GROWTH AND PRODUCTION OF SUGARCANE

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Contents

Summary

Sugar cane is a perennial grass that thrives well in tropical and frost-free warm temperate areas. It requires high temperatures, plenty of sunlight, large quantities of water (at least 1500 mm of rain per year unless grown with irrigation), fertile soils, and good drainage. The crop cycle varies between 10 and 24 months, but can be extended four times or more by additional ratoon cropping. Cane is harvested after 12 to 18 months for most plant crops, after 12 months for ratoon crops. In modern, fully mechanized cultivation areas, as is the case in the US and Australia, the growing period may be considerably shorter, with plant cane harvested 9 months after spring emergence, and 7-8 months for ratoon crops. Harvesting is generally done in the dry period and when the stalks contain the maximum amount of sucrose.

Sugar cane is a Gramineae, tribe Andropogenae which contains 6 species. The currently cultivated crop (*Saccharum spp.*) is an inter-hybrid cane with high sugar content. Propagation is mainly in a vegetative way with 30-40 cm-long fresh cuttings. Average yields are around 90-100 tons/ha for the first planting, and between 40 and 60 tons/ha for the ratoon crops. Smallholders' plantations yield on average 15-20% lower. Fully-mechanized crops in the US (Hawaiï, Louisiana) and Australia may yield up to 200 tons/ha.

Sugar cane provides the cheapest form of energy food with the lowest unit of land area per unit of energy produced. The crop was originally used for chewing, but is now almost exclusively grown for the production of sugar as a food sweetener or for the production of ethanol for motor fuel. Most of the manufacturing process for extracting the sucrose from the cane is done at or nearby the plantation. Only the final refining of the sugar takes place in the importing countries.

1. Introduction

Sugar cane (*Saccharum spp.*) is a perennial grass and one of the few plants which stores its carbohydrate reserves as sucrose. Its economic value lies in the stalks, and the sugar/sucrose they contain after crushing. Sugar cane supplies more than half of the world's sugar consumption. In Brazil, it is moreover a major component of biofuel. Other plants producing sucrose are: sugar beet, sugar maple, sorghum and a few palms. Cane and beet sugar are indistinguishable in terms of composition and quality, and thus serve to supplement each other. In other words, the source of the crop is of little importance as long as the final product is near pure sucrose.

Sugar cane is currently grown on estates and by smallholders. The establishment of a nucleus estate around the sugar mill is both to compensate for the short-term fluctuations in the cane supply to the mill, and to be assured that freshly-cut cane can be rapidly processed. To be economically viable such an estate should constitute a more or less uniform block of 3,000 to 4,000 ha. Smallholders cultivate however smaller fields and either deliver the cane to the factories on the estates (outgrowers) or process their cane themselves into brown sugar (gur or jaggery).

Traditionally, sugar cane was grown in developing countries where much unskilled labor was available for harvesting. When the crop extended into industrial countries field preparation and harvest were gradually mechanized. In the US the sugar cane industry varies between production areas. In Louisiana individual owners produce cane for the local mills, and farms range from 200 to 2000 ha in size. In Florida, most of the cane is produced by large companies, although some is also produced by individual growers. In Brazil, the mill size varies greatly, with some individual mills having a capacity to threat the yield of 75,000 ha or more.

Sugar cane originates from New Guinea and the South Pacific, where it was mainly used for chewing. From there it progressed westwards, especially under the form of the hybrids *Saccharum sinense* (in China) and *S. barberi* (in India). During the conquest of India by Alexander's army in 326 BC sugar from cane was reported as "honey produced from reeds". By 500 BC *S. barberi* had reached Persia and the Mediterranean region, where it took its mark as a source of sugar and food sweetener in Syria, Cyprus, Crete, Sicily, etc. The Arabs introduced it in AD 641 in Egypt, in Morocco and in Spain (introduced in AD 714), and by AD 1150 there were 30,000 ha of sugar cane under cultivation in Spain**.**

In the 15th century the Portuguese brought canes to Madeira and subsequently to the Canaries and Western Africa. Columbus took them in 1493 to Hispaniola (where they first disappeared) and a second time in 1506. The first West Indian sugar was made in Hispaniola, now Haiti and the Dominican Republic, in 1509. The crop was later taken to Mexico in 1520, Brazil in 1532, Peru in 1533. In the US, sugar cane cultivation did not become established until the 18th century. Its development is closely linked to the introduction of slave labor.

For more than two centuries only one variety, *S. barberi* (Cana Criolla) was grown in the New World. Towards the end of the 19th century it was replaced in Brazil by *S. sinense*, which was hardier and more resistant to several diseases. *S. sinense* was then introduced into Mauritius and into Natal in 1882.

The present day sugar cane varieties have been the subject of many improvements. The original *S. spontaneum* and S. *robustum* were rapidly replaced by *S. barberi* and *S. sinense* (see above), but were themselves ousted later by *S. officinarum* or *noble cane*. The latter is the result of numerous intra-specific and inter-specific crosses, and is characterized by a good productivity and high sucrose (or saccharose) content, and a low proportion of fiber. The term *nobilization* has been coined to describe this process of improvement.

The evolution described above was to a large extent driven by different uses of the plant. Originally, sugar cane was grown solely for chewing, mainly in the Pacific and Southeast Asia. Thick noble canes which are relatively soft with a higher sugar and juice content and low fiber are the best for chewing. Over time, cane became a source for sweetening food. The production of sugar by boiling the juice was first discovered in India, probably in the first millennium BC, where the preparation of sugar from palms was already known. This form of raw sugar is known as *gur* in India, *jaggery* in Africa, or *panela* in Latin America. Raw sugar made in the producing countries is now often refined in importing countries by washing and removing the last traces of impurities. The end product is a fine, almost pure white sugar.

Since the Middle Ages sugar from cane has largely replaced honey as a sweetener. At the beginning it was considered a luxury and costly product. With the development of the sugar industry in the 18^{th} century in the New World sugar became much more plentiful and cheaper worldwide.

2. Botany

2.1. Cultivars and Classification

Sugar cane (*Saccharum spp.*) is a monocotyledonous perennial belonging to the family of Poaceae or Gramineae, tribe Andropogenae. The plant can be cut 10 times or more in succession depending upon the fertility of the site and the care with which its growth is managed. Two to three weeks after harvesting the stumps shoot again, producing the *ratoon crop*. The cycle in between two successive plantings may last up to 4 years in highly intensive, mechanized cropping, or 10-12 years in more extensive agriculture or smallholder farming. The first vegetation produced after planting is called *virgin cane* (or *primary stalks*).

The tribe Andropogenae contains 6 species:

- *Saccharum spontaneum* is a wild form of cane occurring from East Asia to North Africa through the Middle East, India, China, Taiwan and Malaysia up to the Pacific. It is rather disease-resistant and is still used for breeding commercial hybrids. Natural hybridization with *S. officinarum* has produced *S. barberi* and *S. sinense*.
- *Saccharum robustum*, another wild species, is indigenous in New Guinea and Melanesia. It is renowned for its excellent vigor and hardiness, forms dense cane-breaks up to 10m high along river banks, and is sometimes used for fencing. *S. robustum* probably gave rise to *S. officinarum*, with which it is inter-fertile.
- *Saccharum edule* is a sterile form of *S. robustum*; it is a food crop in Melanesia and is appreciated for its flowers.
- *Saccharum barberi*, containing a series of hybrids, is mainly found in India and other subtropical and warm-temperate climates. Stalks are short, medium to slender in thickness, with high fiber and medium sucrose contents. Because of its rather poor yields it is no longer cultivated.
- *Saccharum sinense*, another hybrid, is indigenous to Canton, Indo-China, Taiwan, Southern India, Bihar and Bengal. Clones are tall, hardy and vigorous, with a wide adaptability and early maturity, high fiber content, and poor juice quality. *S. sinense* is thought to be a hybrid between *S. officinarum* and *S. spontaneum*. It is resistant to mosaic disease, but susceptible to red rot and streak (see below: Pests and Diseases). It is no longer cultivated.
- The cultivar *Uba*, is a commercially grown *S. sinense* variety in Brazil (late 1860s), Mauritius (1869), Natal, South Africa and India (1882) after the cultivar *Otaheite* was attacked by diseases in these countries. In recent years, it has mainly been replaced by *S. officinarum.*
- *Saccharum officinarum* (noble cane) originates from the South Pacific islands,

where it is still given prominence in the folklore of many of its peoples. *S. officinarum* is only suited to tropical conditions and requires a favorable soil and climate to perform well. A vast number of clones are recognized, with selections being made for sweetness, quantity of juice, fiber content, etc.

- The cultivar *Otaheite* (or *Bourbon*) is a vigorous and thick noble cane with a high sugar content and high yields, particularly on virgin or relatively new land. *Otaheite* replaced the much thinner *Creole* variety and was dominant in Mauritius until its sudden failure in 1840. The *Cheribon* variety, first developed in Java, replaced later *Otaheite* and is now still widely used in breeding; most of the present-day commercial cultivars are derived from it.

Almost all modern commercial varieties are inter-specific hybrids of *Saccharum spp*., many of which are hybrids between *Saccharum officinarum* and *S. spontaneum*. The Louisiana industry was dependent on noble canes at the turn of the 20th century and was almost destroyed when the mosaic disease moved into the area. It were the new hybrids that saved the industry and also allowed to achieve yields that rival many tropical areas with a much shorter crop cycle. The same is true for the majority of other subtropical and warm-temperate areas.

2.2. Structure

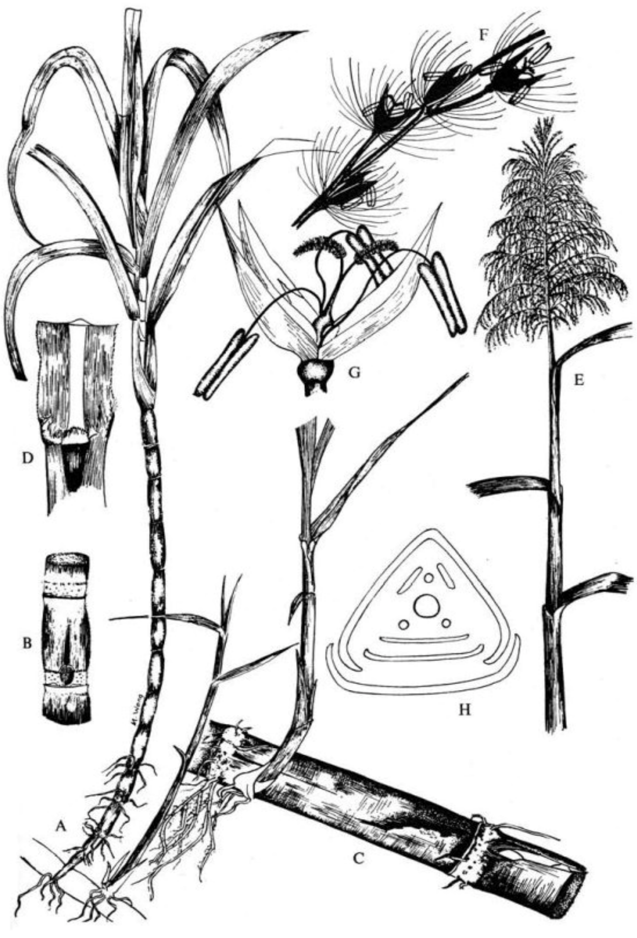

Figure 1. Structure of sugarcane (Legend: A: young plant growing from sett; B: portion of stem; C: sett, showing early growth; D: base of lamina; E: inflorescence; F: portion

of inflorescence; G: spikelet; H: floral diagram). (Courtesy Purseglove, 1976)

The cane is a tall stalk formed by a series of joints both above and below ground. The cylindrical or slightly flattened stalk reaches a height of 2 to 4 meter, with a diameter of 3-5 cm. The cane has more or less protruding nodes and slightly bulging internodes, with a vegetative bud at the node which develops in the axil of the leaf sheath. On the joints above ground the leaves develop fully, while roots and buds normally remain dormant (Figure 1).

Roots – Immediately after planting the young cane depends for a while upon the vigor of the thin branched roots of the sett, being the name given to stem cuttings of living canes used for propagation (see below, section 2.3: Propagation and Pollination). Shortly afterwards, thick white roots grow out from the basal nodes of the new plant, and take over from the sett roots. After the third month these are already supplying all the nutrients. Buttress roots are produced from nodes near the base of the stem, and these help to anchor the plant. The majority of fibrous roots most active in absorption are in the top 25-30 cm of soil. The new tillers of the ratoon crop form their own root system and soon replace the old roots of the stool, which die and break down. The root system of the ratoon crop is sensitive to soil compaction and is more superficial than that of the original plant crop.

Stem – The erect stem is usually unbranched and is composed of a series of joints, 5-25 cm long and 1.5-5 cm in diameter, consisting of a node and inter-node. The length, diameter, shape and color of the joints vary with the cultivar and are a means of identifying them. The length of internodes is shorter at the base and apex of the stem, and is longer in the middle; adverse growing conditions result in a shortening of internodes. The top portion of the stem is low in sucrose and is therefore removed before processing. The terminal meristem which may eventually produce an inflorescence, is surrounded by leaf sheaths.

The stem consists of a hard epidermis or rind, fibro-vascular bundles and soft parenchyma full of sap containing sugar. The somewhat harder rind protects the plant against borers, rodents, jackals and other pests, but may add to the difficulty of chewing and milling. The variety *Uba* for example has very hard rinds, *Otaheite* has a much softer rind.

Leaves – Sugarcane is a C4 plant with alternate leaves, 1-2 m long and 5-7 cm wide, borne in two rows on either side of the stem at nodes (Figure 1). The first leaves from the bud are scale leaves, but as the cane grows the leaves increase in size to a maximum, followed by a reduction in size at flowering. As new leaves emerge, the older lower leaves dry and die; they may drop off or be retained. Thanks to its total leaf surface, which may be up to 7 times the soil surface covered by the crop, sugar cane is one of the plants that can capture a maximum of solar energy per hectare and per month.

Inflorescence – At maturity the cane changes from a vegetative to a reproductive stage. The terminal meristem ceases to form leaves, and may turn into an inflorescence (or arrow), especially during short-day periods. The axis of the inflorescence elongates and pushes the panicle up through the enclosing sheath. This loose terminal pyramidal panicle, 25-50 cm long, has a silky appearance due to rings of long hairs below each spikelet. On the ultimate branches are the spikelets, oblong lanceolate in shape with two boat-shaped hard glumes, borne in pairs at each node. Within the glumes are two florets: a lower sterile and an upper hermaphrodite floret. The flower is bisexual, with only one ovule (Figure 1).

Fructification is rarely observed, but can not be ruled out. The small seed is a caryopsis as in other grasses. It is about 1mm long, with persistent stigmas, and with whorls of silky hairs for wind dispersal. The fruits mature and are shed about three weeks after fertilization.

Sugarcane rarely flowers in an annual crop, but often does in a 24-month crop. Flowering can be avoided in a 24-month crop as well by selecting varieties not likely to flower, or to use growth regulators. Flowering is detrimental to sucrose yield because flowering stalks use up sucrose and therefore deteriorate the quality of the cane. After producing seed the cane dies.

2.3. Propagation and Pollination

Cultivars of sugar cane are clones which are mainly propagated in a vegetative way. This is achieved by stem cuttings of immature canes known as “setts”, with 2-3 lateral buds (or dormant eyes). Cuttings are usually taken from the upper third of the stalk in plant canes 8-12 months old or from ratoons of 6-8 months. Setts are usually 30-45 cm in length, and are planted in long furrows 15-30 cm deep, or in trenches. After planting, the buds develop into primary and secondary stalks, and gradually form a dense, homogeneous tuft, known as a stool. Cuttings are carefully sorted in order to eliminate those that are misshapen or have already started to sprout. They are soaked for 20-30 minutes in a bath of hot water at 52° C to which a fungicide has been added by way of diseases control.

Cuttings are taken from carefully selected canes. While the cane grows, the lateral buds remain dormant because of the terminal meristem’s apical dominance. A few days before the cuttings are taken the stem’s terminal section is removed, allowing the buds to burst. The upper parts of the canes, which are low in sugar, yield the best cuttings; they are taken before flowering. On industrial plantations, a whole field is sometimes set aside as a nursery for the production of cuttings. In such a case the cane is harvested prematurely and the whole stalk is used.

The average planting density is 15,000 to 24,000 cuttings per hectare, with an intended stalk density of 90,000-150,000/ha. Setts may be planted at an angle of 45° or laid horizontally in the base of a furrow, sometimes placed end to end. Setts grown in a nursery have the advantage that they have received special attention and have been monitored for virus and other diseases.

Commercial sugar cane production focuses logically on the most productive variety in terms of sucrose and sugar content. This was for a long time almost exclusively obtained from noble canes, i.e. *S. officinarum*. The sudden and almost worldwide failure of *Otaheite* in the 19th century lead to the search for other cultivars which were more resistant to diseases.

With the rediscovery of fertility and seed in sugar cane in 1888 by Soltwedel in Java and Harrison and Bovel in Barbados, breeding became possible. While at first breeding methods were largely empirical, modern methods have placed the application of cytogenetics on a more scientific basis.

Plant breeding is achieved by true seed or fuzz from specially cultivated canes, as flowering is undesirable in the commercial crop. The spikelets open about sunrise, beginning at the top of the panicle and proceeding downwards and from the tips of the branches inward over a period of 5-15 days. The swelling of the lodicules by water uptake causes the glumes to be pushed apart and the stigmas are excluded.

The seed has a short viability, but can be stored in a desiccator for 1-2 weeks. Dry fuzz in airtight polyethylene bags in the deep-freeze will retain its viability for several years. The fuzz, which germinates better in light, is placed on the surface of shallow trays of sterilized compost and kept at a high atmospheric humidity. Germination takes 2-5 days, and after 6 weeks the seedlings are ready for transplanting.

Male sterility occurs in some cultivars and is now utilized in cane breeding; this male sterility may be genetic due to incompatibility of chromosome complements which cause abortion during pollen development. A few noble canes are male-sterile, as is the case for *Otaheite*. A second cause of male sterility is largely environmental: although some pollen may be produced, the anthers may not dehisce and may vary when a cultivar is grown in different countries. Sugar cane pollen, under normal environmental conditions, remain viable for only a few hours, but modern freeze-drying techniques permit storage and the transport between countries. Resistance to disease is usually governed by a few major genes; such oligogenetic resistance tends to be rather impermanent, and new virulent strains of the pathogen arise. Modern cultivars are complex polyploids or aneuploids, but often behave as auto-polyploids showing diploid segregation ratios. Seedling populations tend to be very variable and most breeders use as wide a range of parent types as possible to produce maximum variability.

3. Ecology and Growing Conditions

Sugar cane is a warm-temperate and (sub)tropical crop which requires a warm, sunny and moist climate and fertile, deep and well aerated soils. The crop cycle, growth and maturation are largely influenced by climatic conditions: moisture and heat favor growth, while dry sunny periods and low night temperatures are favorable for maturation and sugar accumulation. The crop is sensitive to frost and hurricanes or typhoons. Most commercial sugar cane is grown between 37° North (Spain) and 35° South (South Africa) from the Equator. The various cultivars require a particular ecology. The wild species of *Saccharum* behave best in open situations: *S. robustum* grows along river banks; *S. spontaneum* extends mainly in warm temperate regions and can tolerate a much wider range of conditions; *S. officinarum* is essentially tropical, while *S. barberi* and *S. sinense* can be grown in subtropical and temperate countries. New modern hybrids have been developed which are adapted to a shorter growth cycle in subtropical areas.

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Biographical Sketch

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