Origin, Domestication and Evolution of Cotton, Tobacco and Sugarcane

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ABSTRACT

Cotton, tobacco and sugarcane are among the most economically important industrial crops that have undergone extensive domestication and evolutionary diversification across tropical and subtropical regions of the world. The genus *Gossypium* (cotton) includes about 50 species, of which four—*G. hirsutum*, *G. barbadense*, *G. arboreum* and *G. herbaceum* are cultivated. Cotton was independently domesticated in both the Old and New Worlds, with tetraploid species evolving through allopolyploidy between A- and D-genome progenitors. Tobacco (*Nicotiana* spp.), represented mainly by *N. tabacum* and *N. rustica*, originated in South America, with *N. tabacum* evolving through hybridization between *N. sylvestris* and *N. tomentosiformis*. The crop spread globally through early human trade and colonization. Sugarcane (*Saccharum* spp.), belonging to the Poaceae family, originated in the Indonesia–New Guinea region and was later hybridized with wild species to enhance yield and adaptability. Modern commercial cultivars are complex interspecific hybrids, primarily derived from crosses between *S. officinarum* and *S. spontaneum*. Collectively, these crops illustrate how natural evolution, polyploidy and human selection have shaped their domestication histories and global agricultural importance.

INTRODUCTION

Cotton

Cotton, which is taxonomically described under the order Malvales, family Malvaceae, series Hibiscae and the genus *Gossypium.* Genus *Gossypium* occurs naturally throughout tropical and subtropical areas and includes about 50 species divided between two ploidy levels, diploid (2n = 2x = 26) and tetraploid (2n = 4x = 52). Of the 50 *Gossypium* species, two tetraploids *viz., Gossypium hirsutum* and *Gossypium barbadense* and two diploids namely *Gossypium arboreum* and *Gossypium herbaceum* are cultivated. Tetraploids cover more than 80% of the world's cotton area. In Asia and the Middle East, however, diploid cottons are grown. *G.hirsutum* is the major cultivated cotton species in the world. Globally, 90% area is covered by *G.hirsutum*, followed by *G. barbadense* (8%); *G. arboreum* and *G. herbaceum* occupy rest of the area. In India, All the four cultivated species are grown (Yuan and Wendel, 2010).

❖ FOUR TYPES COTTON GROWEN ALL OVER THE WORLD

- *Gossypium hirsutum* – 2n = 4x = 52, (American/upland cotton)
- *Gossypium barbadense* – 2n = 4x = 52, known as extra-long staple cotton (Egyptian/Sea Island/Tanguish/Quality cotton)
- *Gossypium arboreum* – 2n = 2x = 26, tree cotton
- *Gossypium herbaceum* – 2n = 2x = 26, Levant cotton

❖ Origin:

- The genus Gossypium, commonly known as cotton, consists of around 50 species, most of which are native to tropical and subtropical regions.
- The primary center of origin of cotton is believed to be the region encompassing modern-day Mexico and northern South America.
- The multiple wild species of cotton, collectively known as New World cotton, can be found.
- These wild cotton species have been used by indigenous cultures for thousands of years.

❖ DOMESTICATION

- Cotton is one of the earliest domesticated non-food crops, independently domesticated at least four different times in four different parts of the world. The first cotton domesticate was from the wild tree form in Pakistan or Madagascar at least 6,000 years ago; the next oldest was domesticated in Mexico about 5,000 years ago.

▪ Old World Cotton

- Cotton was first domesticated in the Old World about 7,000 years ago.
- The earliest archaeological evidence for cotton use is from the Neolithic occupation, in the Kachi Plain of Balochistan and Pakistan in the sixth millennium BC.
- Cultivation of *G. arboreum* began in the Indus Valley of India and Pakistan and then eventually spread over Africa and Asia.
- Whereas *G. herbaceum* was first cultivated in Arabia and Syria.
- The two main species, *G. arboreum* and *G. herbaceum,* are genetically very different

and probably diverged well before domestication.

- Specialists agree that the wild progenitor of *G. herbaceum* was an African species, whereas, the ancestor of *G. arboreum* is still unknown.
- Regions of the possible origin of the *G. arboreum* wild progenitor are likely Madagascar or the Indus Valley.

- ***Gossypium arboreum***

- Abundant archaeological evidence exists for the initial domestication and use of *G. arboreum* by the Harappan (*aka* Indus Valley) civilization in Pakistan.
- The earliest agricultural villages in the Indus Valley, holds multiple lines of evidence of cotton seeds and fibers beginning about 6000 BP.

- ***Gossypium herbaceum***

- *G. herbaceum* is much less well-known than *G. arboreum*.
- Traditionally it is known to grow in African open forests and grasslands.
- Characteristics of its wild species are a taller plant, compared to the domesticated shrubs, smaller fruit and thicker seed coats. Unfortunately, no clear domesticated remains of *G. herbaceum* have been recovered from archaeological contexts.
- However, the distribution of its closest wild progenitor suggests a northward distribution toward North Africa and the Near East.

- **New World Cotton**

- Among the American species, *G. hirsutum* was apparently cultivated first in Mexico and *G. barbadense* later in Peru.

- ***Gossypium hirsutum*** (Upland Cotton)

- The oldest evidence of *Gossypium hirsutum* in Mesoamerica comes from the Tehuacan valley and has been dated between 3400 and 2300 BC.

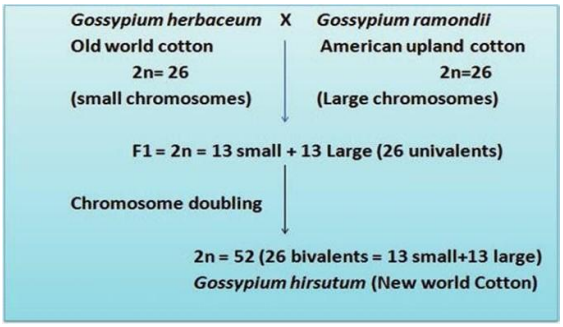
- ***Gossypium barbadense*** **(Pima Cotton)**

- *G. barbadense* cultivars are known for their production of high-quality fiber and called variously Pima, Egyptian or Sea Island cotton.
- The first clear evidence of domesticated Pima cotton comes from the Ancon-Chillon area of the central coast of Peru.
- The sites in this area show the domestication process began during the Preceramic period beginning about 2500 BC.
- By 1000 BC the size and shape of Peruvian cotton bolls were indistinguishable from today's modern cultivars of *G. barbadense*.

❖ EVOLUTION OF COTTON

- Classic cytogenetic investigations demonstrated that the American tetraploid species are allopolyploids containing two resident genomes, an A-genome from Africa or Asia, and D-genome similar to those found in the American diploids.
- That of polyploid parentage, it is now clear that both extant A-genome species

(*G. arboreum, G. herbaceum*) are equally divergent from the A-genome of allopolyploid cottons and that the closest living relative of the progenitor D-genome donor is *G. raimondii* (Wendel JF and Grover, 2015)



Tobacco

The tobacco is germinated in cold frames or hotbeds and then transplanted to the field until it matures. It is grown in warm climates with rich, well-drained soil. About 4.2 million hectares of tobacco were under cultivation worldwide in 2000, yielding over seven million tonnes of tobacco. In India, tobacco is grown on 0.45 M ha of area (accounting for only 0.31% of net cultivated area in the country) with 750 M kg production. The world tobacco production is ~7 billion kg, China occupying the first place with 2.35 billion kg. There are ten distinct tobacco types grown in 15 states of the country which include cigarette (FCV, burley, Oriental) and non-cigarette types (Bidi, chewing, hookah, natu, cheroot, cigar and HDBRG). India stands second in tobacco production and exports in the world.

❖ **Origin**

➢ Tobacco was first used around 5000 to 3000 years ago.

➢ The native peoples of Mesoamerica and South America discovered tobacco where it was first grown.

➢ The two species that were domesticated and that historically represent the majority of consumption worldwide.

➢ These are *Nicotiana rustica* and *Nicotiana tabacum*.

❖ **Domestication And Evolution**

- A group of recent biogeographical studies reports that modern tobacco (*N. tabacum*) originated in the highland Andes, probably Bolivia or northern Argentina
- It was likely a result of the hybridization of two older species, *N. sylvestris* and a member of the section Tomentosae, perhaps *N. tomentosiformis* Goodspeed.
- Due to Spanish colonization, tobacco had been distributed well outside its origins, throughout South America, into Mesoamerica and reaching the Eastern Woodlands of North America
- *Nicotiana tabacum* is a classic amphidiploid that likely arose on the eastern slopes of the Andes Mountains in Bolivia or northern Argentina by union of two unreduced gametes, or by chance hybridization between two 2n=24 progenitor species followed by chromosome doubling.
- The amphidiploid species has two cytologically distinct parental genomes, the S- genome and the T-genome.
- Molecular and biochemical evidence suggests that *N. sylvestris* was the maternal parent and contributed the S-genome as well as the cytoplasm to the original interspecific hybrid.
- The most, likely *N. tomentosiformis* provided evidence that the T-genome of *N. tabacum* is derived from a particular

lineage of *N. tomentosiformis*. (Goodspeed, 1954)

Sugarcane

Sugarcanes belong to the grass family, Poaceae, an economically important flowering plant family that includes maize, wheat, rice, and sorghum, and many forage crops. It is native to the warm temperate and tropical regions of India, Southeast Asia, and New Guinea. Grown in tropical and subtropical regions, sugarcane is the world's largest crop by production quantity, totaling 1.9 billion tonnes in 2020, with Brazil accounting for 40% of the world total. Sugarcane accounts for 79% of sugar produced globally (most of the rest is made from sugar beets). About 70% of the sugar produced comes from *Saccharum officinarum* and its hybrids. All sugarcane species can interbreed, and the major commercial cultivars are complex hybrids.

❖ **Classification and Nomenclature**

- Sugarcane belongs to the genus Saccharum traditionally placed in the tribe Andropogoneae of the grass family (Poaceae). This tribe also includes tropical and subtropical grasses and the cereal genera Sorghum and Zea (known as maize or corn).
- The taxonomy and phylogeny of sugarcane is complicated as plants from five genera share common characteristics and form a closely related interbreeding group known as the "Saccharum complex".
- The Saccharum complex comprises Saccharum, Erianthus section Ripidium, Miscanthus section Diandra, Narenga and Sclerostachya.
- The genus Saccharum traditionally comprises six species: *S. spontaneum, S. officinarum, S. robustum, S. edule, S. barberi* and *S. sinense*. (D'Hont *et al.*, 1996).

Table 2.1. **Members of genus *Saccharum***

Species	Description	Sugar content	Chromosome number
S. spontaneum L.	Wild species	Very low-low	2n=40-128
S. robustum Brandes and Jeswiet ex Grassl	Wild species	Very low	2n=60-200
S. officinarum L.	Noble canes	High	2n=80
S. barberi Jeswiet	Ancient hybrid	Low	2n=111-120
S. sinense Roxb.	Ancient hybrid	Low	2n=80-124
S. edule Hassk.	Cultivated species	Low. Compacted inflorescence, eaten as a vegetable	2n=60-80 with aneuploid forms

Source: Buzacott (1965); Daniels and Roach (1987).

Origin and Domestication

- The centre of origin of *S. officinarum* is thought to be in the Indonesia/New Guinea area, where it has been grown as a garden crop since 8000 B.C.
- It has been proposed that *S. officinarum* evolved from the selection of sweet forms of *S. robustum*.
- Its cultivation spread along the human migration routes to South East Asia, India and the Pacific, hybridizing with wild canes. It reached the Mediterranean around 500 B.C.
- From there it spread to Morocco, Egypt, Syrian Arab Republic, Crete and Greece.
- It is thought to have reached Australia in 1788 on the First Fleet and it was reintroduced in 1817 from Tahiti.
- The centre of diversity of *S. officinarum* is thought to be in Papua New Guinea, a view supported more recently by amplified fragment length polymorphism (AFLP) marker analysis.
- *S. spontaneum* is believed to have evolved in Southern Asia.
- It accumulates little sucrose content and has thinner stalks and higher fibre content than *S. officinarum*.

- *Saccharum spontaneum* is an adaptable species and grows across three geographical zones. These are:

1) The east zone which is Burma, China, Japan, Malaysia, the Philippines, Chinese Taipei, Thailand, Vietnam and the South Pacific Islands.

2) The central zone which includes Afghanistan, Bangladesh, India, the Islamic Republic of Iran, Nepal, Pakistan, Sri Lanka and the Middle East.

3) The west zone which includes Egypt, Kenya, Sudan, the United Republic of Tanzania, Uganda and other countries in the Mediterranean.

➢ Sugarcane is grown in over 100 countries on all continents worldwide between latitudes 30°N and 30°S.

➢ Cultivated noble canes spread from India to the Middle East, Mediterranean and to the New World in 1493

➢ in the Caribbean in 1789 (Aitken *et al.,* 2006).

❖ **Evolution of Sugarcane**

➢ Modern commercial hybrid cultivars of sugarcane are mainly descended from interspecific hybridization between *S. officinarum* and *S. spontaneum*.

➢ The basic breeding concept involved the combination of vigorous growth, ratooning ability and tolerance to abiotic stresses and disease resistance from *S. spontaneum* and high sucrose content from *S. officinarum*.

➢ This interspecific hybridization has increased the geographic range of economic sugarcane production (Wu *et al.,* 2014)

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