each other today. Preliminary studies indicate that no changes in chromosome number have occurred during this process; all counts reported so far give a diploid number 2n = 24 (Plowman et al. 1978).

The following scenario outlines a hypothetical sequence of events for the discovery and domestication of coca. *E. coca* was first discovered as a wild plant in the *montaña* of the eastern Andes, possibly in eastern Peru, where it originally existed as small scattered populations, similar to the distribution of many wild species today.

After the invigorating effects of the leaf were discovered by early hunters and gatherers, people began to consume the leaves in ever-increasing amounts. Presumably only wild plants were harvested at first, but supplies in the wild became insufficient to meet growing needs, as knowledge of coca's medicinal and stimulating effects became more generally known. In early agricultural times, plants were probably transplanted from the wild nearer to habitations so that a constant supply of leaves would be available. Thus commenced coca's long history as a cultivated plant.

Simultaneously, the infrequent wild populations dwindled until they were virtually exterminated by over-exploitation. Subsequent planting of the seed insured continuation of the species in association with humans. Expansion of coca use and cultivation in new areas in the *montaña* could have taken place at this time. Some gene exchange was maintained between escaped and infrequent wild plants throughout the area of cultivation in the *montaña*, thus preventing complete domestication.

With the development of agriculture and broader cultural contacts among different groups of Andean peoples, coca was carried to new and varied environments. This resulted in the isolation and gradual differentiation of distinct forms, including an ancestral *E. novogranatense*, in drier habitats. This possibly occurred in northern Peru or southern Ecuador, through an intermediate similar to present day Trujillo coca. Colombian coca as we know it today may have developed somewhat later in partial isolation in the northern Andes in Colombia.

There is little evidence from archeology to support this scenario and it would be presumptuous even to suggest a time scale. Other interpretations are both possible and under consideration, especially as new information becomes available. Comprehensive interdisciplinary studies are now very much in order to correlate data and expertise from many scientific fields, including botany, phytochemistry, archeology, ethnology, ethnohistory, pharmacology, human physiology and others. Only through such a collaborative effort will the true history of coca be revealed.

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NOTES

1. There has been much disagreement among botanists concerning spelling of the generic name. See Plowman (1976) for a discussion of the orthography of *Erythroxylum*.

2. Both varieties of *E. novogranatense* have equal taxonomic status. For consistency, the Colombian variety may be written *E. novogranatense* var. *novogranatense* to distinguish it from var. *truxillense*. If the variety name is not written, the former is understood.

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