SUGARCANE

Dr. Ashirbachan Mahapatra
Assistant Professor
Agronomy, MSSSoA, CUTM

IMPORTANCE

- Sugarcare is the main source of sugar in India and holds a prominent position as a cane crop. India has the largest area under sugarcane in the world and also ranks first in sugar production. Sugar juice is used for making white sugar, brown sugar (khandsari) and jaggery (gur). Sugarcane is one of the main crops of earning foreign exchange.
- The main by-products of the sugarcane industries are bagasse and molasses.
- Bagasse is mainly used as fuel. It is also used for the production or compressed fibre board, paper, plastics and furfural.
- Molasses is used in distilleries for the manufacture of ethyl alcohol, butyl alcohol, citric acid, etc.
- Rum is the best potable spirit made from molasses. Molasses is also used as an additive to feeds for livestock.
- Green tops of cane are a good source of fodder for cattle.
- Sugar mills also produce large quantity of biodegradable pressmud which is used as a manure in alkaline and saline soils.
- Sugar industry in India is next in importance only to the textile industry and provides gainful employment to a large number of people.

Sugarcane - A multipurpose crop

JUICE → SUGAR

MOLASSES → Ethanol

BAGASSE → Ethanol

LEAVES & TOPS → CO-GENERATION OF ELECTRICITY

ORIGIN and HISTORY

- The cultivated ***Saccharum officinarum*** (also called noble cane) was evolved by repeated back crossing of *S. officinarum* of New Guinea with wild *S. spontaneum* to improve the commercially important characters like high sucrose, low fibres, long inter nodes, late maturity, long leaves, etc. The attainment of such characters by natural crossing is known as **Nobilisation**.
- Cultivation of sugarcane in India dates back to the **Vedic period**.
- The earliest mention of sugarcane cultivation is found in Indian writings of the period 1400 to 1000 BC.
- The word 'sugar' is derived from the Sanskrit word **'Sakkara'** or '**Sarkara**'.
- Barber (1931) was of the opinion that the thin Indian canes probably originated in the **moist parts of North Eastern India**, from some plant closely related to ***Saccharum spontaneum*** (Kans).
- Tropical cane might have originated on some of the larger islands of Oceania, most probably in **New Guinea**.
- Brandes (1956) also concluded that it originated in New Guinea, where various forms of thick, tall, tropical cane have been grown from ancient times.

AREA and DISTRIBUTION

- Sugarcane is grown over the land surface of the earth between latitudes 35°N and 35°S.
- The important sugarcane producing countries in the world are, India, Brazil, Cuba, Exico, Pakistan, China, Philippines and Thailand.
- It is one of the important crops of the world cultivated over an area of 19.4 million hectares with a total production of 1274.7 million tonnes of cane.
- In India, area and production of sugarcane has been fluctuating from year to year depending upon pricing policy and climatic conditions.
- It occupies about 4.43 million hectares.
- The total production of cane is 306 million tonnes.
- Uttar Pradesh has the largest acreage under sugarcane, and accounts for about 48% of the area under this crop in whole of India and also accounts for 38.6% of the total annual production.
- But the production/ha is highest in Tamil Nadu followed by Maharashtra and Karnataka (2016-17). (FAI Statistics 2017-18)

TOP CANE-GROWING NATIONS (AVERAGE OF 2014-18)

Leaders in India

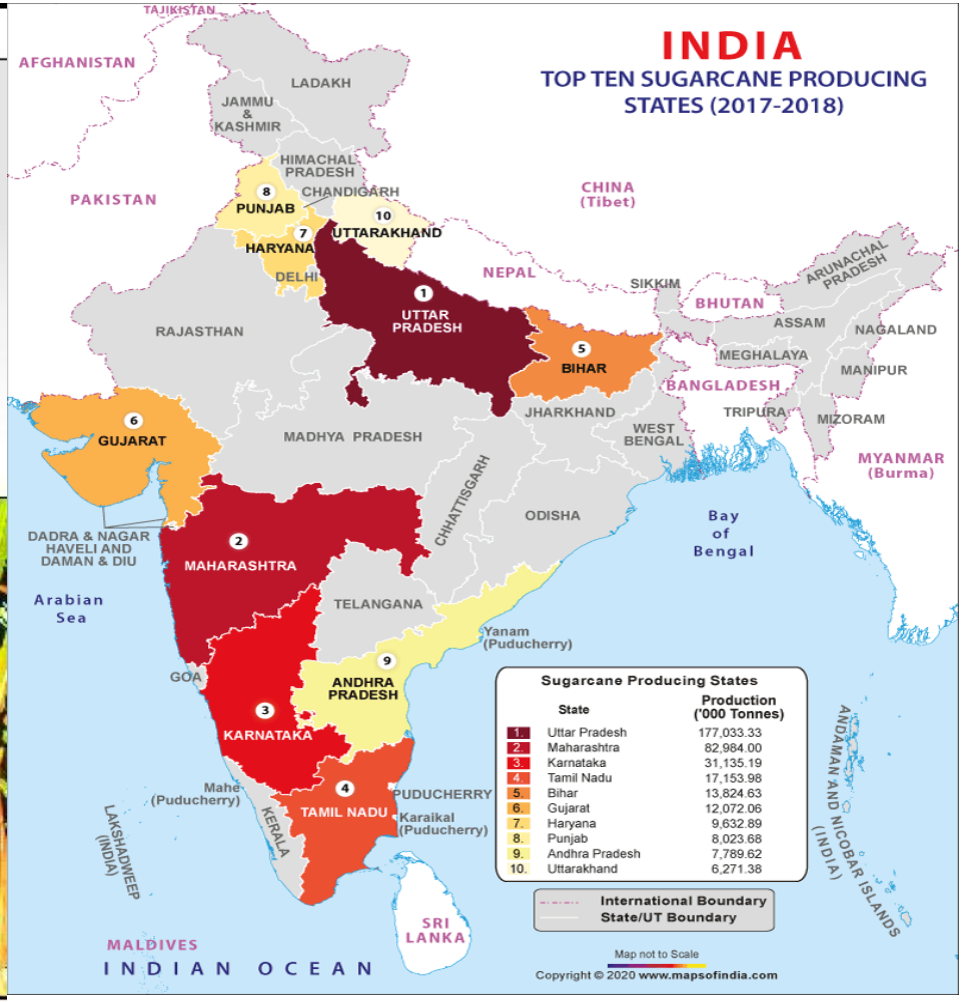
State	Area	Production
Uttar Pradesh	43%	37%
Maharashtra	20%	23%
Karnataka	9%	11%
Tamil Nadu	6%	9%
Gujarat	4%	4%

In terms of cane area and production, Hoshiarpur & Gurdaspur are Punjab's top districts

SOURCE: DIRECTORATE OF SUGARCANE DEVELOPMENT, MINISTRY OF AGRICULTURE & FARMERS' WELFARE, GOVT OF INDIA

INDIA

TOP TEN SUGARCANE PRODUCING STATES (2017-2018)



CLASSIFICATION

Sugarcane belongs to the genus *Saccharum* in the family Poaceae. Cultivated sugarcane is classified into three species.

1. ***Saccharum officinarum***: These are thick and juicy canes good for chewing purpose. This species includes the tropical canes indigenous to the **New Guinea**. These canes contain high sugar content, low fibre and produce high tonnage. These are generally resistant to smut but are susceptible to red rot and mosaic diseases. The cultivation of this species is limited to tropical areas. But in recent years these canes have been succeeded by hybridization among *Officinarum spontaneum* and other species in subtropical regions.

2. ***Saccharum sinense***: This species of cultivated sugarcane is indigenous to **north-eastern India**. This species is characterized by long and thin stalks, broad leaves, low to medium sucrose content and early maturity. This species includes "Pansahi'. ‘Nargori’ and 'Mungo’ groups of sugarcane. Internodes of these canes are long and more or less zigzag and nodes are prominent.

3. ***Saccharum barberi***: This species is also indigenous to **north-eastern India**. It is characterized by short and thin stalks, narrow leaves, low to medium sucrose content, and early maturity. This species includes ‘Saretha’ and ‘Sunnabile’ groups of sugarcane.

Both the above-mentioned species, indigenous to north-eastern India were in cultivation for many centuries but nowadays canes of these species have been replaced by complex hybrid clones. In addition to the above three cultivated species there are two wild species ***S. spontaneum*** and ***S. robustum***.

Cultivated Species

Saccharum officinarum

Saccharum sinense

Saccharum barberi

Wild Species

Saccharum spontaneum

Saccharum robustum

Saccharum officinarum

Saccharum sinense

Saccharum barberi

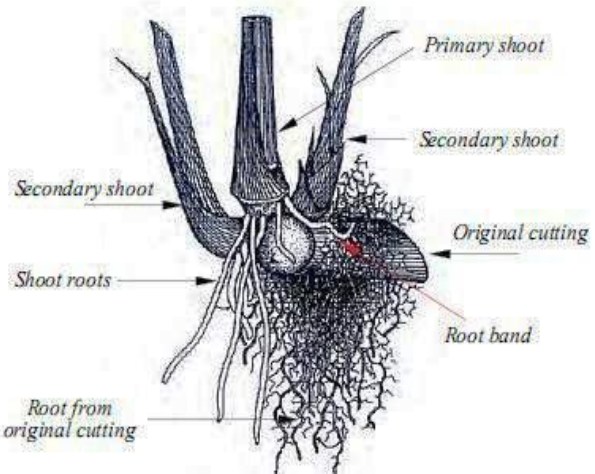
BOTANICAL DESCRIPTION

Sugarcane is tall perennial plant growing erect even up to 5 or 6 m. The plant is composed of four principal parts i.e. the **root system**, the **stalk**, the **leaves** and the **inflorescence**.

Root system

The root system is fibrous and consists of two types of roots, namely "sett roots" and "shoot roots". When sugarcane sett is planted in the soil and covered with moist soil, the root primordia (transluscent dots) situated at the base of every cane joint is activated and produces roots. These roots are known as "sett roots" and are mostly temporary. These are thin and much branched and function for a limited period. These roots provide moisture and nutrients for the growing primary shoot until it forms roots of its own.

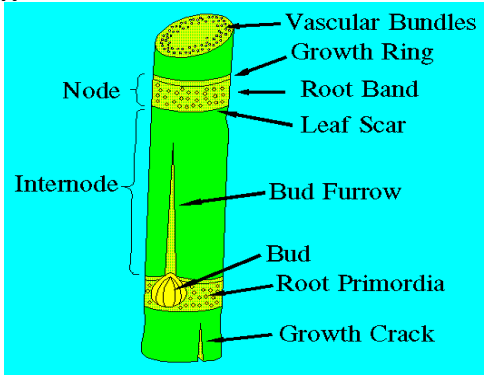
Later on these "sett roots" cease to function and die. After the emergence of the primary shoot from the bud, other roots are produced from lower rings of the flower nodes of the shoot. Later, this process occurs progressively in upper rings of the nodes near the soil surface. Those formed first go downwards, where as those formed near the soil surface grow in upper layer of soil for providing anchorage for the plant. These roots produced from shoot are known as "shoot roots" These are permanent roots are thick, fleshy and white in colour. New roots are continually produced from tillers.



Stalk

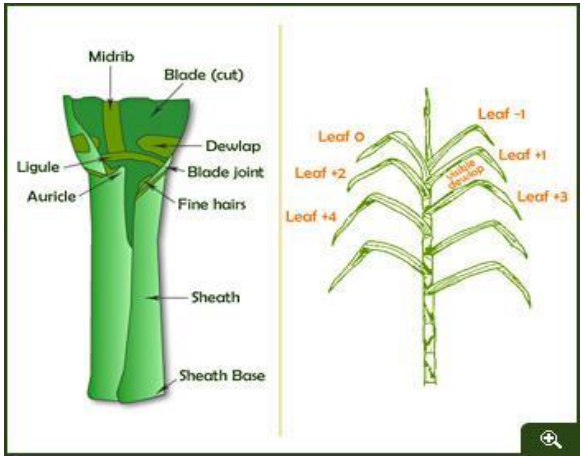
Sugarcane stalk is roughly cyllindrical and is composed of many distinct nodes and internodes. It is above ground portion of the plant which bears leaves and flowers. A small portion of the stalk is below ground which is called rootstalk. At each node there is bud, sometimes known as “Eye” appearing on opposite sides of the cane. These buds are protected by the leaf sheath, which is folded tightly around the internode. Just below the bud is a raised portion is known as the leaf scar.

- Sugarcane is propagated vegetatively with stem cuttings.
- The stem of sugarcane is roughly cylindrical and consists of nodes and internodes, the former being the area around the bud from the leaf scar to the growth ring and the latter being the part between the two nodes.
- The node consists of a lateral bud, root primordia and growth ring.
- Bud is situated in the axil of the leaf on alternate sides of the stalk.
- Root primordia at lower side of the leaf scar are arranged in rows.
- Growth ring is present immediately above the each node, coated with waxy layer.
- Sucrose content is higher at the bottom portion and decreases towards the top of the cane.



Leaf

- The leaf consists of two parts, the blade and the sheath, separated by a leaf joint.
- The leaves are attached to the nodes of the stem on alternate sides.
- The leaf sheath is tubular in shape and is inserted at the node.
- The leaf blade is linear or lanceolate reaching upto 3 feet and the midrib is prominent with groove on upper surface.
- The ligule is a membranous ring found as an appendage of the sheath, separating the latter from the leaf blade, and bears long hairs.
- The scarious extension of the leaf sheath is known as auricle.



Inflorescence

Inflorescence: The inflorescence or tassel of sugarcane, generally called as **'Arrow'** is a loose terminal panicle. 25-50 cm long arrow with silky appearance owing to rings of long hairs below each spikelet. The arrangement of the spikelet is **racemose**. Each tassel consists of several thousand tiny flowers, each capable of producing one seed. Sugarcane usually flowers at the age of 10-12 months but some varieties do not flower at all.

SOIL REQUIREMENTS

Sugarcane is well adopted to wide range of soil from sandy to heavy clay soils – if water, drainage, fertility and depth are not constraints. But, the sugarcane yield are always better in **medium black soil** of Northern Karnataka, AP and South/Mid Maharashtra as well as alluvial soils of Punjab, Haryana and UP. Sugarcane roots prefer to be well aerated and grow deeper. Hence, the depth of weathered zone is crucial (min: 60-80 cm). Hard pan, subsoil lime band or salt zone, poor drainage reduce the growth and yields. But surface salinity is tolerable (up to 1.7 dSm^{-1}). The tolerable pH range is 4-9 (with yield reduction), but ideal pH range is 6-8. Sugarcane needs high fertility in soil, as it mines large quantity of nutrients during its year long duration. Shallow alfisols are not suitable.

- Cultivated in wide range of soils
- Moderately heavy medium deep (1-2m) loams are better than Heavier and shallow soils
- The soil must be of good depth and drainage
- No salt and compaction

CLIMATIC REQUIREMENTS

Sugarcane is a **C4** plant and is more adapted to tropical climate with year round sunshine than subtropical regions, where it was originated. If moisture is not limiting, it prefers the **hot weather** with **bright sunshine** throughout the year. It is thermo sensitive, photo sensitive **short day plant** (**photo synthesis sensitive to temperatures and day length and flowering sensitive to photoperiod**).

For Growth	For Ripening
Mean Maximum Temp 30-36^{o}C	Mean Maximum Temp 20-25^{o}C
Mean Minimum Temp >20^{o}C	Mean Minimum Temp not less than 15^{o}C
Altitude 300-600 m	Altitude 300-1500 m
Rainfall 1500-1800 mm in 10 months	Rainfall Nil
Sunshine hours 10-12 hours	Sunshine hours 8-10 hours
Relative humidity 60-70%	Relative humidity 40-50%

Season of Growing

- Annual cane (***Eksali***): 11-12 months
- Spring – Feb-Mar in North India
  Jan – Feb in Peninsular India
- Autumn – Sep-Oct in North India (Except Bihar)
  Oct – Nov in Bihar and Peninsular India
  - Such planting is called Pre-seasonal planting (13-15 months), supplies sugar for early crushing
- Late planting – beyond March or Mar-April in North Western India, MP and UP after harvest of wheat. The cane matures in 9-10 months and reduction in duration and yield.
- Monsoon planting (***Adsali***) – July - Aug in Maharashtra and Northern Karnataka
  - 16-18 months
  - Increase in yield & sugar recovery
  - Though advantageous area is declining due to water problem

Why Sugarcane Breeding Institute (SBI) is located in Coimbatore?

Many varieties of sugarcane fail to flower and set the seeds. Some of them need artificial inducement to flower. But, in Coimbatore, located at 77^{o}E longitude and 11^{o}N latitude, the temperatures and altitudes are ideal for natural flowering of most of the varieties. This facilitates crossing programmes and varietal improvement. Hence SBI is located in Coimbatore.

Sugarcane Growing Zones

SBI, Coimbatore has divided the country into five sugarcane growing zones, based on climate, soils and sugarcane growing areas. The are:

- **North western zone:** Punjab, Rajasthan, Haryana, UP and Gujarat.
- **North eastern zone:** Assam, Bihar, Nagaland, WB and Odisha.
- **North central zone:** Madhya Pradesh

Sub-tropical climate

- **Coastal zone:** Coastal region of Andhra Pradesh, Karnataka, Tamil Nadu, Odisha, Maharashtra and Gujarat.
- **Penninsular zone:** Karnataka, Andhra Pradesh, TN and Kerala.

Tropical climate

Why Productivity is higher in South India than North India?

- Latitude are lesser in South India than North Indian states.
- Day length for most part of the growing period is more than 10 hours in South India.
- Minimum temperatures hardly reduce below 20^{o}C during growing period in South India.
- Most of the Sugarcane area is irrigated in South India, which favours use of more inputs.
- Temp during maturity is in the range of 20-25^{o}C in South India, while it is 8-15^{o}C in North.

Land Preparation

Ploughing

- The common method of tillage preparation is ploughing the land and bringing the soil to fine tilth.
- Plough the field for 2 to 4 times at the depth of 50-60 cm with tractor drawn disc plough or victory plough.

Harrowing

- It is the secondary tillage operation in sugarcane cultivation which pulverizes, smoothens and compact the soil to conserve the moisture.
- Harrowing is done at shallow depth of 12-15 cm to crush the clods by disc harrow or rotavator

Levelling

- To ensure a uniform crop stand levelling is important also for easy movement of irrigation water.
- Levelling can be carried out using a tractor operated leveller.

Lay out of field

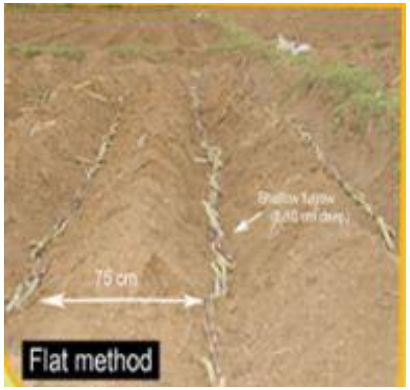
- Irrigation – cum – drainage channels along and across the slope of the field at 10-15m intervals**.**

METHODS OF PLANTING

1. Flat bed planting
2. Trench planting
3. Ridges and furrow planting
4. Paired row planting
5. Partha planting
6. Skip row planting
7. I.I.S.R. method
8. STP method
9. Ring system
10. Machine planting
11. Poly bag seedling transplanting
12. 'Chip-bud' or 'bud-chip' technique
13. Tissue culture method

1. Flat bed planting

- In this method, shallow (8-10 cm deep) furrows are opened with a local plough or cultivator at a distance of 75 to 90 cm
- There should be adequate moisture in the field at the time of planting
- The setts are planted in them end to end
- Furrows are covered with 5-7 cm soil
- In most parts of northern India and some tracts of Maharastra, cane is planted by this method



2. Trench planting

- In some coastal areas as well as in other areas where the crop grows very tall and the strong winds during rainy season cause lodging of cane, trench method is adopted to save the crop from lodging
- Trenches at a distance of 75-90 cm are dug with the help of ridger or by manual labour
- Trenches should be about 20-25 cm deep and 30-40 cm wide.
- Fertilizers (NPK) are spread uniformly in the trenches and mixed thoroughly in the soil
- The setts are planted end to end in trenches and covered with shallow layer (5 cm) of soil.
- The tractor-drawn sugarcane planter is a very suitable device for planting cane in trenches

3. Ridges and furrow planting

- It is followed in Mharshtra, Karnataka, Andhra Pradesh and Tamil Nadu.
- Furrows of 30-40 cm deep are opened at 90 cm distance.
- Setts are placed end-to-end on the top of the ridge and slightly pressed on them.
- Furrows are irrigated.

4. Paired row planting

- This is a recent system to facilitate mechanized harvesting followed in peninsular India, also called **wide row planting.**
- Keeping the distance between ridges up to 5 feet, two rows of sugarcane are established (which are 1 feet apart) on wide topped ridge.
- The two rows of canes are placed end-to-end on ridge and irrigated by separate furrow for each crop row.
- This system more suits drip irrigation, wherein the lateral can be laid in between rows.

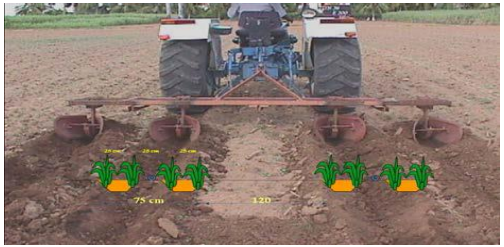
- In a comparative study of two different methods of wide row planting, the dual row system gave a cane yield of 136.3 t/ha compared to 126.7 t/ha recorded by the single row system.

5. Partha planting

- A technique developed by Mr. S.V. Parthasaradhy an eminent sugarcane scientist.
- It is principally followed in coastal heavy rainfall regions of Andhra Pradesh and Tamil Nadu.
- Suggested for water logged or excess soil moisture conditions (coastal Andhra Pradesh and Tamil Nadu during N-E monsoon period)
- In this method
  - Three eye budded setts are planted in a slanting position, 60° to the vertical, in the wet furrow or half-way on the ridges
  - Usually one eye bud is thrust into the soil and the remaining two will be above, which will sprout
  - Once the monsoon recedes, they are irrigated and the *in situ* sprouted setts are pressed down into the soil and made to lie horizontally
  - Soil is put to the base
  - At this stage, the crop is manured

6. Skip row planting

- It is followed in Odisha.
- It is modified trench method, wherein continuous trenches of 45 cm width and 15-20 cm deep are made in paired order in such a way that each pair of trench rows are placed 90 cm apart.
- Setts are placed end-to-end in each trench and soil is covered on them.
- After emergence, the planting results into paired rows of 45 cm, each pair located 90 cm apart.



7. I.I.S.R. method

- Trenches of 90 cm wide are opened at a distance of 20 cm between two trenches.
- They are filled with FYM and litter and 3-4 budded canes (called long rayunguns) are planted vertically with intra row spacing of 30 cm.

8. STP Method

- It is a technique developed by Indian Institute of Sugar Research (Popularly called as STP method – **Spaced Transplanting Technique**).
- A nursery bed (50 m^2) area is sufficient for 1 ha is prepared and sinfle budded setts are planted closely and vertically in such a way that bud is outside.
- The seedlings are ready after 5 weeks.
- These are transplanted in the main field at a distance of 45 cm in each row which are 90 cm apart.
- This method helps to improve the germination percentage (85-95%) as well as reduce seed requirement to 2 t/ha as compared to 6-7 t/ha, required by regular method.

Advantages of STP Method

- Saving of 4 tons of seed cane/ha.
- Uniform crop stand with higher yield.
- Reduction in late shoot production.
- Reduced cane lodging.
- Increase in seed multiplication ratio (1:40 as compared to 1:10)
- Higher stalk population/ha.

9. Ring System / Pit method / Ring pit method

- In the pit method, the crops are raised in pits (90 cm diameter) at the spacing of 180 cm between rows and 150 cm between individual pits in a row.
- The pits are dug using specially designed tractor drawn power tillers.
- The pits are then filled with top soil, 5 kg of farmyard manure (FYM), 100 gms gypsum and 125 gms super phosphate and watered well before planting.
- About 16 double budded or 32 single budded setts were used for planting.
- The setts were collected from the eight-month-old plants and were treated with 0.1 per cent carbendazim for 10 minutes before planting.
- About 60,000 double budded setts were required for planting in one hectare. Germination is as high as 80-90%.
- The pits were irrigated daily for an hour through drip fertigation.
- Detrashing was done on fifth month after planting and the plants were tied without lodging by dried leaves.
- The most important factor was that the sugarcane setts were placed at a depth, which were always moist, hence, in case of drought, or non-availability of water the yield was not affected.

10. Machine Planting

- In recent days, the cane is planted by using specialized machines developed to drop the setts at required spacing, as the machine moves in row.
- It saves the labour and can cover large area in short time.
- They are gaining popularity in many sugarcane growing areas.

11. Poly bag seedling transplanting

- This technique is also more or less same as STP technique.
- Here the seedlings are raised in perforater plastic bags of size 10x15 cm filled with FYM or pressmud, soil and sand 1:1:1 proportion.
- In this technique field establishment of seedlings is better, around 95-99%, as there is no damage to the root system.
- In this method, a small pit is dug out at specified spacing (45cm).
- A small quantity of phosphatic fertilizer is placed and covered with some soil. Then the settling is planted after clipping the green leaves.

12. 'Chip-bud' or 'bud-chip' technique

- In this technique the bud along with a portion of the nodal region is chipped off using a bud chipping machine.
- The bud chips are treated with fungicide and planted in the raised bed nursery or in polythene bags filled with FYM/press mud, soil and sand in 1:1:1 proportion.
- Seedlings are transplanted as in case of STP technique.
- The advantages are that the quantity of seed material (chip buds) required is only around 1 to 1.5 tonnes and the cane after taking chips can be sent for milling.

13. Tissue culture method

- Micropropagation of seed cane through Tissue Culture technology is useful in developing large scale production of true to type and disease free sugarcane plantlets using apical meristem culture technique.faster multiplication of a sugarcane variety can be done.
- Apical meristem (growing part of sugarcane) is dissected and inoculated on a growth medium having definite nutrient composition.
- The apical meristem starts producing tillers in the laboratory after about 45 days of incubation in temperature and light controlled conditions.
- one apical meristem one can develop millions of plantlets in a period of seven to eight months.

- The plantlets well established and hardened in plastic bags are transplanted to field condition.
- Apply 16.5 Kgs. of granular lindane per hectare in the soil after fifteen days of transplantation and irrigate the field. This helps in preventing early shoot borer infestation.
- A seed multiplication ratio of 1:25 (planting material for 25 hectares is obtained from one hectare seednursery) is obtained from the seed nursery planted with tissue culture plantlets.
- The well hardened plantlets developed when used give 98 to 100 % survival under field condition.

PLANTING MATERIALS

1. Setts

- Most commonly used seed material for planting is 1/2/3 budded immature piece of cane called **sett**. They are obtained by raising a separate seed cane (6-7 months-entire cane could be used as sett) or by cuttings from top one-third of mature harvested cane.
- ***Preparation for setts***: It is desirable to grow separate sugarcane crop for seed materials, rather than using 1/3rd top of harvested cane for better germination and cane yield. Such crop is harvested at 6-7 months, when entire plant can be used for sett preparation and entire cane is filled with glucose.
- In later stages, this glucose is converted into sucrose, which is not desirable for germination and growth.
- **Due to apical dominance, it is not desirable to use entire cane or more than three budded cane as planting material.** If such material is used, the germination of lower bud will take an extended time and stand of crop will not be uniform. Seblang or tiller separation can also be adopted to produce setts.

- It is desirable to treat setts with moist hot air treatment at 54^{o}C and 99% humidity for 2-2.5 hours to minimize the diseases like red rot, smut, ratoon stunting disease, grassy shoot disease and leaf scald. In addition, it is useful to treat the setts with 0.5% Agallol slution for half an hour.

2. Rayungans

- The top of the mature cane is cut off to facilitate auxillary bud to sprout (due to apical dominance). Then the cane pieces with 3-4 buds are planted in portion of field selected for rayungan production. After sprouting, they are cut into single budded rayungans. They are transplanted after 3-4 weeks. (**Rayungan** is Indonesian term: this technology is adopted in South Eastern Asia).

3. Seblang

- Setts are planted in fertile soil at wider spacing. Immediately after they germinate and tiller (After 2-3 months), the tillers are separated along with roots and used for transplantation (Practiced in Cuba and Java).

3. Pre-germinated setts

- In spaced Transplantation Technique of planting, setts germinated in nursery are used. They are also called rangoons in Kolhapur.

What is Apical Dominance…?

- Apical dominance is a phenomenon indicating dominance of apical buds than other lower buds due to the presence of auxins. When apical bud is cut, next bud is activated.

4. Tissue culture

- Meristem tips are excited and grown in an independent artificial medium under control condition. This is not used for commercial cultivation, bud adopted to revive degenerated varieties.

5. Tjeblocks

- The whole cane is cut in middle at about 6-7 months and upper part is planted vertically with the lowest node in soil for rooting. Such planted pieces of cane are called **tjeblocks.** After 20-25 days, single budded setts are prepared from both tjeblocks and mother cane and used as Rayungans. This is improved rayungan method.

6. Buds and chips

- Buds on each stalk are scooped along with little flesh and planted in small polythene sleeves with manure and soil and allowed to sprout for 10-15 days. The sleeves will have holes below for rooting. They are used for transplantation in main field.

Preparation of Planting Material and Planting Methods

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Intercultural Operations

1. Trash mulching
2. Raising inter crops
3. Crop rotation
4. Gap filling
5. Earthing up
6. Control / Regulation of flowering in sugarcane
7. Detrashing
8. Propping
9. Removal of water shoots
10. Covering the field with green leaf manure plants

Trash mulching

- Mulch the ridges uniformly with cane trash to a thickness of 10 cm within a week after planting.
- It helps to tide over drought, conserves moisture, reduce weed population and minimize shoot borer incidence.
- Mulch the field with trash after 21 days of planting in heavy soil and wetland conditions. Avoid trash mulching in areas where incidence of termites is noticed.

Advantages of Trash Mulching

1. Reduces the weed population
2. Helps in better bud germination
3. Conserves the moisture
4. Postpones irrigation
5. Improves the biological activity
6. Helps in better decomposition

Raising inter crops

Tamilnadu

- Areas of adequate irrigation, sow one row of soybean or blackgram or greengram along the centre of the ridge on the 3rd day of planting.
- Intercropping of daincha or sunhemp along ridges and incorporation of the same on the 45th day during partial earthing up helps to increase the soil fertility, and also the cane yield.
- Especially Intercropping of Co.1 Soybean gives a yield of 800 kg/ha without any adverse effect on cane yield.

Kerala: Intercropping with short duration pulse crop.

Karnataka: They sow groundnut and pulse as inter crop with sugarcane.

Sugarcane intercropped with green gram, black gram, coriander and soybean

Sugarcane intercropped with marigold

Crop rotation

- Sugarcane is generally grown after the harvest of cotton, rice, maize, toria, potato, wheat, etc. In sequence under 2 to 3 years rotation.

Gap filling

- Fill the gaps, if any, within 30 days after planting with sprouted setts.
- Maintain adequate moisture for 3 weeks for proper establishment of the sprouted setts.

Earthing up

- Earthing-up operation is also known as "hilling-up".
- This operation is carried out in two or three stages. The first earthing-up operation is known “**partial earthing-up”** and the second/third operation is known as "**full earthing-up**".
- The partial earthing-up is done at 45 days after planting. In partial earthing-up, little amount of soil from either side of the furrow is taken and placed around the base of the shoots.
- Full earthing-up is done after 120 days after planting coinciding with the peak tiller population stage. During full earthing-up the soil from the ridge in between is fully removed and placed near the cane on either side.
- This operation converts the furrows into ridges and ridges into furrows. This operation could be done either manually or by using a bullock-drawn/tractor drawn furrower depending upon the spacing adopted.
- After application of 3rd dose fertilizer (90 days), work victory plough along the ridges for efficient and economical earthing up.
- At 150 days after planting, earthing up may be done with spade.

Control / Regulation of flowering in sugarcane

- Ethephon (ethrel) applied at the rate of 500 ppm effectively controlled flowering in a number of profuse flowering varieties.
- By altering the planting date, flowering can be avoided in heavy flowering areas.
- Adsali planting or special season planting (July to September) helps in avoiding flowering and its adverse effects.
- Non-flowering varieties are Co 8021, Co 86032, Co 87025, Co 91010, Co 94005 and Co 94008.

Detrashing

- Detrashing refers to removal of unwanted bottom dry and green leaves at regular intervals.
- Sugarcane stalk bears large number of leaves (30-35) equal to the number of inter-nodes under good management systems.
- Detrashing should be taken up after the cane formation around 150 days after planting. There after it could be done at bi-monthly interval depending up on the labour availability.

Propping

- The operation of tying the leaves together using the bottom dry and green leaves is known as propping.
- It is primarily done to avoid lodging of cane.
- Propping can be either done for each row or two rows can be brought together and tied.
- It is done at the age of 210 days of the crop

Removal of water shoots

- Water shoots are late formed tillers or side shoots, which are robust and fast growing.
- They originate mainly due to excess water supply, heavy and late manuring, inadequate earthing up.
- Water shoots contain lot of water, low sucrose and more of reducing sugars. Water shoots affects the growth of adjacent statics.
- Therefore removal of water shoots whenever they appear is highly essential. Water shoots can be used as cattle feed.

Covering the field with green leaf manure plants

- There is a practice of spreading lightly one to two tonnes of green wild indigo plants per acre over the entire planted fields immediately after the planting.
- When this is done, the evaporation of moisture from the recently planted fields is controlled to some extent and it will be possible to prolong the interval between irrigation.
- Subsequently the green matter can be incorporated in the soil.

Nutrient Management

- Bulky organic manures like farmyard manure, compost and pressmud must be incorporated into the soil at the rate of 15 to 25 t/ha before planting.
- Soil-test based fertiliser schedules are advisable. When this is not possible, a blanket schedule of 275-65-115 kg of N, P and K can be adopted.
  - For Coastal and flow irrigated areas - 270 : 112.5: 60 N: P_2O_5: K_2O kg /ha
  - For Lift irrigated areas - 225 : 112.5: 60 N: P_2O_5: K_2O kg /ha
  - For Jaggery producing areas - 175 : 112.5: 60 N: P_2O_5: K_2O kg /ha
- Phosphatic fertilisers, preferably super phosphates can be applied basally or at the time of first hoeing and weeding during 30 to 45 days after planting.
- Nitrogenous and potassic fertilisers must be applied in four splits, first split during 30 – 45 days, second split during 60-75 days, third split during 90 – 105 days and fourth split during 120 – 135 days after planting.
- The efficiency of urea can be enhanced by blending it with neem cake powder in 4:1 ratio, a day before application. It is advisable to apply the mixture of urea and potash fertiliser in holes of 10 cm depth at intervals of 15 cm spacing on the sides of the plant rows.

- Fifty kg of micronutrient mixture/ha made up of 20 kg of ferrous sulphate, 10 kg of manganous sulphate, 10 kg of zinc sulphate, 5 kg of copper sulphate and 5 kg of borax may be applied basally in the planting furrows.
- When the chlorotic symptoms due to deficiency of iron or zinc are observed on the leaves of the crop, 5 kg of ferrous sulphate, 2.5 kg of zinc sulphate and 5 kg of urea per hectare may be dissolved in 500 litres of water and sprayed over the foliage. If necessary, one or two more sprayings can be given at intervals of 15 days.
- Azospirillum and phosphobacteria biofertilisers at 10 kg each/ha may be mixed with 10 kg of compost and applied basally in the planting furrows or at the time of first hoeing and weeding during 30 – 45 days after planting. The soil pH must be maintained in the neutral range of 6.5 to 7.5 for the crop.
- Foliar Nutrition of urea @1- 2.5% & potassium @2.5% under moisture stress is useful to improve yield and quality.

Nitrogen

Influences sugar yields and quality. Required for vegetative growth [tillering foliage formation, stalk formation and root growth]. Deficiency of Nitrogen: shows paleness of foliage, early leaf senescence thinner and shorter stalks longer but thinner roots. Excess Nitrogen, prolongs vegetative growth, delays maturity and ripening, and lowers juice quality, susceptible to lodging and pests and diseases incidence.

Phosphorus

“P” requirement is less than N and K. Required for adequate tillering. Interacts with N and thus enhance ripening.P deficiency leads to reduced tillering, delays in canopy development, Affects stalk elongation, Less production of secondary and tillering stalks and leaf color appear violet green.

Potassium

Essential for carbon assimilation, photosynthesis translocation of carbohydrates. Involved in various enzymatic activities. Important for sugar synthesis, maintains cell turgidity, moist stress. Develop resistance to pests and diseases and lodging. Balances the effect of N & P.

Water Management

- Water requirement of cane is high and varies with region. In Tropics, water requirement is 2000-3000 mm, in sub-tropics 1500-2000 mm. Under severe stress the yield loss may go up to 60-70 per cent.
  - Germination phase = up to 60 DAP
  - Formative phase = 60- 130 DAP
  - Maturity = 250-365 DAP.
- Water requirement during formative and grand growth phases is more. Light & frequent irrigations gave higher yield, than heavy irrigations at longer intervals. In summer, irrigation interval depends up on soil type and season. Generally shorter interval in winter and in heavy soils whereas longer intervals in summer. In light soils trash mulching has to be done @3t/ha.
- To support and sustain a vigorous nursery crop, irrigating at optimum levels in important
- Any shortage in the irrigation would lead to reduced sett yield
- Moisture stress would pre-dispose the crop to the attack of some pests and diseases

- **Tillering, cane elongation** and **early ripening** are critical stages for soil moisture.
- Last 4 weeks should not be irrigated to facilitate maturity.
- Irrigation can be provided: 0.75, and 0.50 IW/CPE ratio at tillering, grand growth, maturity.
  - According to moisture depletion irrigating at 25% depletion of available soil moisture (ASM) may be ideal
  - This in practical terms means:
    - Once in 6-7days in a loamy soil and
    - At around 10-12 days in heavy clay soil

Weed Management

- Critical period can be defined, as “the shortest span of time in the ontogeny of crop growth when weeding will result in higher economic returns”.
- Sugarcane being initially slow-growing crop faces an acute competition from weeds.
- In sugarcane, weed infestation during 60-120 days after planting has been found detrimental for the final crop yield.
- In some cases it requires weed free for the first 90-100 days before and, most sensitive to weeds during tillering stage. It can be even up to 120-150 days in some situations.
- In ratoon crop, critical period of crop-weed competition has been identified as 30-50 days after ratoon initiation.
- Besides, weeds remove large amount of nutrients from soil. Direct yield losses ranged from 11-74% depending upon the nature and intensity of weed flora and period of occurrence of weeds.
- The loss is mainly due to restriction of tiller production.
- Removing weed at any time during growing season may not be beneficial. It is necessary to identify critical period of crop-weed competition to render weed control practices more effective.

- **Major weed:**
  - **Sedges**
    - *Cyperus rotundus.*
  - **Grasses**
    - *Cynodon dactylon*, *Sorghum halepense*, *Panicum* spp., *Dactylocterium aegyptium*.
  - **Broad leaved weeds**
    - *Chenapodium album*, *Convolvulus arvensis* L., *Amaranthus viridis* L., *Portulaca oleraceae* L., *Commelina bengalensis* L., *Trianthema portulacastrum* L., *Striga* spp.
- 1st option: Frequent intercultivation i.e. Manual weeding at 30, 60 & 90 days after planting (DAP) is effective to control weeds.
- 2nd option: Grow companion crops for first 60-90 days, so that crop experiences less weed competition.
- 3rd option: Trash mulch at 45 DAP @ 7-10 t/ha, 10 cm thick is effective against many weeds.
- 4th option: Chemical weed management
  - Pre-emergence application of Metribuzin (1-2 kg/ha) or Alachlor (1-1.5 kg/ha) or Atrazin (1-2 kg/ha) can be applied to reduce the weed population.
  - Post-emergence spray of Prosulfuron (20-30 g/ha) or Metsulfuron-methyl are useful to reduce the weed population up to 120-140 days.

Management of parasitic weed Striga (commonly known as witch weed) in sugarcane

- *Striga* is a becoming a major problem in sugarcane in many sugarcane growing areas of the country.
- *Striga* removes nutrients and extracts water from the sugarcane plant and causes heavy loss in cane productivity and quality.
- Intercropping with legumes such as soybean, cowpea or groundnut within the sugarcane rows row can significantly reduce the number of *Striga* coming to maturity. Plants which are pulled, within 2-3 weeks of the start of flowering, should be taken out of the field and burned so that seeds are not produced and shed from the drying plants.
- Where it is available and feasible or the farmer, the herbicide 2,4-D can be used before *Striga* flowering, as an alternative to hand-pulling but it may need to be repeated.
- trash mulching at 5.0 tonnes/ha at 90 days after planting has been found effective in reducing the density and dry weight of *Striga*.
- Pre-emergence application of atrazine at 1.0 kg/ha + 1 hand weeding at 45 days after planting with an earthing up at 60 days after planting combine with post-emergence application of 2,4-D Na salt at 5 g/l (0.50%) + urea 20 g/l (2%) at 90 days after planting has been recommended for effective control of *Striga* in sugarcane.

Crop Protection

Diseases

Red rot

Smut

Wilt

Ratoon stunt

Red stripe

Disease Management strategies

Cultural method

- Select healthy setts for planting.
- Field should maintain at proper sanitation.
- Ungerminated setts should be removed and fill the gap with new setts which should be treated before planting.

Mechanical method

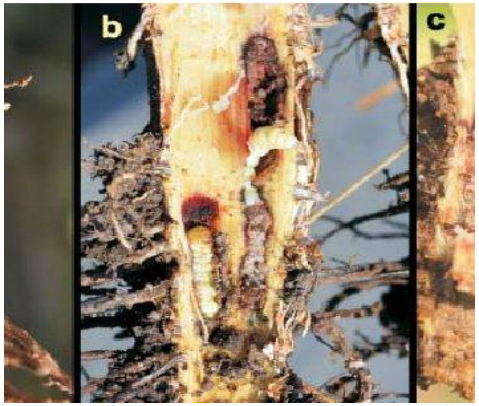
- Treat the setts with hot water at 50°C for about 2 hours this gives 100 per cent control. A temperature higher than this would kill the cane and lower temperature than the specified enables the pathogen to survive.
- Aerated steam therapy eliminates the pathogen from the infected canes. Use of disinfectants to clean seed cutting tools which would reduce the chance of spread of pathogen from the infected to healthy setts.

Chemical method

- Chemical disinfectants that may be used on cane cutting knives includes, Lysol, Dettol, ethanol, Mirrol and Roccal. Atleast 5 minutes of contact with the cutting surface is needed to assure disinfection.

Insect pests

Early shoot borer



Root borer

Top borer

White fly

Black bug

Insect Pest Management strategies

ETL: 15% dead heart

Cultural method

- Use resistant varieties like CO 312, CO 421, CO 661, CO 917 and CO 853
- Early planting during December – January escapes the early shoot borer incidence.
- Sugarcane intercropped with Daincha recorded the lowest early shoot borer incidence.
- Trash mulching along the ridges to a thickness of 10-15 cm 3 days after planting.
- Ensure adequate moisture to bring down the soil temperature and increase humidity (unfavourable condition for the multiplication of early shoot borer).
- Partial earthing up on 45 days after planting reduces the incidence.

Physical method

- Remove and destroy dead hearts.
- Install pheromone traps @ 10Nos. /ha for surveillance and monitoring, change the septa/lure once in 30 days.

Biological method

- Apply granulosis virus 1.5 x 13 5 IBS / ha (750 diseased larvae / ha)along with teepol twice on 35 and 50 DAP.
- Release 125 gravid females of *Sturmiopsis inferens* a tachinid parasite per ac.

Chemical method

- Apply any one of the following insecticides if the pest crosses ETL.
- Carboryl +Sevidol 4% G 12.5 kg, Carbofuron 3G 33 kg (Soil application). The granular application should be immediately followed by irrigation.
- Chlorpyriphos 1000 ml a sticker like Teepol (250 ml / 500 l of water) can also be added to make the solution stick on to the surface of the crop and it is preferable to use high volume sprayer to be most effective.

Ratoon Management

- Select variety suitable during plant crop. Plant crop should be harvested at right maturity Plant crop should be harvested in February to ensure favorable re-growth of ratoon sprout, because sprouting will be poor under low temperatures. Delayed harvesting should be avoided.
- Harvesting close to the ground with sharp cutting is most important for good ratooning
  - Stubble shaving to 4-6 cm is recommended if no uniform cut at harvest
- Remove the trash but do not burn it
- Irrigated the field properly
- Shoulder breaking or off-barring to remove decayed stubbles
- Gap filling with sprouted setts or seedlings
- Ratoon is less efficient in N utilization, hence 25% additional N of the recommended dose of N for the plant crop, from 5-7 days after ratooning is desirable
- Nitrogen should be applied in 2 splits at ratoon initiation and 60 days after root initiation.Entire dose of P & K should be applied at ratoon initiation.
- Spraying of $FeSO_4$ @ 2.5kg/ha in 150 litres on 15^{th} day if chlorotic symptom is noticed
  - If persists repeat twice at 15 days interval
  - In the last spray add 12.5kg urea
- After cultivation practices to be done more effectively
- Ratoon requires more plant protection
  - Grassy shoot disease, ratoon stunting

Maturity and Harvest

- Sugarcane matures after the ripening phase, which is the process of sucrose accumulation preceded by the conversion of glucose into sucrose. Ripening is influenced by climatic features, age of the cane as well as many management factors like intercropping, lodging and fertilizers.
- Harvesting mature cane gives maximum recovery percentage as well as maximum sugar or jaggery yield.
- Identification of maturity is crucial for the success in sugar production, as under mature canes and over mature canes pose similar problems of low recovery.
- Onset of cold season, or reduction in temperature of 20-25^{o}C is invariably favourable to maturity, if associated with dry weather.
- A sugarcane crop of more than 6-8 months will mature when it is exposed to such climate- irrespective of planting time. But cane of less than 6 months may not mature, even when it is exposed to such climate.
- The ripening process is also assisted by no irrigation in the last 30-45 days of the crop.
- **Ripening is influenced by number of factors :** 1. Climate; 2. Nutrition; 3. Variety

- When, the sucrose is converted back into glucose due to over maturity, it is called **inversion**.
- The sugar or jaggery yields are the function of sucrose in the cane and hence over mature cane should not be harvested. Even when harvested, sugarcane is left uncrushed for more than two to three days, inversion may set in and reduce the sugar yield.
- Normally, a mature cane should be able to give a sugar recovery of 10-11% under ideal climatic and crushing condition and around jaggery recovery of 9.5-11.5%.
- Sugarcane farmers believe that cane matures after flowering. The process of flowering (arrowing) is also governed by the age and climatic features like maturity, hence they may be correct partially. Sometimes the process of arrowing itself may get extended leading to harvesting over mature canes. Generally if the arrowing take 5-8 days, it is correct to harvest the canes within 10-15 days of arrowing. Delay in harvesting after 15 days of arrowing may lead to reduced sugars.
- Sometimes flowering is misleading, as some varieties flowers well before the onset of cold season, when maturity has not yet set in. In fact, arrowing itself is considered as deterrent to increasing sugar in the Cane, as un-flowered cane has highest sugar yield. Attempts are made to suppress the flowering by chemicals (called artificial ripening).
- Polaris, Sodium metasilicate and Ethrel are used for **artificial ripening** of cane (Polaris @ 5kg in 600 l of water/ha)

- Ripening of sugarcane refers to rapid synthesis and storage of sucrose in the stalk
- Accumulation of sugar in the stalk starts soon after completion of elongation phase
- Glucose produced during photosynthesis is not utilized for conversion but stored as sucrose
- When the concentration exceeds 16% in the juice and 85% purity the cane is said to be matured
- As the crop advances in maturity:
  - Water content decreases
  - Sucrose content increases
  - Reducing sugars decreases
    - Both organic and inorganic non-sugars also decreases
- At peak maturity sucrose content is at maximum and non-sugars at minimum
- The maturity of sugarcane is generally recognized by the lower leaves gradually withering up and leaving fewer green leaves at the top.

- If the grower can keep and use a hand sugar refractometer, the testing of maturity becomes easier. If the sample of juice taken from middle portion of stalk shows a reading between **17-18**, the cane crop may be considered ready for harvest. In case hand refractometer is not available, decide the harvesting time by sweetness of the cane. Stalks are cut at the ground level, preferably after digging the down the earthed up ridges.
- When the refractometer reading between top and bottom of cane is 1:1 – is right time to harvest. If harvesting delayed
    - Sucrose content decreases
    - Non-sugars increases
    - Fibre content increases
- The dried leaves are stripped off from the cane and green top is cut from the topmost part of the cane and clean canes are tied up in bundles.

Yield

- The average yield of 11-12 month old plant crop in Northern India ranges from 400-500 quintals/ha.
- A good crop under good management may yield about 800-1000 quintals/ha.
- The 18 month crop in Southern India especially in Maharashtra and Tamil Nadu usually give a 1000-1200 quintals of canes/ha.
- Ratoon crop ordinarily give a somewhat lower yield than the plant crop.

Cropping systems

❑ Intercropping

- Since a slow grower during initial 2-3 months may be an intercrop raised
- The crop should not affect cane yield
- Marketability, ability and feasibility decides the short crops
- Pulses, potato, onion etc are some

❑ Sequential cropping - Rotations

- After sugarcane 1 or 2 or 3 crops
  - Rice based cropping system for one year
  - Wheat based
- Sugarcane-banana- rice based crop rotations

Constraints: (less sugar recovery and quality)

- Harvested canes should be supplied with in 5-10 days.
- Limited crushing capacity of mills.
- Stocking of canes at mill yard.
- Inordinate delay in transport of harvested cane from field to mills.
- Week end shut down of the factory and unforeseen circumstances.
- Weather parameters like high temp & humidity leads to greater deterioration.

Products from sugarcane juice

- Jaggery
- Juice concentrate
- Powder jaggery
- Vinegar
- Sugar

Quality Considerations

- The maturity is best indicated by testing the cane by **Brix refractometer** (Hand Refractometer). It is hand held portable instrument to measure total dissolved solids. The total dissolved solids increase with age and is maximum at maturity. The ideal Brix reading to indicate harvesting time is 17-18. A drop of juice from freshly cut cane is placed on refractometer plate and read against sunlight to get instant readings. But correction factor needs to be applied, as the readings are calibrated for 20^{o}C.
- As the crop matures, the moisture content reduces, sucrose content increases, reducing sugars and non-sugar solids rduce.
- **Brix values:** A good mature cane have Brix values between 17-18 and such cane should give high sugar recovery and high juice recovery.
- **Pol in juice: Polarimeter** readings of sample juice (pol in juice) give more precise reading of sucrose content and is a better measure of quality. These values vary between 11-16%. However, polarimeter readings in cane (pol in cane) can be lesser than pol in juice as total cane is considered.
- **Purity percentage:** It indicates the share of sucrose in total dissolved solids. Ir is obtained by dividing pol in juice with corrected Brix% of juice, expressed as percentage

Purity % = (pol in juice/corrected Brix values) x 100

- **Recovery percentage:** It indicates quantity of jagerry or sugar obtained per unit of cane weight. It is calculated by

Recovery % = (Weigt of sugar or jagerry obtained/Weight of cane crushed) x 100

It may also be obtained by:

Sugar recovery % = [S - 0.5 (B-S)] x 0.73

Where, S = Sucrose % (pol in juice) and B = Corrected Brix values

- **Commercial cane sugar (CCS):** It is a measure of sugar obtained per unit area from the millable cane harvested. It is obtained by:

CCS (t/ha) = Recovery % x Weight of millable cane (t/ha)

- **Crystal sugar:** Bright white to dull white colour; crystalline freely falling; crystal size 0.5-3 mm; 2-3 years keeping quality; sucrose content 98-99%; 100% solubility.
- **Jagerry:** Dark brown to light crimson (natural) or light yellow to light brown or whitish yellow to dark golden coloured; various shaped-bucket shape, cubical shape, powdered, flakes, hand shaped and even liquid jagerry is available; sucrose 70-80%, balance made of moisture, minerals and vitamins; keeping quality 2 months to 1 year; hardness depends on the setting point or mineral content of juice.

Terms Used in Sugarcane

- **Sett:** Piece of sugarcane stalk having 2-3 buds on it, used for planting the fresh crop.
- **Arrowing:** The process of initiation and growth of inflorescence in sugarcane.
- **Fluff:** Fertilized mass of seed of sugarcane, often in mass of fibrous awns.
- **Sett roots:** First set of roots evolved from the **root eyes** at the base of each sett, when ideal conditions are provided at the time of planting. They are temporary in nature.
- **Bagasse:** Fibrous part of cane left over after the juice is extracted.
- **Detrashing:** Process of removal of dried leaves at the time of harvesting.
- **Water shoots:** Late grown shoots, which do not accumulate sucrose at the time of harvest and pose problems of recovery percentage. They are expected to be removed or not harvested.
- **Millable cane:** That part of cane which is obtained by cutting top 1/3rd part of the harvested cane (to remove glucose rich part) and detrash it to make it ready to be crushed.
- **Planted cane:** Sugarcane obtained by planting the setts freshly.
- **Seed cane:** The cane raised specifically for the purpose of obtaining setts for propagation.
- **Stale cane:** The cane not used for crushing, as the cane would have deteriorated in terms of its sucrose content.

- **Inversion:** Process of conversion of sucrose back into glucose, when the over-mature, cane is harvested or harvested cane is kept uncrushed for more than 1-2 days.
- ***Eksali*:** Sugarcane crop planted during normal season maturing in 10-12 months.
- **Adsali:** A sugarcane crop, planted 3-6 months in advance and harvested after 15-18 months.
- **Jaggery:** Solidified sweet blocks obtained by boiling the sugarcane juice.
- **Ratoon:** A crop raised from subterranean buds from the stubbles after the harvest of the main crop.
- **LTD/TVD leaf:** Last transverse mark/transverse visible dewlap leaf of sugarcane, used as an indicator leaf for foliar analysis of nutrients to know the needs of the crop.
- **Seedling/Settling:** Seedling is young plant developed from the germination of true seed, normally used by breeders; settling refers to **young plant coming out of sett**, commonly known to produce commercial canes.
- **Brix:** The values of Brix Refractometer, indicating the total dissolved solids, including sucrose. The values of Brix should be around 17-18 at the time of harvest.
- **Pol. in juice:** It refers to **Polarimeter readings**, indicating the sucrose percentage in juice. The pol in juice values vary between 11-16% in the juice from the cane ready for harvest.
- **Commercial cane sugar (CCS):** It is sugar manufactured from 1 ha of land, expressed as t/ha. It is calculated by multiplying recovery % with cane yield (millable cane).

JAGGERY MAKING

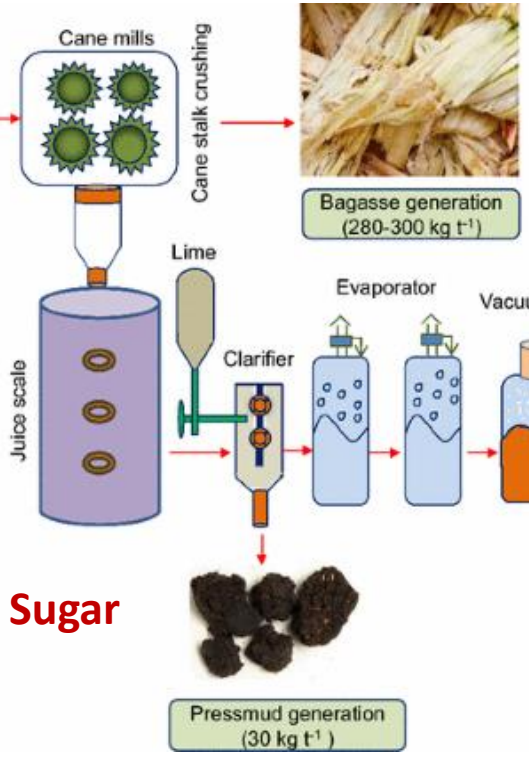
Step 1. Cutting sugar cane from fields
Step 2. Feeding the grinder to extract juice
Step 3. Boiling the juice
Step 4. Adding Ingredients (Na_2CO_3 - reducing agent helps in making jaggery balls)
Step 5. Tray Feeding
Step 6. Jaggery output

Jaggery and Health

Crystal sugar manufactured from sugar mill has 98% sucrose and negligible quantity of other nutrients. But, jaggery has arround 75-78% sucrose, 5-6% moisture and minerals like Fe, P, Ca, Mn as well as vitamins. For this reason, use of jaggery is always advantageous to human health than crystal sugar.

Use of Brix Refractometer: https://youtu.be/AWpNv59VLHg

1,600 million t y^{-1} sugarcane produced globally. Among these, 540 million t y^{-1} sugarcane goes for processing



White Crystal Sugar

Bioethanol

Paper

Thank You...