Erythroxylum coca Lam

Monograph - Agricultural Sciences

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Chapter 1: Introduction

Erythroxylum coca Lam is a plant that grows in the Andean region. It has been cultivated for thousands of years by native peoples because of its medicinal properties. However, when its narcotic properties were discovered, it began to become commercialized and traded as cocaine, one of the most popular drugs in the market. *Erythroxylum* coca Lam is a strong, resistant plant that grows anywhere between 300 and 2000 meters above sea level, and suffers from few pests and diseases. Although there is little research done on the life cycle, and other important sections of this plant, this monograph includes a considerable amount of information publicly available about it. Chapter two discusses the ecology of the plant, discussing its present distribution and its origin, its affinities and taxonomy, along with other topics that are relevant to understanding the plant as a whole. In Chapter three the biology of the plant is surveyed from its chromosome complement to its reproductive system and pollinators, understanding how this plant spreads. Chapter four encompases inforamation as to how to propagate it. Interestingly, for such an important plant there has been very little research conducted on this aspect of the plant, this might be because of the illicit narcotic component, which turns the plant into a taboo and might reduce the number of publications of how to plant it. The final chapter concludes by discussing the products and markets of the plant, it includes the uses that humans have given this plant, such as edible uses, medicinal uses, narcotic usage and its role in one of the biggest companies in the world, Coca-Cola.

Chapter 2: Ecology:

2.1: Distribution:

2.1.1: Affinities:

Erythroxylum coca Lam is one of the four species of *Erythroxylum* that exist in the world, having two direct variations, *Erythroxylum coca* Lam and *Erythroxylum coca* Lam Plowman also known as *Amazonian coca.* This species is from order Malpighiales, from class Magnoliopsida and division Tracheophyta (Integrated Taxonomic Information System, 2019).

In terms of taxonomy, it belongs to the genus *Erythroxylum* (figure 1 below), which has 230 members. Although very diverse, the members of this genus are tropical flowering seeding plants found all around the tropical zone (Islam, 2011). Although they are the most varied Neotropics, the cultivated members such as *Erythroxylum Coca* Lam*, Erythroxylum coca var. ipadu (Eci), Erythroxylum novogranatense var. novogranatense (Enn)* and some others, are highly similar (Emche, Zhang, Islam, Bailey, & Meinhardt, 2011). *Erythroxylum Coca* Lam has always been an important plant, ancestors used it for medical purposes, but when cocaine was invented, it started to get an even higher demand ("Coca—New World Encyclopedia," n.d.). The class to which *Erythroxylum coca* Lam belongs to is the *Magnoliopsida*, which is the class that covers all flowering plants. In the past, there used to be two types of classes for flowering plants, *Magnolipsida* and *Liliopsida*. *Magnoliopsida*, also known as *dicotyledoneae*, included all *dicotyledons*. *Dicotyledons* are all plants that carry two *cotyledons*, which are seed leaves. On the other hand, Liliopsida, or *Monocotyledoneae*, only embark plants that carry one *Cotyledon* ("Magnoliopsida," 1981).

2.1.2: Taxonomy:

Taxonomic Rank	**Name**	**Meaning**
Kingdom:	*Plantae*	Plantes, Planta, Vegetal, plants
Subkingdom:	*Viridiplantae*	Green plants
Infrakingdom:	*Streptophyta*	land plants
Superdivision:	*Embryophyta*	Plants that descend from algae, but with time adapted to life on earth
Division:	*Tracheophyta*	vascular plants, tracheophytes
Subdivision:	*Spermatophytina*	spermatophytes, seed plants, phanérogames
Class:	*Magnoliopsida*	Seed embryo has 2 cotyledons
Superorder:	*Rosanae*	Closed leaf margins
Order:	*Malpighiales*	Genetic structure
Family:	*Erythroxylaceae*	Trees or bushes with oval leaves and small flowers
Genus:	*Erythroxylum P. Br.*	coca
Species:	*Erythroxylum coca* Lam	coca

Figure 1|: Taxonomy of *Erythroxylum coca Lam* ("ITIS Standard Report Page: Erythroxylum," n.d.)

Direct Children: *Erythroxylum coca* var. coca Lam. – coca; *Erythroxylum coca* var. ipadu Plowman – Amazonian coca. ("ITIS Standard Report Page: Erythroxylum," n.d.)

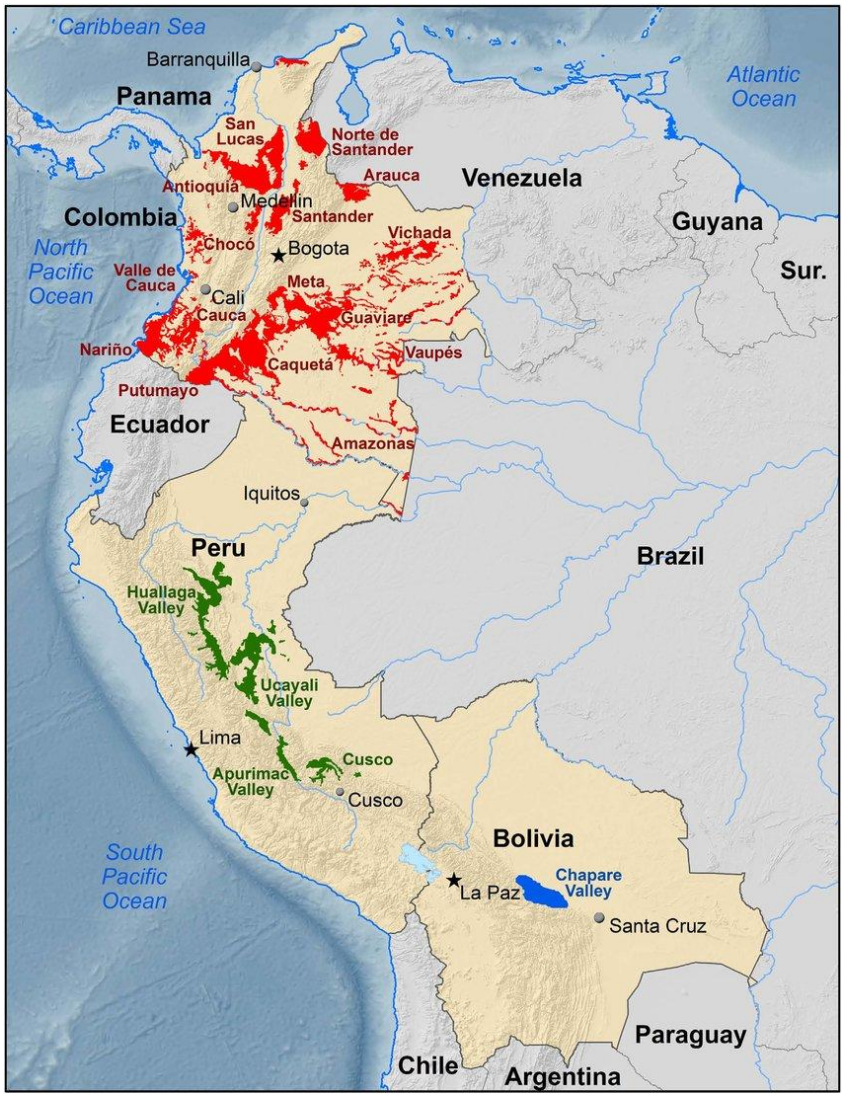
2.1.3: Fossil Record:

According to Islam (2011), there are no reliable fossil records of *Erythroxylum coca* .

2.1.4: Origin:

Erythroxylum coca Lam is a native plant of South America, Mexico, and the West Indies. It was originally used by the natives of the Andes Mountains and the Altiplano(South America), called Aymara. They were the ones to give *Erythroxylum Coca* Lam its original name, *Khoka*, which translates to the *tree*, and from which its species name *coca* came from (Biondich & Joslin, 2016).

Figure 2|: Origin of *Erythroxylum coca* Lam (Casale, n.d.)



2.1.5: Present Distribution:

The present distribution of *Erythroxylum coca* is not too different from its origin since Coca grows in the Amazonian region of Colombia, Chile, and Brazil, having its highest concentration all along the tropical Peruvian Andes, Ecuador, and Bolivia. Low concentrations are found in Mexico and the Western Indies, with it also being cultivated in Indonesia (Madeiros & Rahde, n.d.).

2.2: Environmental Factors in Distribution:

2.2.1: Elevation:

Erythroxylum coca grows best on higher levels of elevation due to its natural habitat in the Andes Mountains, where *E. coca* grows in the wild between the 300 and 2000 meters (Madeiros & Rahde, n.d.).

2.2.2: Climate:

The most appropriate environment for this plant is a temperature around 17 - 23°C with direct sunlight, and annual rainfall in the range 1,000 - 2,100mm (Lam, 2012). Although these are the optimal conditions for the plant's development, *E. coca* Lam is able to tolerate a rainfall between 700 - 4,000mm and a temperature between 14 - 27°c without major alterations in the plant's physiology (Lam, 2012).

2.2.3: Geology and Soils:

The best soil conditions for the plant include, well-drained, fertile soil with a pH between 5.5 - 6.5, nevertheless, the plant is capable of successfully growing with a pH between 4.3 - 8 (Lam, 2012).

Chapter 3: Biology

3.1: Chromosome Complement

Erythroxylum coca has two groups of 12 chromosomes, having a structure of 2n=24, and n=12 (Plowman et al., 1978).

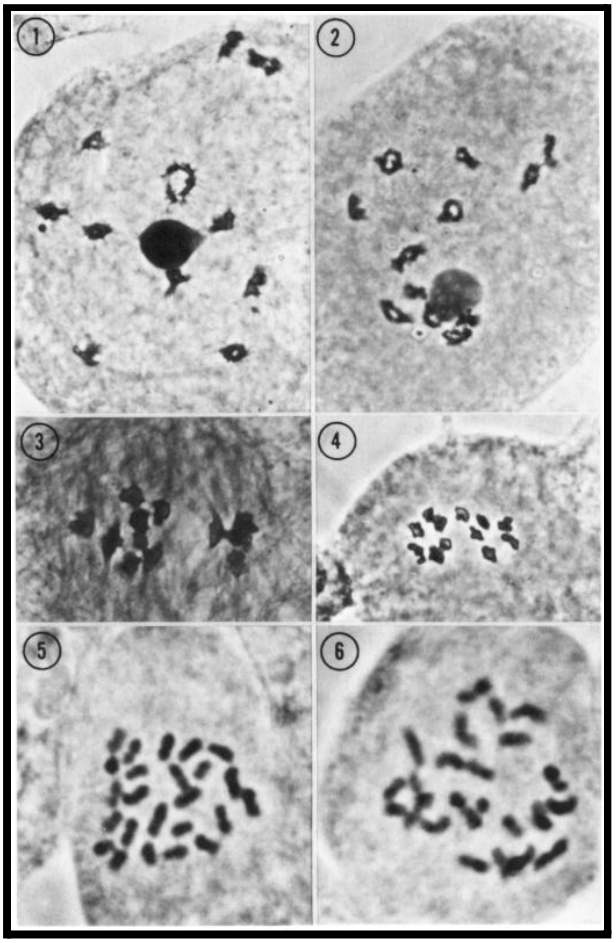


Figure 2: Chromosome division of Erythroxylum coca Lam *(Plowman et al., 1978).*

3.2: Life Cycles and Phenology

3.2.1: Life cycle:

After extensive research, no information was found on the life cycle of this plant.

3.2.2: Phenology

After extensive research, no information was found on the life cycle of this plant.

3.3: Reproductive Biology

3.3.1: Sexuality

Erythroxylum coca Lam utilizes its flowers for reproduction purposes. This plant produces white flowers, in which there are both male and female reproductive parts. The male reproductive component, the stamen, produces microspores, which with time morph into pollen which are full of gametophyte. The female reproductive part is made up of the stigma, style, and ovary, and it's known as the carpel. The gametophytes generate two sperm cells and a pollen tube, while the carpel produces the embryo sac (*E. coca Reproduction*, n.d.).

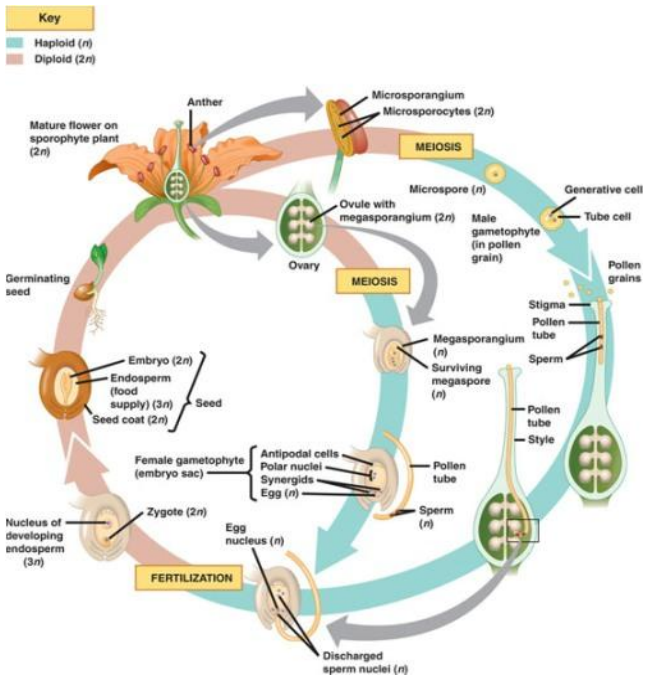


Figure 2: Reproduction cycle of coca, (*E. coca Reproduction*, n.d.)

3.3.2: Pollen

The plant is a distylous species (Ganders, 1979), which makes their flowers' structure vary in stamen length and style position. Therefore, *Erythroxylum coca Lam* produces pin flowers, where the stigma is found at the top to the flower with the anthers in the middle of the tube, and it produces trum flowers, in which the stigma is found halfway down the middle of the tube and the antherns at the top (Shailes, 2013). Pin flowers produce more pollen than thrum flowers, but the later mentioned flower's pollen is bigger in diameter (Ganders, 1979).

Figure 3: Diagram of pin-eyed flower

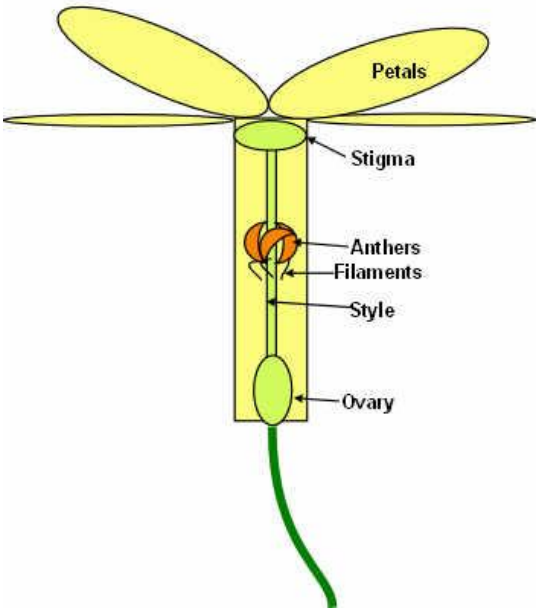
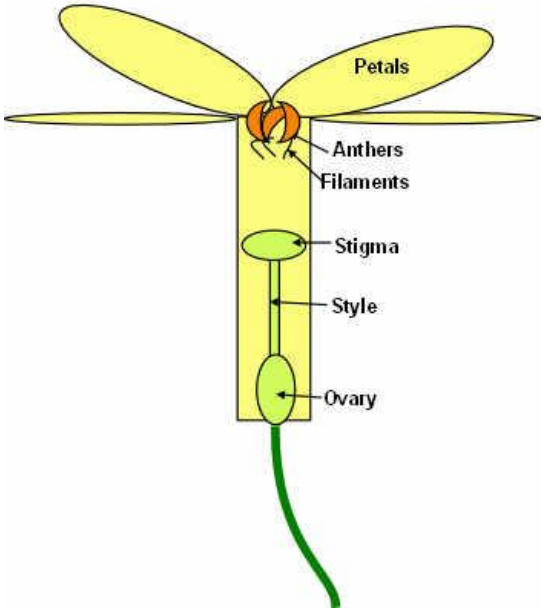


Figure 3: Diagram of thrum-eyed flower



(Devon County Council, n.d.).

3.3.3: Pollination and Potential Pollinators

According to Dora Lucila Troyano, an ecologist of the Agropecuary center of Cauca, no studies have been done about the pollination of this plant (Pers.Com. Troyano, 2020).

3.3.4: Fruit Development and Seed Set

Once the pollen found in the stamen is located in the stigma, the pollen tube starts to play its function. It begins to grow until it reaches the style, and finally discharges two sperm cells into the embryo sac when it is in contact with the ovary. One of the sperm cells forms a

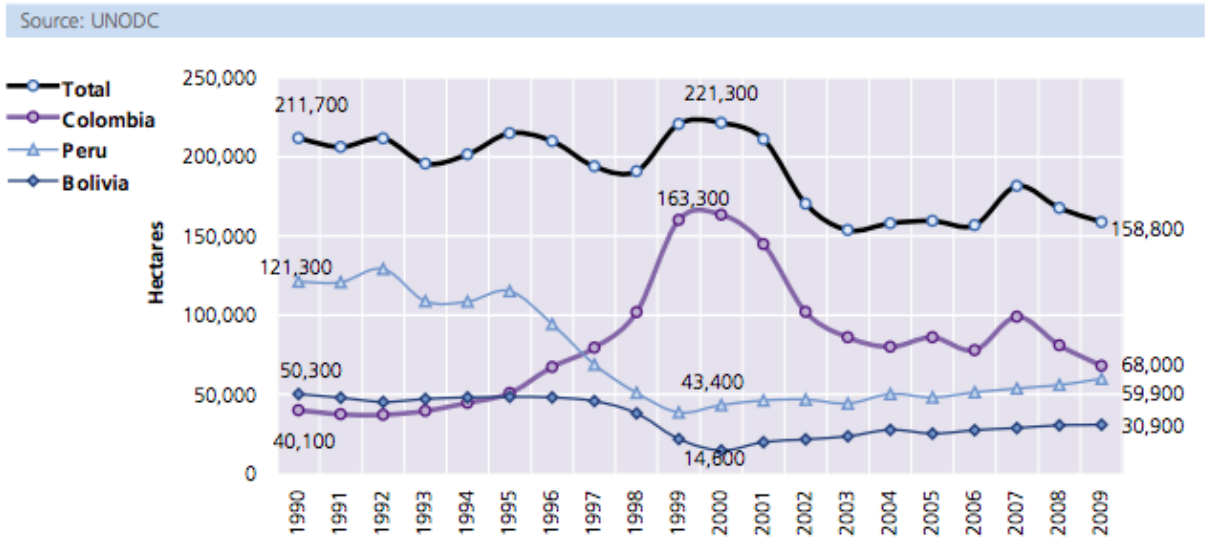
triploid cell and the other one fertilizes the egg, which will continue to form until it creates a seed with the embryo developing inside, surrounded by an endosperm and nutrients to enable the proper development of the plant. Meanwhile, the ovary is going through a similar process to form the fruit, which contains the seed (*E. coca Reproduction*, n.d.).

Chapter 4: Propagation and Management

4.1 Cultivation of *Erythroxylum coca*

In the cultures of the Andean Natives, women are in charge of collecting the small drupes when they are about to be ripe. They let the drupes sit for a few days until the fruit is soft, and then remove the pulp to let the seeds dry in the sun. After the seeds have dried out, they proceed to place them in seed beds and wait approximately 24 days till they germinate. It's very important that when the plant has four leaves, it's protected with lattice covering, to prevent any pests and diseases - which will be talked about later in chapter 4.1.4 - from harming the plant for a whole year. Once the plant reaches anywhere between 30-40 cm of height, it can be transplanted to adequate fields during the rainy season only (Rottman, 1997).

Figure 1: *Global Coca Bush cultivation 1990 - 2009 (1.3_The_globa_cocaine_market.Pdf).*



The biggest producers of coca, as seen in figure 1, are Bolivia, Peru and Colombia, even though it's an illicit crop.

4.2 Planting

Coca plantations have to be started from seed, as mentioned before in *Cultivation*, or from cuttings. Once they are big enough to get transferred to the fields, the spacing required is one plant per m^2, they don't need to get water since they only grow in climates with a lot of

rainfall in an altitude anywhere between 500 and 2,500 meters. The soil requires many minerals and nutrients such as humus, iron, and magnesium, which can be found directly in the soil or added through fertilizers if needed.

From the data of the article *Coca Growing Areas in South America: Substantial Room to Maneuver,* we can extrapolate how much a plant produces roughly. Assuming dry matter content of a leaf of about 20%. In the first three years a hectare produces about 33kilos of dry matter, and this occurs 4 times per year, giving about 132 kgs of coca leaf -dry. In the next years about 267kg per harvest and years 4-8, producing about 833kg per hectare which equals about 3332kg per hectare. Some have said that it can go up to as much as 5000kg per year per hectare, which would mean about 1222kg per harvest (Directorate of Intelligence, 1982).

4.3 Management

The first three years they will not produce any leaf harvest, and at the third year they may produce a small one. After this, they will start producing enough leaves to harvest four times a year, this harvests may round between 680kg to 910 kg of leaves for each acre/year. The plantation must be renewed every twenty years (Rottman, 1997).

4.4 Pests and Diseases

4.4.1 Organisms

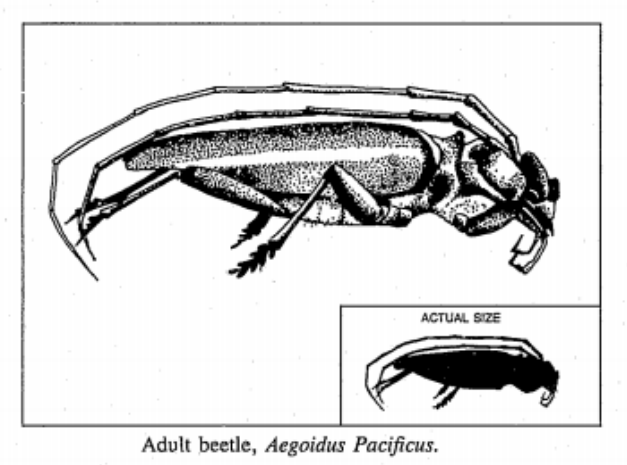
Although most insects that attack coca plants only do so when their food sources are scarce, the following two pests only feed from this plant during their earlier stages of life, but coca plants are the only thing they nourish from.

One of the main enemies of the coca plant is the larvae of the moth *Eloria noyesi*, since its food source is exclusively the *E. coca,* and its native to the same region of origin of the plant. The larvae take around 30 days to develop, and consume up to 50 leaves during this period of time, but this moth is only common from the months of December to April. Eloria Noyesi larvaes devour the coca plant without control, since after harvesting, they will also eat the

new leaves that are flourishing. This repetitive behaviour can be the cause of death of an otherwise perfectly healthy plant. (U.S. Department of Justice and Drug Enforcement Administration, 1991).

Figure 2: *Eloria Noyesi Moth (Actualidad RT 2017).*

Another pest that affects coca cultivation is the beetle *Aegoidus pacificus,* which causes the death of a plant because they lay their eggs on the bark of the plant. When the eggs hatch, the larvae begins burrowing down the stem, not only leaving the stem empty on the inside and weak, but causes a pathological fungus to take over and kill the plant (U.S. Department of Justice and Drug Enforcement Administration, 1991).



Adult beetle, *Aegoidus Pacificus.*

Figure 3: *Aegoidus pacificus Beetle (USDA,1991).*

Even though these two pests are a big threat to the plant, E. coca's biggest enemy are some pathological fungi, which apex during the rainy season. As mentioned before on Chapter

4.1.1, it is during the rainy season that the young plants are transplanted from the planting beds to fields, so their state of vulnerability is also at its highest since they aren't very strong. The most threatening fungus to coca plantations is known by the name *Witches broom*, but there is little information on the effects that this fungus has on the plant.

4.1.2 Pests and Disease Control

To eradicate this pest, coca farmers use various pesticides and manual methods. In many parts of Latin America, like in Peru, workers have to go on the fields and tear out the whole plant from the ground when they are infected. For efficiency and health reasons, workers were given machines fueled with gasoline, that mechanically chop off the plant and just leave the roots and a piece of the stem. The problem with this new method is that the stem can take up to one year and a half to rebloom, which lays back a lot the production of coca leaves (U.S. Department of Justice and Drug Enforcement Administration, 1991).

For herbicides as a solution to pests and fungi they have tested a lot, like hexazinone and tebuthiuron. These two chemical agents work against diseases and pests by killing the plant, preventing the propagation of the plague. It takes the right amount of product placed in the correct places of the plant so that in 10-20 days after the application, all the leaves fall out, and 60-90 days later, the whole plant will be dead. There is no way to kill the parasite affecting the plant without getting rid of the plant itself, even though the US has been trying to create more herbicides (U.S. Department of Justice and Drug Enforcement Administration, 1991).

Chapter 5: Emerging Products and Markets

5.1: Emerging products and potential markets

In a street of Bogotá D.C, Colombia, a little store is trying to revive the culture of coca leaves, bringing back all the positive qualities this plant has. The store is called “The Coca Embassy” and it's a small restaurant and health food store where the sacred plant is once again being used for the right reasons. This cafe does not only provide coca leaves to chew on or coca tea, but offers a menu of various dishes that are made from coca leaves and other traditional superfoods of the Andean natives such as quinoa and Matcha. The coca leaves get grinded into flour, which is the base ingredients of pastries, baked goods, and even beverages such as smoothies and juices (Malandra, 2017).

5.1.2: Erythroxylum Coca Lam Products:

Coca-Cola was originally a product that involved coca leaves developed in 1886, including the cocaine alkaloid, but the narcotic got removed from the formula shortly after in 1903 (Lewis, 2012). Up to this day, the soft drink gets its flavour from an abstract of the coca leaf, and it's the only legal import of coca leaves in the US, done by Stephan Laboratory in Maywood, MJ. As mentioned before, its narcotic properties are abstracted from the formula, but they don't go to waste, since they get sent off to Mallinckrodt Inc. for medicinal purposes. Mallinckrodt Inc. is the only pharmaceutical manufacturer in the US licensed to purify the cocaine alkaloids (May, 1988).

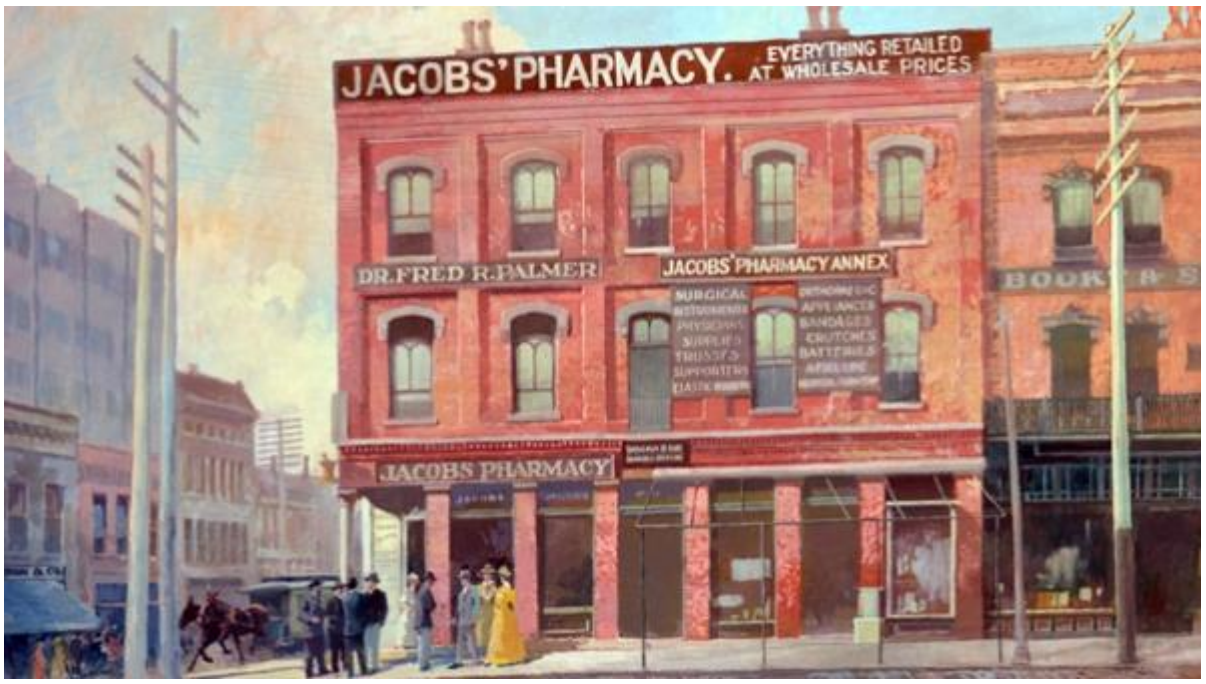


***Figure 1**: Jacobs' Pharmacy was the first place where Coca-Cola beverage was ever sold, on May 8th 1886 ("Coca-Cola History | The Coca-Cola Company")*

5.1.3: Medicinal Uses:

Erythroxylum coca Lam is a plant with various medicinal qualities that have been used for thousands of years by natives, and a few centuries ago started getting used by occidental cultures as well. They were not only used for treatments and antidotes, but for diagnosis too. Their properties mixed with the properties of other plants such as lime or plant ash get activated, and stimulate the central nervous system. This can help with easing pain, removing hunger, increasing stamina or physical endurance, and gives a feeling of strength and welfare. It was even used by the colonizers, who gave coca to the peasants so they would work harder and eat less, minoritizing the cost of their maintenance and increasing production of crops. (Minderovic, 2020).

In the present, coca is used to treat psychiatric symptoms like sleep problems generated by other pharmaceutical medicines on depressive patients. It's also an antidepressant, functions as an anti fatigue agent and coca tea is used as treatment on cocaine dependent patients to stop their addiction. It is the only known natural anesthetic, used for local anesthesia, discovered after 1859 when coca got purified for the first time (Ke 2013).

5.1.4. Edible and various uses

Coca plants have been used to produce cocaine for centuries. There are around 200 coca species, but only 17 can be used to produce cocaine, and out of the 17 species, 15 produce very low levels of cocaine alkaloids, making them sufficient for the business, which are the Erythroxylum coca Species and the Erythroxylum novogranatense Species (U.S. Department of Justice & Drug Enforcement Administration, 1991). On the opposite of E. coca's virtues, humanity has been capable of turning this plant's properties into one of the strongest drugs on the market: cocaine. The alkaloids were first isolated in 1859 by Angelo Mariani, who developed a coca drink called "Vin Mariani". It became a recognized drink, used as an anesthetic, that even Sigmon Freud wrote about it.

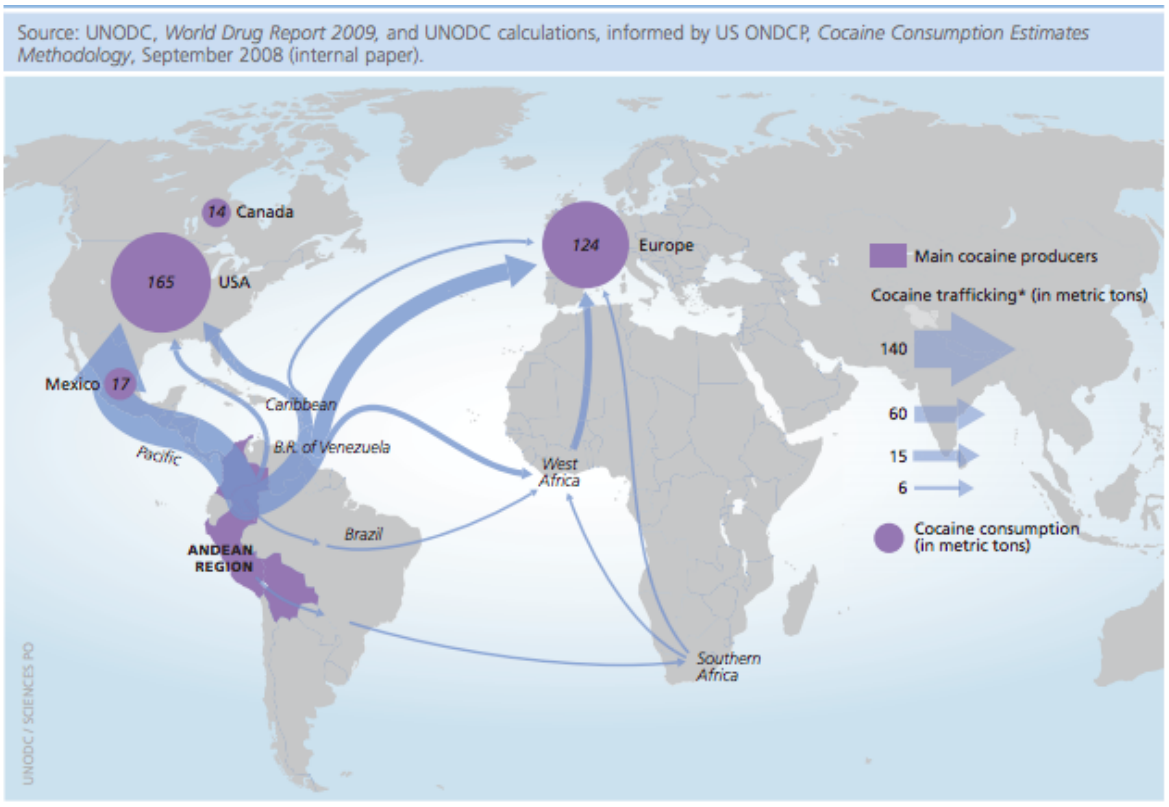
The plant is also used to chew on their leaves, as many native Americans have been doing this for thousands of years. Coca leaf chewing is used differently for many communities, for example, the Incas in Peru considered only the privileged classes, chieftains, and priests, since it was a sacred plant. For this culture, and more, like the Tayrona in Colombia, Coca is the connection between the spiritual world and the physical world. This is why chieftains chew on the leaves while performing sacred ceremonies or rituals and fortune telling. They were even used in funerals, as those who died got buried with coca leaves to help them in their journey. Natives also used it for medical purposes, as mentioned earlier in this chapter (Minderovic, 2020).

Figure 2: *Incas during a sacred ritual (Norma, 2011).*

5.2: Imports and exports

As mentioned previously on Chapter 4, the 3 countries that cultivate the coca plant the most are Peru, Bolivia and Colombia. When the illegal groups have already harvested the fields, they send the majority of the leaves to Colombia, where the cocaine labs are located to create coca paste in the clandestine labs known as “kitchens”. It is this coca paste that then gets dried and processed into cocaine powder, and shipped off illegally to the US and other countries in Europe, as seen on *Map 1: Main Global cocaine flows*. Even though Colombia was the one with fewer hectares of coca fields out of the 3 countries, the roles switched, making Colombia have 67% of the crops (Mejía & Posada, 2007).

The biggest consumers are the United states, where cocaine is the second most consumed illegal drug after marihuana; and Europe, where it's the third most consumed illegal drug after marihuana and Heroin. None of the countries in these regions are big producers of cocaine, making them the biggest buyers of cocaine imports, and increasing the demand of cocaine (Mejía & Posada, 2007).



Map 1: *Main Global cocaine flows, 2008*

Monograph: *Erythroxylum coca* Lam

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