

**VIVEKANANDA COLLEGE**  
**THAKURPUKUR**  
**KOLKATA 700063**

**NAAC Accredited Grade—A**



**Topic:** Sugar Crops: Sugarcane

**Course Title:** BSc Botany Honours (CBCS)

**Paper:** Core Course 9 (Theoretical) Economic Botany

**Unit:** 4A

**Semester:** 4

**Name of the Teacher:** Kuntal Narayan Chaudhuri

**Name of the Department:** Botany

**SUGAR CROPS: SUGARCANE**

**Sugar crops** are **cash crops** from which the **juice** is extracted to manufacture **sugar** *i.e.* **sucrose** (**common sugar** or **table sugar**). Sucrose, a **disaccharide** (carbohydrate), is the most economically-important and industrially-produced sugar. Sugars are **energy sources** and **sweetening agents**. Perhaps the oldest-known sweetening agent is the **honey** of **honey bees** obtained from the wild and apiculture. Sugar (sucrose) is obtained from the **tropical crop—sugarcane** (stem, *Saccharum officinarum* of Poaceae yielding **cane sugar**) and the **temperate crop—sugarbeet** (root, *Beta vulgaris* of Chenopodiaceae yielding **beet sugar**). Minor sources include **tropical palms** (Arecaceae) *e.g.* **toddy palm** (*Borassus flabellifer*) and **date palm** (*Phoenix sylvestris*) in India and **sugar palm** (*Arenga pinnata*) in Malaya (all yielding **palm sugar** from the stem sap) and the **temperate sugar maple** (*Acer saccharum* of Aceraceae) in Canada (yielding **maple sugar** from the stem sap). Sugarcane juice and palm sap are also consumed as **non-alcoholic beverages** and can be fermented to produce **alcoholic beverages** (rum and toddy respectively). In addition to **refined sugar (sucrose)**, the juice and sap are also used to make **unrefined sugar** called **jaggery (gur)**.

**Sugarcane (Akh B.)**

*Saccharum officinarum* L.

Poaceae (= Gramineae) of the tribe Andropogonae

Stem (culm or cane-like aerial stem)

Sugarcane is **tropical grass** that is cultivated as a **cash crop**. Most of the sugar (70%) produced worldwide is in the form of **cane sugar**. **Modern cultivars** of sugarcanes used for **commercial cultivation** are complex **hybrids** of two or more of the **six species** of the genus *Saccharum*: three cultivated species *S. officinarum* (noble cane), *S. barberi* (Indian cane) and *S. sinense* (Chinese cane), and three wild species *S. spontaneum*, *S. robustum*, *S. edule*, all originating in the Old World.<sup>1</sup> Sugarcane (*S. officinarum*) was domesticated from its wild relative (*S. robustum*) more than 10,000 years ago in **New Guinea (centre of origin)** in the East Indies by the indigenous **Papuan** people. It was then spread by the **Austronesian people**<sup>2</sup> to **Oceania**<sup>3</sup> (South Pacific), as well as to **China** and **India**, about 5,000 years ago. About 2,500 years ago, after the Greek invasion, growing sugarcane and making sugar (*sarkara* in Sanskrit) diffused from India to West Asia and Europe. During the last 500 years this reached the New World along colonial sea trade routes. The **tropical islands** of the Philippines, Mauritius and the Caribbean (West Indies) emerged as new "sugar bowls." Presently, **Brazil, India and China** are the **largest producers** of sugar, in the form of **cane sugar**, in the world. **Cuba and Brazil** are however the **largest exporters**. In India, sugarcane production is highest in **Uttar Pradesh** followed by **Maharashtra**, and then **Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Bihar, Haryana and Punjab**.

<sup>1</sup> Refers to Europe, Africa and Asia, the 'known world' before the discovery of the New World (the Americas and Oceania).

<sup>2</sup> The first humans to invent ocean-faring technologies.

<sup>3</sup> The South Pacific islands with three sub-regions: Melanesia, Micronesia and Polynesia.

## Ecology

*Habit:* Perennial, reed-like, tall grass, up to 6-8 m (height).

*Habitat:* Terrestrial, tropical, subtropical and warm-temperate, riparian, in dense clusters.

**NB:** Cultivated in agricultural fields (anthropogenic) as an annual.

## Morphology

### *Stem:*

Underground stem rhizomatous, with fibrous, adventitious roots, and cane-like solid, thick (2-5 cm diameter), cylindrical, jointed, unbranched, glabrous, white, yellow to green, or purple, aerial stem known as **culm** (or **tiller**); joints thicker and longer in the middle, five parts—node (covered by leaf sheath or leaf scar), root band (with root primordia) above the node, intercalary meristem above the root band, internode (with wax band below the node) and axillary buds (or **eyes**) at the node (with **eye grooves** in the internode above).

### *Leaf:*

Simple, alternate (distichous), exstipulate, sessile, green, adaxially scabrous and abaxially glaucous, linear to lanceolate, uncostate-parallel, apex acuminate, base broad forming leaf sheath with **auricle** and **ligule**, margin finely serrated, size 1-1.5 m (length) x 5-6 cm (width).

### *Inflorescence:*

Terminal, pyramidal, feathery, silvery, large (30-60 cm length) panicle (**arrow** or **tassel**) with long, branched, glabrous rachis having linear to oblong, brown, glabrous, deciduous, muticous, 3-4 mm (length) spikelets in pairs of upper (primary) pedicellate and lower (secondary) sessile and enveloped by long, silvery bristles (3-6 times length); each spikelet with: **glumes** 2 (equal), sterile, oblong, coriaceous, nerved; **lemma** 1 (lower floret), sterile, oblong-lanceolate, membranous, nerveless; **palea** 1 (upper floret), fertile, linear, membranous, nerveless; florets 2, lower reduced to empty lemma.

### *Flower:*

Axillary, solitary, colourless, actinomorphic (regular), trimerous, complete, bisexual, hypogynous, minute (floret), 2.5-3 mm (length).

*Perianth:* Lodicules 2, cuneate, smooth, truncated.

*Androecium:* Stamens 3; anthers versatile.

*Gynoecium:* Carpels 2 (syncarpous); ovary superior, placentation basal, one-celled with one ovule (in T.S.); style bifid, terminal; stigmas 2, plumose.

### *Fruit & Seed:*

Caryopsis (one-seeded), oblong, 1.5 mm (length).

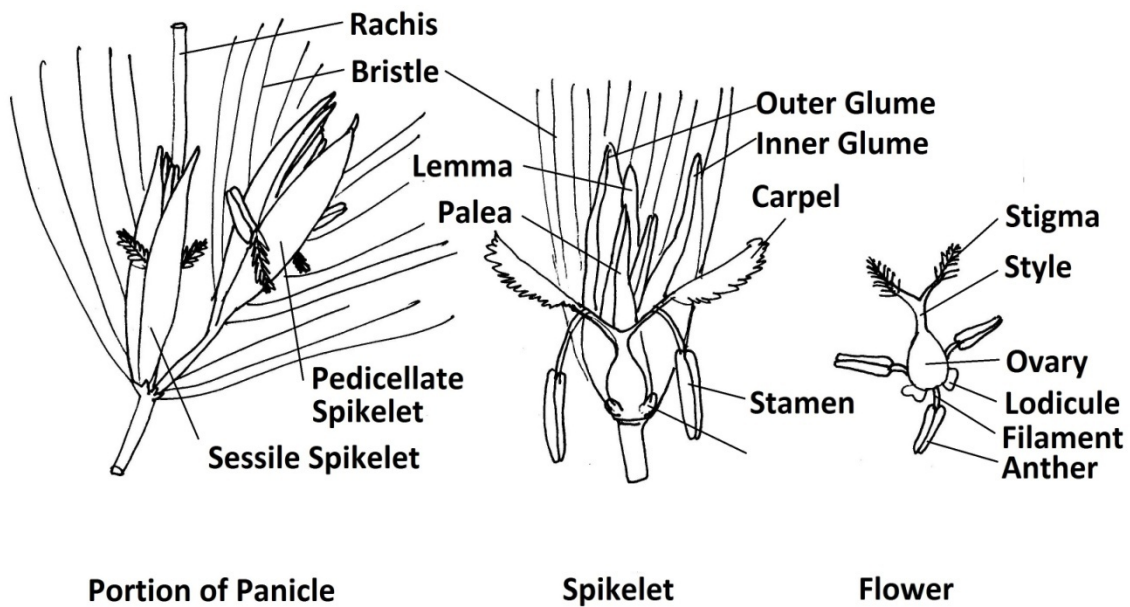
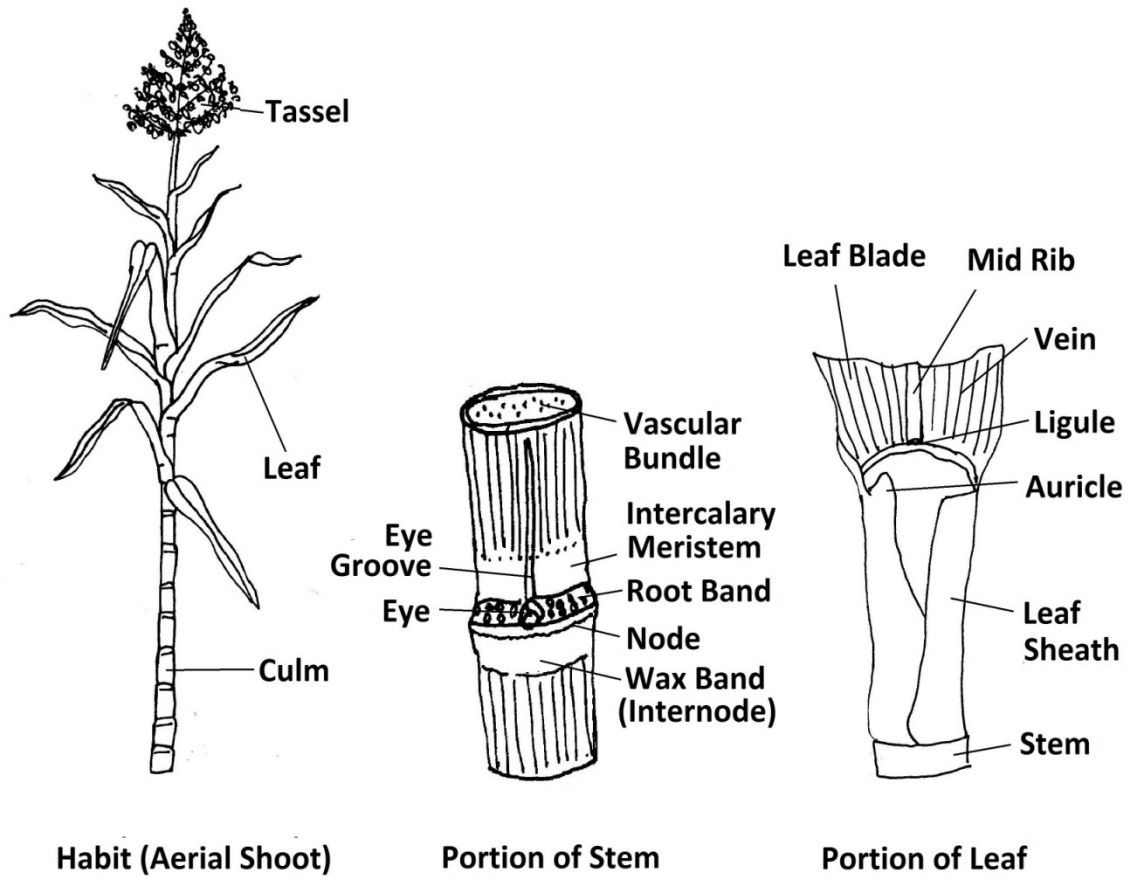
## Anatomy

T.S. of the stem shows two distinct regions:

*Rind:* Outer, hard layer with uniseriate epidermis (heavily **cuticularized**) and multiseriate hypodermis (**sclerenchymatous**).

*Pith:* Inner, soft core with massive ground tissue (**parenchymatous**) scattered with vascular bundles (conjoint, collateral, open; xylem endarch—atactostele), each surrounded by bundle sheath (**sclerenchymatous**); contains sucrose in the stem sap.

**Diagram:** Morphology of *Saccharum officinarum* (Poaceae)



Redrawn with modifications from Sambamurty and Subrahmanyam (1989).

## Cultivation

Sugarcane is a **tropical cash crop**. It is commercially grown in dense **clumps** (or **strands**) in **agricultural plots throughout the tropical and sub-tropical plains**. This crop requires an average **rainfall of 150 cm per annum** and **temperature** range of **26 to 32°C** with dry, sunny, frost-free conditions during ripening. The **soil** must be **well-drained, clay loam** but can range from **sandy to heavy loam**. It grows not only in **alluvial** but also **laterite**<sup>4</sup> and **regur**<sup>5</sup> soils. The growth period of this crop ranges from 10 to 18 months for **early-** and **late-maturing** varieties respectively. This are three phases: **formative phase** (first 120 days), **grand period of growth** (the median 120 days) and **maturity phase** (the last 60 days).

### *Propagation:*

This crop is **vegetatively propagated** by **stem cuttings** (or **sections**) consisting of **multiple-node** segments of the aerial stem (cane) from the **cane tops**. These are called **seed-pieces** or **cane setts**. Each has one or more buds. Usually 30-50 cm (length) **3-budded setts** are used (middle bud has the highest germinating capacity followed by top and bottom ones) for **direct planting**. **Single-node** setts with **roots** and **shoots** are known as **seedlings**. **Stem fragments** with a **bud** are called **bud chips**. Both of these can also be raised in **nurseries** and **transplanted** to the field. In an alternate method called **ratooning**, dormant vegetative buds of the underground **rootstocks** or **stubbles** (left in the field after harvesting) give rise to the next crop called **ratoon** or **stubble crop** (as opposed to **plant crop** from stem cuttings which requires **planting**). However, **ratooning** results in successive **loss in yield** and the fields are cleared of stubbles after three to four years and **replanted** with fresh stem cuttings. Sugarcane is not propagation sexually (with true-seeds) as cold, dry conditions (in **North India**) during winter **inhibits flowering**. There are also problems like high **pollen sterility**, low **seed setting**, short **seed viability** and seedlings not being **true to type**.<sup>6</sup>

### *Planting:*

This is done from January to March. The soil is **tilled** by **ploughing, harrowing**<sup>7</sup> and **levelling**. Setts are **pre-soaked** (36-48 hr), put **end-to-end** in **furrows** (25 to 100 thousand settes per hectare) and covered with 5-10 cm (depth) soil. There are three planting methods:

*Flat Planting:* Only **shallow furrows** (5-10 cm) are made with **plough** at 80-100 cm apart, setts are placed and covered with soil to **completely fill** the furrows to a **flat level**.

*Furrow planting:* **Deeper furrows** (10-20 cm) are made with **ridgers** and setts are covered with soil (as above) to only **partly fill** these furrows.

*Trench planting:* **Rectangular trenches** (20-25 cm deep) are made along with **shallow furrows** (or **pits**) in the **trench bed** and the setts are covered with soil (as above) to **completely fill** the furrows to a **flat level**, but within the **trenches**.

### *Detrashing:*

This is the manual process of removal of unwanted **dry leaves (trash)** from the **bottom** of the **culms** at regular intervals, usually **bimonthly** since 150 days after planting .

<sup>4</sup> Iron oxide-rich red soil of Central India.

<sup>5</sup> Black soil of the Deccan trap (Basalt) region.

<sup>6</sup> Clones

<sup>7</sup> Shallow tillage by breaking up the soil surface with a harrow.

*Irrigation:*

Since this crop is mostly grown in **arid** and **semi-arid** regions therefore frequent irrigation is important for maintaining high yield (up to 80 tonnes per hectare). This is mostly required during the first 120 days (**formative phase**) only. Fields are irrigated by **spreading water** across the fields in **flat planting**, or by **running water** into furrows or trenches in **furrow planting** and **trench planting** respectively.

*Weeding:*

This is regularly done from 3-4 weeks after planting, especially during the **rainy season**. After manual or mechanized **hoeing** of the soil the weeds are manually removed. This practice also improves **soil aeration** for better **root growth**.

*Manuring:*

This **C<sub>4</sub> plant** can efficiently convert solar energy into biomass. Adding **manure, compost** (including **sugarcane trash**), **biofertilizer (organic)** to the soil (at 100 quintals<sup>8</sup> per hectare) **before planting** increases yield. For **vigorous growth** during the first 90 days after planting, **nitrogenous** (at 120-250 kg per hectare), **phosphatic** (at 75 kg per hectare) and **potassic** (at 75-135 kg per hectare) **fertilizers (inorganic)** are added to maintain the **soil fertility**.

*Propping:*

This important operation involves **tying** the canes together with their lower **dried** or **partly-dried leaves** to providing **mechanical support (prop)** in keeping them erect and therefore prevent **lodging**.<sup>9</sup> This is important under field conditions with **heavy cane tops** and **high wind velocities**. Instead of removing all the **dry leaves (trash)**, some of them are **twisted** into **ropes** and **wrapped** around the **canes** to keep them together. This technique is called **trash-twist propping**. Propping can involve one row or two adjoining rows. In Andhra Pradesh, the long and narrow culms are often propped with **bamboo poles**, although this is an expensive strategy.

*Crop Rotation and Intercropping:*

This crop is usually cultivated after the harvest of cereals, pulses, cotton, potato, etc. with two- or three-year system of **rotation**. **Intercropping** is done with pulses, sunhemp, groundnut, etc. These **leguminous** crops have **root nodules** with **nitrogen-fixing bacteria** that increases **nitrogenous** nutrients in the soil.

*Harvesting:*

The mature canes are harvested **before flowering** from December to March. The lower leaves dry up while green ones are restricted to the **cane tops**. These **cane tops** with green leaves are **poor in sucrose** (and **rich in starch**) which can reduce **sugar yield** during factory processing. Thus, these are first removed by manual **cutting**. The remaining cane is then harvested by **cutting close to the ground** by hand or with **harvester** machines. The dry leaves are **rich in silica** which can cause wear and tear of the sugar mill machinery. These are **stripped off** from the harvested canes in the field itself.

---

<sup>8</sup> One quintal is 100 kg.

<sup>9</sup> This is the bending of culms (stems) which results in problems such as reduced yield, pest and pathogen infestations, sprouting, rooting, etc.

## Processing

**Cane sugar** (sucrose) is manufactured from harvested fresh **culms**. Being perishable, as the **sucrose** undergoes natural **enzymatic degradation** to **glucose** and **fructose**, the harvested canes cannot be stored for long and must be immediately processed at the **sugar mills** or **factories**. This involves the following four steps.

### *Extraction:*

This process removes **sugary juice** from harvested **culms**. There are three **mechanized** steps: **crushing** (shredding), **milling** or **rolling** (squeezing) and **diffusing** (**imbibition**). Fresh culms are **shredded** into pieces by **crushers**. Then, this is passed through heavy, grooved **roller mills** to **squeeze** out **raw juice** (75% water) which is **sweet, acidic** (pH 5), **turbid, dark green**, with **impurities** like minerals, organic acids, pigments (dissolved), starch, proteins (colloids), cane bits, mud (suspended), etc. The **by-product**, a dry (50% water), light, fibrous mass called **bagasse**, is sprayed with water in **diffusers** to **leach** out any **residual sugar**.

### *Purification:*

This process, also called **clarification**, removes **impurities** from the raw juice by **physical** and **chemical treatments**. The **raw juice** is at first **strained** through a **rotor vacuum** or **press leaf** type **filter** to get rid of most of the **suspended** (insoluble) **debris**. Then the **filtrate** passes through a series of chemical treatment **tanks** to remove **dissolved** and **colloidal** (soluble) **non-sugars** by three successive steps: **defecation**, **carbonation** and **sulphitation**, each ending with **filtration** to produce clear, dark brown **clarified juice**. The dark, muddy, solid **by-product** left behind in the filter of the press is called **filter cake** or **press mud**.

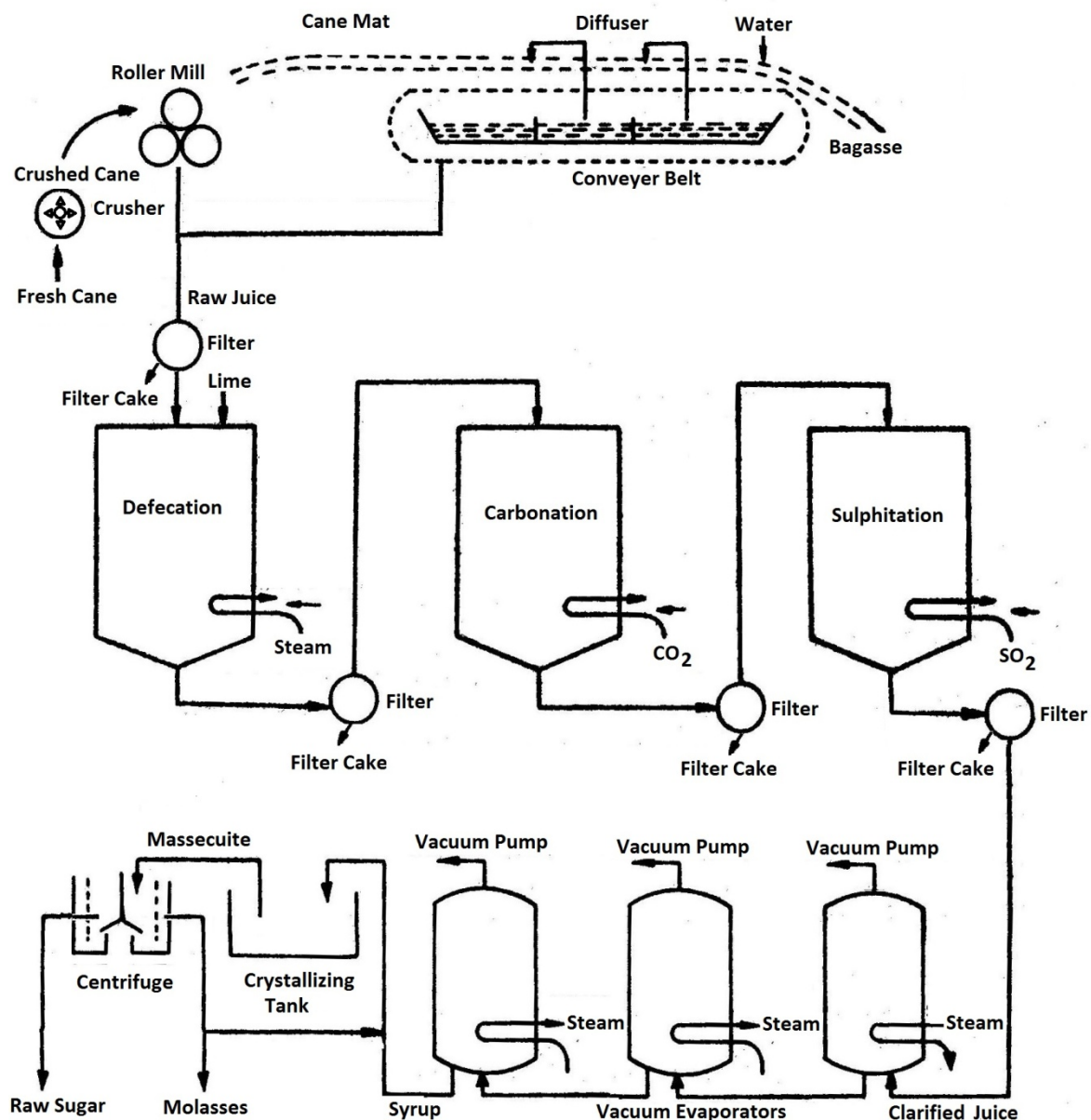
*Defecation:* Filtered juice is **mixed** with **milk of lime** (CaO) as **clarifying agent** (5 kg per tonne of cane) and **heated** (**steam**). The alkali **precipitates** minerals and organic acids as insoluble **calcium salts**. The heat **coagulates** proteins and gums as thick, floating **scum** (which entraps any fine suspended solids left). Both **precipitate** and **scum** are removed by **filtration**.

*Carbonation:* Defecated juice is mixed with gaseous **carbon dioxide** (CO<sub>2</sub>) to **precipitate excess lime** as **calcium carbonate** (CaCO<sub>3</sub>) and **decompose** the intermediate product **calcium sucrate** into soluble sucrose. The **precipitate** is removed by **filtration**.

*Sulphitation:* Carbonated juice is mixed with gaseous **sulphur dioxide** (SO<sub>2</sub>) to complete **neutralization** of **lime** (pH 7) and **decomposition** of **calcium sucrate**, and **filtered**.

### *Crystallization:*

This key process is centred around the **chemical phenomenon** of **sucrose crystal** formation by three **mechanized** steps: **evaporation** (concentration), **crystallization** (stirring) and **centrifugation** (separation). **Clarified juice** (85% water) is **boiled** under **reduced pressure** in a series of **vacuum evaporators** (or **pans**) with gradually lower **partial pressure** (and **boiling point**) to **evaporate** two-third of the water. The **concentrated** juice (35% water) reaches the **crystallization point** as a brown **syrup**. **Partial vacuum** boiling at a **lower temperature** (45°C) prevents **charring** of sugar. The sugar **syrup** is **stirred** in **vacuum pans** called **crystallizing tanks** with **seed grains** (crystals) as **nuclei** for **crystallization**. The resulting mixture of **crystals** and **mother liquor** form a dense mass called **massecuite**. **Spinning** (1,800 rpm) in **centrifuges** separates the **liquid molasses** (through perforated walls) from the **crystals** of **raw sugar** left behind. Molasses with **residual sugar** are mixed with fresh **syrup** and **reprocessed** three to four times. The **by-product** is the exhausted **molasses**.

**Diagram:** Manufacturing of cane sugar

Redrawn with modifications from Sambamurty and Subrahmanyam (1989).

**Refining:**

This final process essentially removes **impurities** from the **brown crystals** of **raw sugar**. Exported **raw sugar** is refined in **sugar refineries**. The first step is **affination** by **mixing** the **raw sugar** with **warm water** or **syrup** to remove the **film** of **molasses** on the **crystal surface** followed by **washing** with a spray of **cold water**. Then this is **re-dissolved** in half its weight of **hot water** (65°C) in stirring tanks called **melts**. The resulting **yellow** to **brown liquid** is passed through **press filters** with two adsorbents: **diatomaceous earth** to remove **fine suspended matter** followed by **bone charcoal** (or by modern ion-exchange resins of **acrylic** or **styrenic** materials) to **decolourize** and produce a **colourless liquid**. This liquid is then **vacuum evaporated** to a clear **syrup**, **stirred** for **re-crystallization** and finally **centrifuged** to separate the **white crystals** of **refined sugar**. This is finally dried in rotor **driers** with hot air current and graded through mechanized **sieves** as per crystal size.

**Cane juice** is a **watery fluid** (75% water) representing about 80% of the fresh cane **biomass**. It is **sweet** due to dissolved **sugars** of which the dominant is **sucrose** (130-185 mg per litre)—a **disaccharide** (and **non-reducing sugar**) along with some **glucose** (3-6 mg per litre), **fructose** (3-10 mg per litre)—both **monosaccharides** (and **reducing sugars**) formed by the breakdown of sucrose by the enzyme **invertase** (which is ultimately **denatured** during **clarification**). Trace amounts of dissolved **minerals** such as  $K_2O$ ,  $SO_3$ ,  $CaCl_2$ ,  $CaO$ ,  $MgO$ ,  $SiO_2$ ,  $P_2O_5$ ,  $Fe_2O_3$  as well as **colloids** such as starch, proteins, fats, waxes, gums, etc. are also usually present.

### Products and By-products

Sugarcane is a rich source of (1) **food**, (2) **beverage**, (3) **compost**, (4) **fodder**, (5) **fuel**, (6) **paper** and (7) **chemicals**. Both **industrial** and **non-industrial** processing of **cane juice** yields (1) **sugar**, (2) **muscovado** and (3) **jaggery** as the main **products** that are primarily used as **sweetening agents**, as well as (4) **bagasse**, (5) **filter cake** and (6) **molasses** as the main **by-products** with diverse uses. These account for 80-90% of the sugarcane use. The rest is used to extract fresh juice as **beverage** or for **chewing** due to softness and high juice content, as well as **propagules** for cultivation.

#### *Sugar:*

This is the common **table sugar** which is also called **regular sugar**, **white sugar** or **granulated sugar**. It is the **centrifuged refined** cane sugar produced by refining **raw sugar**. This **product** is a sweet, white, crystalline solid. It is commonly used as **sweetening agent** and **energy source**. It is used for **cooking**, and for making **beverages** and **confectionaries**. Sugar is available in diverse forms in addition to the regular, white, **granulated** sugar. **Powdered sugar**, **confectioners' sugar** or **icing sugar**, is a finely-ground sugar produced by **milling** of **granulated sugar**. **Caster sugar** is a **small-crystal** sugar with size between **regular** and **powdered sugar**. In contrast, **coarse sugar**, **rock candy**, **sugar candy** or **rock sugar**, has much larger crystals than **regular sugar**. In India, this is available in lumps is called **misri**. **Sanding sugar** is a **large-crystal** sugar with size between **regular** and **coarse sugar**. Sugar is also used to manufacture **cosmetics**, **medicines**, **adhesives**, **explosives**, etc. It is used in **tanning** of leather and **silvering** of mirrors.

#### *Muscovado:*

This is also called **khandsari** or **khand**. It is a **centrifuged** or **non-centrifuged partially-refined** cane sugar. This **product** is a sweet, brown, crystalline solid. It is used as a substitute **sweetening agent** and **energy source**. Molasses present in it render **brown colour**, **moist texture** and **strong flavour**. Lesser the **refining**, greater is the **molasses content**, **flavour** and **colour**. This also contains high levels of **minerals** and therefore is considered **healthier** than white sugar. As a **sweetening agent** it is used for **cooking**, and for making **beverages** and **confectionaries**. It is also used as **raw material** for manufacturing **rum**. India is the **largest producer** and **consumer** of **muscovado**. Similar **centrifuged** sugars include (**unrefined**) **raw sugar** (also called **natural brown sugar** or **whole cane sugar**) containing **residual molasses** and (**refined**) **white sugar** with **added back molasses** called **commercial brown sugar**.

**Jaggery:**

This is called **gur** in India. It is a **non-centrifuged unrefined** cane sugar (as well as palm sugar). This **product** is sweet, yellow to brown, amorphous solid. However, in addition to the moulded block of **solid jaggery**, this is also produced as a viscous liquid (**liquid jaggery**) or crystalline solid (**granular jaggery**). It is used as traditional **sweetening agent** and **energy source**. **Sugarcane jaggery** contains **sucrose** (50%), along with **glucose**, **fructose** (20%) as well as **water** (20%). Like **khandsari**, molasses present in it render **brown colour**, **moist texture** and **strong flavour**. This also contains high levels of **proteins**, **fats**, **vitamins**, **minerals** and even (bagasse) **fibres** and therefore is considered **healthier** than brown or white sugar. As **sweetening agent** it is used by for **cooking**, and in making **beverages** and **confectionaries**. In Bengal, **jaggery** (as well as **sugar**) is used to prepare **traditional candies**—*batasha*, *kadma*, *nakuldana*, *math*. Flavored tobacco mixed with jaggery is used as **fumatory** (in **hookah**). It is used in **cattle feed** during winters. It is also used in India to prepare **natural dyes** for dyeing fabrics with **deep black** hue. It is also used in **medicine** as an ingredient of many **Ayurveda formulations**. India is the **largest producer** and **consumer** of jaggery. However jaggery made from date palm stem sap is the most prized.

**Bagasse:**

This is also called **cane fibre**. It is the initial residue in the form of fibrous matter left from **mechanized extraction** of **juice** from **sugarcane**. This **by-product** is a light, dry (45-50% water), fibrous pulp. The yield is about 300 kg per tonne of cane. Its dried biomass contains **cellulose** (45-55%), **hemicellulose** (20-25%) and **lignin** (18-24%). It is burnt as **boiler fuel** including during sugar and jaggery manufacturing (as the primary **energy source**). It is used as a **mulch** for crops and **litter** or **bedding** for livestock. This pulp (instead of bamboo and *sabai grass*<sup>10</sup>) is used for making **paper** as well as related products such as **paperboards**, **cardboards**, **fibreboards** and **biodegradable tableware**. However, this heterogeneous pulp is rich in fibres, both **pith fibres** (30-40%) from the core and **rind fibres** (60-70%) from the surface, which is problematic for paper manufacturing. From its **hemicellulose (pentosan)** content **furfural (aldehyde)** is synthesized which is widely used as **industrial solvent** and **agrochemical (fungicide and herbicide)**.

**Filter Cake:**

This is also called **press mud**. It is the recurring deposit, as impurities, retained in the **vacuum** or **press filters** during **clarification** of **raw juice**. This deposit grows in thickness in the course of **filtration** and increases **flow resistance**. Eventually it is **flushed** out from the **filter**. This **by-product** is a soft, spongy, amorphous, dark brown solid. The yield is about 30 kg per tonne of cane. Filter cake contains **water** (75–80%), **sugar** (2–5%) and **fibres** (5–10%). It has been used as **famine food** by resource-deficient families in the countryside. It is used as a **compost** including in sugarcane fields because of its high **nitrogen**, **phosphorous** and **calcium** content. It is also used as **soil conditioner**.<sup>11</sup> It is mixed with **animal feed** because of its **sugar** and **mineral** content. It is also used as **compacting agent** for **silage**<sup>12</sup> used for livestock. It yields **sugarcane wax** which is extracted with solvents and used for manufacturing **polishes**, **cosmetics**, **candles**, **specialty coated paper**, etc.

<sup>10</sup> *Eulaliopsis binata* (Poaceae).

<sup>11</sup> Product which is added to soil to improve its physical qualities.

<sup>12</sup> Type of fodder made from green foliage crops through preservation.

**Molasses:**

This is also called **black treacle**. It is the **final effluent** in the form of the **mother liquor** (or **supernatant**) left after the **mechanical separation of** sugar crystals from the **massecuite**. This **by-product** is a sweet, dark, viscous fluid. The yield is about 130 kg per tonne of cane. Molasses contain **water** (22%), **sucrose** (29%), **glucose** (12%), **fructose** (13%), but no fat or protein. **Superior grades** are used in **cooking**, and in making **beverages** and **confectionary** as **sweetening, colouring** and **flavouring agents**. Unlike refined sugars it has **vitamins** and **minerals** and is therefore more **nutritious** as a **dietary supplement**. This is also fermented to produce the **alcoholic beverage** called **rum**. **Inferior grades** are mixed with **animal feed** because of **sugars** and **minerals**. A mixture of **bagasse** and **molasses** called **molascuit** is used as **cattle feed**. Molasses is also used to prepare a host of **industrial chemicals** such as **alcohols, vinegar, glycerol, organic acids, monosodium glutamate**, etc. **Ethanol** produced from molasses is the most common **biofuel** worldwide, particularly in Brazil. **Monosodium glutamate** is a **flavouring agent**. **Molasses** is **added** back to **refined sugar** to make **commercial brown sugar** as an alternative **sweetening agent** and **energy source**.

**Further Reading:**

Kochhar, SL (2016) *Economic Botany: A Comprehensive Study*. Oxford University Press, Delhi.

Mitra, D, J Ghua & S Chowdhury (2010) *Studies in Botany* (Vol. 2). Moulik Library, Kolkata.

Mukherjee, SK (2016) *College Botany* (Vol. 3). New Central Book Agency, Kolkata.

Sambamurty, AVSS & S Subrahmanyam (1989) *A Textbook of Economic Botany*. Wiley Eastern, New Delhi.