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Review Article

Sustainable Initiative Technology for Enhanced Cane Production and Profitable Economic Returns: A Review

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Abstract

The new technology of sugarcane planting, known as one-eye-set seedlings, offer a high standard of plant health and vegetative vigor. Sugarcane crop requires huge quantity of seed cane for planting under conventional method, which contributes a major share in cost of cultivation. Besides, large quantity of seed material poses a big challenge for transportation and handling. This problem can be effectively addressed through adoption of sustainable sugarcane initiative through planting of bud chips, which can save the cost and inconveniences associated with conventional planting methods. Several authors have reported advantages of planting single bud chips over conventional methods with respect to germination, crop establishment, growth and development of sugarcane crop. Sustainable sugarcane initiative technology favourably influenced various yield attributing factors such as plant stand, millable cane per clump and weight of single cane thereby resulting in higher yield. Some authors have also recorded higher brix value and higher juice weight at harvesting stage with planting of single chip bud seedlings of sugarcane. Compared with conventional method, economics of cultivation goes in favour of bud chip method of planting. Based on research findings by various workers, it can be said that planting of sugarcane by bud chip method is superior to planting by conventional methods. The first species hybrids were obtained in 1893 by Wakker, who crossed noble sugar cane, *Saccharum officinarum*, with Kassoer, considered by him as a wild species. In later years it appeared from morphological investigations by Jeswiet, (1916) and from cytological investigations by Bremer, (1921) that Kassoer is to be considered as a spontaneous hybrid between *S. officinarum* and *S. spontaneum*, the wild glagah. In 1895 Kobus imported the Indian sugar cane Chunnee in Java.

Keywords: *Sugarcane, bud chip method, sustainable sugarcane initiative.*

Introduction

Sugarcane is a tall perennial tropical grass, which tillers at the base to produce unbranched stems of 2-8 m tall, and of around 5cm in diameter. It could be called as giant

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grass. It is cultivated for these thick stems or stalks or canes, from which the sugar is extracted. Modern sugarcane varieties are complex hybrids synthesized from *S. officinarum*, the noble sugarcanes; *S. barberi,* the Indian sugarcanes; *S. sinense*, the Chinese sugarcanes; and the two wild species *S. spontaneum* and *S. robustum*. So far, the involvement of *S. robustum* germplasm is limited and is restricted to a few commercial varieties in Hawaii. The genes for sucrose accumulation are derived from *S. officinarum*, *S. barberi*, and *S. sinense*. The wild species, *S. spontaneum*, has contributed disease resistance, tolerance to environmental stress, and higher yield potential through higher biomass production. The genus Saccharum belongs to the tribe Andropogoneae in the family Gramineae and has undergone extensive taxonomic revision. The generally accepted present classification is that of Jeswiet, (1925) as modified by Brandes, (1956) to include the species *S. robustum* which was discovered and described after Jeswiet's revision. A group of clones in which the inflorescence is aborted, resulting in a cauliflower-like delicacy, is classified as a separate species, S. edule. Three species, *S. officinarum*, *S. barberi*, and *S. sinense*, were cultivated in different parts of the world long before the advent of man-made hybrids. Two species, *S. spontaneum* and *S. robustum* are wild.

Sugarcane is an important export in many countries worldwide. Sugarcane (*Saccharum officinarum* L.) occupies an important position among commercial crops grown in the world. For the 2022/23 harvest, 596 million tons of sugarcane are estimated, according to the National Supply Company, up 2.9% than the previous crop. Sugar production for the current harvest is estimated at 40.3 million tons; ethanol produced is expected to reach 24.8 billion liters. About 80% of the world's sugar is produced from cane grown in tropical and subtropical climates. The remaining 20% comes from sugar beets, which are grown mostly in the temperate zones of the Northern Hemisphere. Sugarcane is a tropical and subtropical crop that thrives in hot, humid environments. Sugarcane cultivation is limited to 30° North and south latitudes. Tropical Asia, Mexico, and South America, Africa, South-western Europe, temperate Asia, the Pacific, Southeastern USA, Australia, are cultivating sugar cane. It was grown after 6000 BC in New Guinea and eventually spread across the human migratory routes to Asia and the Indian subcontinent from around 1000 BC on. Here is a summarized list of the top ten countries in order of the amount of overall sugar they produ- du-
ce Brazil, India, China, Thailand,USA, Pakista n, Mexico, Russia, France, and Germany. In the 2022/2023 crop year, global sugar production is expected to be 182 million metric tons, up 1.7 million tons from the previous year.

More than 110 countries produce sugar and the size of their contributions is affected by local politics and economic policy. For example, the war in Ukraine is expected to reduce that country's sugar beet production by 23% in 2022/2023. This crop is efficient in utilizing solar energy for production of sugar and other renewable energy (Mohanty, *et al.*, 2015). Sugarcane cultivation is facing several challenges due to increasing cost of input and labor (Loganandhan, *et al.*, 2013). Under conventional method, planting material occupies a major chunk in cost involved in sugarcane cultivation. Depending on variety and method of growing, there is need for huge quantity of seed cane for planting of sugarcane. Requirement of huge quantity of seed material also poses a big challenge for transportation, handling and planting (Kumar, 2020). Srivastava, *et al.*, (1981) also mentioned that a large quantity (6-8 t/ha) of 3-budded setts are required for sugarcane planting, which is nearly 22 to 25 % of the total cost of production.

In order to reduce the overall cost of production and the drudgery involved in handling huge quantity of planting materials, there is strong need to develop suitable technology for sugarcane cultivation. To address this situation, many authors have suggested adoption of sustainable sugarcane initiative (SSI) with Bud Chip Technology, which can save large quantities of seed canes (Loganandhan, *et al.,* 2013; Parajuli, *et al.,* 2019) under farmers' field situation, Mishra, (2019) suggested use of axillary buds of sugarcane plant, generally known as bud chips, for reducing the volume of seed material and augmenting the quality of seed cane. In this method, a root primordium along with small volume of tissue adhering to the bud is used for regeneration of sugarcane plant. Bud chip method of sugarcane growing can save nearly 80% of the stalk material used for planting (Jain, *et al.,* 2010) that can be alternatively used for consumption purpose.

Arthi, *et al.,* (2016) opined that sustainable Sugarcane Initiative (SSI) is a new method, which can boost the productivity of sugarcane by utilizing less resource such as seed, water and space. Shanthy and Ramanjaneyulu, (2014) described Sustainable Sugarcane Initiative (SSI) as a combination of many viable technologies in order to enhance the yield of sugarcane. Sugarcane production under sustainable sugarcane initiative technique minimizes the requirement of seed & water and enables the crop for proper utilization of plant nutrients to obtain higher yield (Loganandhan, *et al.,* 2013; Naik, *et al.,* 2015). As per Parajuli, *et al.,* (2019), Sustainable Sugarcane Initiative aims at providing valuable solutions to the farmers for enhancement of productivity of land, water and human labour.

Centre of Origin and Diversity

The genus *Saccharum* probably originated before the continents assumed their current shapes and locations. The genus consists of 35–40 species and has two centers of diversity: the Old World (Asia and Africa) and the New World (North, Central and South America). Asia has approximately 25 native species, North America six native species and four or five introduced species, and Central America has three or four native and some introduced species (Webster and Shaw, 1995). Africa has two native and Australia have one naturalized species (Darke, 1999; Bonnett, *et al.,* 2008).The Brazilian *Saccharum* species have not been well characterized. Only regional floristic surveys have reported the presence of these species. One study described the native species *S. asperum, S.angustifolium, S. purpureum, S. biaristatum, S. glabrinodis, S. clandestinus* and *S. villosum*, but the authors commented that these species were poorly defined so that it is possible that they all might be variations of a single species (Smith, *et al.,* 1982). In fact, from the species listed on this work, only *S. asperum*, *S. angustifolium* and *S. villosum* are currently accepted scientific names (The Plant List, 2010). In another study, the native species were identified as *S. villosum, S. asperum* and *S. baldwinii* (Filgueiras and Lerina, 2001).The *Saccharum* species involved in the development of modern sugarcane cultivars originated from Southeast Asia (Roach and Daniels, 1987). Because *S. officinarum* and *S. spontaneum* are the major contributors to the genomes of modern varieties, the geographical origins of these species will be described in more detail. *S. officinarum* has been cultivated since prehistoric times (Sreenivasan, *et al.,* 1987). It is believed that its center of origin is Polynesia and that the species was disseminated throughout Southeast Asia, where a modern center of diversity was created in Papua New Guinea and Java (Indonesia); this is the region where the majority of specimens were collected in the late 19th century (Roach and Daniels, 1987). The center of origin and diversity of *S. spontaneum* is the more temperate regions of subtropical India. However, because *S. spontaneum* can be grown in a wide range of habitats and altitudes (in both tropical and temperate regions), it is currently spread over latitudes ranging from 8°S to 40°N in three geographic zones: a) east, in the South Pacific Islands, Philippines, Taiwan, Japan, China, Vietnam, Thailand, Malaysia and Myanmar; b) central, in India, Nepal, Bangladesh, Sri Lanka, Pakistan, Afghanistan, Iran and the Middle East; and c) west, in Egypt, Kenya, Sudan, Uganda, Tanzania, and other Mediterranean countries. These zones roughly represent natural cytogeographical clusters because *S. spontaneum* tends to present a different number of chromosomes in each of these locations (Daniels and Roach, 1987).

Genetic Constitutients

Saccharum species present high ploidy levels. *S. officinarum* is octoploid (2n = 80) having *x* = 10 chromosomes, which is the basic chromosome number of members of the Andropogoneae tribe (D'Hont, *et al.*, 1995; Cesnik and Miocque, 2004; Nobrega and Dornelas, 2006). *S. spontaneum* has *x* = 8 chromosomes (D'Hont, *et al.*, 1996) but presents great variation in chromosome numbers with five main cytotypes: 2n = 62, 80, 96, 112 or 128 (Daniels and Roach, 1987; Sreenivasan, *et al.*, 1987).

Modern sugarcane cultivars, which were derived from the hybridization between these two species, are considered allopolyploid hybrids (Daniels and Roach, 1987), with most exhibiting a 2n + n constitution, representing two copies of the *S. officinarum* genome plus one copy of the *S. spontaneum* genome (Cesnik and Miocque, 2004). The *S. officinarum* genome usually duplicates when it is hybridized with *S. spontaneum.* This phenomenon facilitated the work of the first breeders because nobilization consisted of increasing the ratio of the *S. officinarum* to that of the *S. spontaneum* genome (Bremer, 1961). In situ hybridization studies have shown that the genomes of modern hybrids are composed of 10–20% of *S. spontaneum* chromosomes, 5–17% of recombinant chromosomes containing part of *S. officinarum* and part of *S. spontaneum* chromosomes and the remainder composed of *S. officinarum* chromosomes (Piperidis and D'Hont, 2001; D'Hont, 2005). The hybrids are usually aneuploid, with a prevalence of bivalents, a significant proportion of univalents and rare multivalent associations during meiosis (Daniels and Roach, 1987). Despite this genome complexity, evidence suggests a diploid-like mode of inheritance (Hogarth, 1987).

Crop Establishment

Crop establishment with proper plant stand plays a vital role in deciding the yield of sugarcane crop. Under agronomic management practices, adequate effort is necessary to maintaindesired plant population and number of millable canes/ha so as to obtain desired yield from sugarcane crop. Chand, *et al.*, (2011) mentioned that germination is a major concern in sugarcane cultivation that requires proper attention through selection of suitable planting materials.

Fig 1: Sugarcane Bud Cutter: A Sugarcane Bud Cutter Is Used To Cut the Buds (Eye) of the Sugarcane Which Can Be Used As Seeds for Plantation Purposes

Fig 2: Conventional method of sugarcane planting requires 7 to 8 tons of seed cane per hectare and this is the main reason for slow rate of seed and varietal replacement. Sugarcane bud settling planting is a new method of sugarcane planting and is gaining popularity

Fig 3: Saplings of a Sugarcane Bud (Eye)

(In this technique, the bud along with a portion of the nodal region is chipped off and planted in raised bed nurseries / portray / polybags filled with FYM or press mud, soil and sand at 1:1:1 proportion. Seed material required under this technique is only 1 to 1.5 t/ha and the remaining cane after taking bud chips can be sent for milling /jaggery. It also facilitates easier handling and transportation. A two row tractor drawn mechanical planter for sugarcane bud chip settlings raised in protrays has been developed by ICAR Central Institute of Agricultural Engineering, Regional Centre, Coimbatore in collaboration with ICAR - Sugarcane Breeding Institute, Coimbatore, Tamil Nadu.)

Fig 4: Clone of Sugarcane Bud (Eye)

Various authors have reported higher germination rate from bud chip method of planting as compared to traditional planting method of sugarcane. Iqbal, *et al.*, (2002) observed higher germination percentage with use of single bud chips for planting as compared with the conventional planting of three budded setts. Mohanty, *et al.*, (2015) from Odisha reported that survival rate of seedling was 88 % in case of SSI technology as compared to 55.81 % germination of buds in case of conventional method thereby creating a sizeable gap in plant population. Mishra, (2019) observed higher percentage of survival (92.6%) of plants in bud chip method as compared with conventional method. Similarly, Sugeerthi, *et al.*, (2018) obtained higher establishment of 87.01% plants with planting of chip bud seedlings as compared to 70.51% establishment with planting of single bud setts. Treatment of sugarcane bud chips with growth promoting chemicals contributed immensely for obtaining higher rate of germination of the buds. It also improved seedling vigor, which ultimately enhanced the rate of seedling survival resulting in optimum plant stand. Kathiresan and Balasubramanian, (1995) reported increase in germination rate by treating the bud chips with 150 ppm NAA. Jain and Solomon, (2010) recorded higher bud sprouting and early plant growth with soaking of bud chips in ethephon solution @ 50-200 mg/l for 24 hours. Similarly, Jamuna, (2019) recorded maximum germination of 98 per cent with treatment of the budchips in the medium containing coco peat, vermicompost and 2% micronutrient mixture in combination with 1% AM fungi + 0.1% *G diazotrophicus* due to the combined effect of the bio- inoculants and organic manure. Jain, *et al.*, (2011) obtained higher rate of bud sprouting, root growth and plant vigor by soaking the bud chips in growth promoting chemicals such as ethephon (0.1 g/dm^3) and calcium chloride (1 g/dm^3) solutions. The size and age of bud chips have a bog role on germination and growth of seedlings.

Fig 5: Nursery of Sugarcane Bud (Eye)

Fig 6: Sugarcane Seedling ready for transplanting

Loganandhan, *et al.*, (2013) recommended normal size bud chips from 4–6 month old canesfor successful raising of seedlings.

Growth and Development

The growth and development of sugarcane plant directly affects the yield attributing factors and yield of the crop. There are diversified reports regarding effect of planting methods ongrowth and development of sugarcane. Bhanupriya, *et al.*, (2014) from Madurai recorded the highest no. of tillers (2,70,690/ha) at 90 DAP and maximum leaf area index (8.8) at 210 DAP with planting of single chip bud seedlings. Under farmers' field situation, Mishra, (2019) recorded higher number of tillers/plant and millable canes/clump by adopting bud chip method of planting as compared to conventional planting method. Loganandhan, *et al.*, (2013) also recorded 55% more tillers and 29% heavier canes in SSI method as compared to conventional method. Sugeerthi, *et al.*, (2018) obtained the tallest plants (229.46 cm), maximum number of tillers (113010/ha) and the highest dry matter production (85.87 t/ha) with planting of chip bud seedlings because of abundant light interception, aeration and lesser competition among plants. Selvan, (2001) reported the highest dry matter production at 30, 90 and 150 DAP (1.17, 2.73 and 9.05 t/ha, respectively) with planting of 40-day old chip bud seedlings raised in polybags. Sugeerthi, *et al.*, (2018) opined that proper care and well maintenance of seedlings under shadenet, in case of SSI technology, resulted in initial crop vigour and production of profuse root mass for effective absorption of nutrients and moisture by the crop.

Fig 7: Cultural Practices in Sugarcane Seedlings after transplanting

Fig 8: Cultural Practices in Sugarcane

Why Seedling of Single Eye Bud (Sugarcane SSB)?

The Seedlings are free from diseases at the time of supply:

The Seedlings are ready to plant in the field and don't require any gap filling

Quicker stem development and less time to harvest

Reduction in cost of irrigation and less cost in farming practices as planting of established seedlings in the field

Increase in sugarcane yield and sugar recovery.

Helpful in implementing season and varietal planting and harvesting program in sugar factory.

There are several reports indicating early growth of sugarcaneplant when bud chips are treated with growth promoting chemicals. Jain and Solomon, (2010) opined that soaking of bud chips with ethephon @ 50-200 mg/l resulted in better performance of rooting activity, plant growth, tillering and photosynthesis through modification of some of the biochemical activities responsible for early plant growth than use of untreated seed materials.

Geographical Distribution

Sugarcane is grown in all tropical and subtropical regions of the world, on both sides of the equator, up to approximately 35° N and 35° S (van Dillewijn, 1952; Gomes and Lima, 1964). In 2007, the main sugarcane-producing countries were Brazil (33% of the world's production), India (23%), China (7%), Thailand (4%), Pakistan (4%), Mexico (3%), Colombia (3%), Australia (2%), the United States (2%) and the Philippines (2%) (FNP, 2009).

In Brazil, sugarcane cultivation is concentrated in the southeastern region, which is responsible for approximately 70% of the national sugarcane production (Fig. 1). Northeastern Brazil, another traditional producing area, is responsible for 14% of sugarcane production, and midwestern Brazil, where the crop is rapidly advancing, represents 13% of the national production (CONAB, 2009). It should be noted that, despite the concerns about the expansion of sugarcane cultivation toward the Amazon region, the actual cultivation in this region is minimal and decreasing.

Classification and Nomenclature

The genus *Saccharum* was first described by Linnaeus, (1753) in his book *Species Plantarum*. The generic name is derived from the Greek word *sakcharon*, which means *sugar* and was duly Latinized by the author. The book described two species: *Saccharum officinarum* L. and *S. spicatum* L., which is currently classified under the genus *Perotis* (*P. spicata* (L.) T. Durand and H. Durand) (Dillon, *et al.*, 2007). The taxonomy and nomenclature of the genus has always been challenging (Bentham, 1883; Hackel, 1883; Pilger, 1940; Hitchcock, 1951; Bor, 1960; Almaraj and Balasundaram, 2006).

The genus has two known synonymous names, *Saccharophorum* and *Saccharifera*. When it was initially described, the genus consisted only of five to ten species from the Old World, including *S. officinarum*, *S. spontaneum*, *S. sinense*, *S. edule* and *S. barberi*. Later, several species that were allocated in other genera, including *Andropogon*, *Anthoxanthum*, *Eriochry sis*, and *Erianthus*, were transferred to *Saccharum*. The case of *Erianthus* is particularly interesting. Currently, the genus *Erianthus* comprises species from the Old World and New World that were previously separated into two different genera since the Old World species were firstly placed under the genus *Ripidium* (Grassl, 1971). Later, authors classified the Old World species under *Erianthus,* section *Ripidium* (Almaraj and Balasundaram, 2006). This distinction is supported by the fact that the Old World species contain a flavonoid (di-C-glycoside) that is absent in New World species (Williams, *et al.*, 1974). Cordeiro, *et al.*, (2003) analyzing these two groups by microsatellites markers also found that *Erianthus* accessions clustered separated in accordance to their geographical origin. *Erianthus* is considered to be closely related to *Saccharum* and many species have been assigned to either of these genera, depending on the criteria used. Several botanists, however, have considered that they are distinct genera (Hooker 1896; Haines, 1921, Jeswiet, 1925; Grassl, 1946; Dutt and Rao, 1950; Mukherjee, 1958). This distinction has been reinforced by studies using the presence of root tip tannin (Rao, *et al.*, 1957), leaf lipoid (Vijayalakshmi and Rao, 1963), esterase isozyme alleles (Waldron and Glasziou, 1972), and flavonoid composition (Williams, *et al.*, 1974) and microsatellites markers (Cordeiro, *et al.*, 2003).

Despite these data, the genera and species are more often separated and identified primarily on the basis of floral characteristics, which are considered by botanists to be more stable than vegetative morphological characters and the basic criterion used to differentiate both genera is the presence (in *Erianthus*) or absence (in *Saccharum*) of a floret structure called an awn, which is an extension of the mid-rib of the floral bract, on the top of lemma II or the upper lemma. The lemma in which the awn is absent is referred to as awnless. The current trend regards *Erianthus* as synonymous with *Saccharum* because this commonly used criterion to differentiate both genera (presence/absence of awn on the lemma) is variable and is not a consistent characteristic in the complex (Bor, 1960; Renvoize, 1984; Clayton and Renvoize, 1986). Therefore, the genus *Saccharum* currently comprises all species that were previously described under *Erianthus*. The tribe Andropogoneae consists of tropical and subtropical grass species that are grown in the Old World and New World. The most important cultivated members of the tribe are corn (*Zea mays*) and sorghum (*Sorghum bicolor*) (Daniels and Roach, 1987). *Saccharum* and *Sorghum* share many similarities in their genetic composition, as they originated from a common ancestral lineage that diverged approximately 5–8 million years ago (Al-Janabi, *et al.*, 1994; Guimarães, *et al.*, 1997; Figueira, *et al.*, 2008).

Botanical Description

Sugarcane is a tall perennial tropical grass, which tillers at the base to produce unbranched stems of 2-8 m tall, and of around 5cm in diameter. It could be called as giant grass. It is cultivated for these thick stems or stalks or canes, from which the sugar is extracted. The botany of cane consists of roots, leaves, stem (stalk) and inflorescence. The plants are perennial grasses that form stools of stalks or culms that can be several meters in length and are juicy, with high concentrations of sucrose. The stalk or culm consists of alternating nodes and internodes. On the node, there is a leaf scar, an axillary bud and a circumferential band of axillary root primordia. Stalk morphology is highly variable from one genotype to another and represents an important element for varietal characterization (Martin, 1961). Sugarcane leaves are alternate and are attached to the stalk, with one leaf per internodes. Sheathes consist of the sheath proper and the much smaller acropetal blade joint consisting of a leaf collar, dewlap, ligule and auricles. The shape, size and distribution of trichomes and the shape of the ligule and auricles are traits of taxonomic importance for varietal identification. Sugarcane leaves are numbered from top to bottom starting

The inflorescence of sugarcane is a ramified, conoidal panicle with a main stem, called the rachis, which is the continuation of the last stalk internode. The rachis holds secondary branches which in turn hold tertiary branches. The spikelets are located at the base of the tertiary branches and on the top of the secondary branches. Each spikelet has one flower, which is disposed alternately along the inflorescence secondary and tertiary branches. At the base of the spikelet, there is a ring of silky, colorless trichomes ('coma') that covers the spikelet **(Fig. 9a)** and help with spikelet dispersion. Next, there is a series of bracts called glumes ('glume I' and 'glume II'), both glabrous (Fig. 9b and c); upper lemma (or fertile lemma); and palea, which is hyaline and without veins and may be either rudimentary or absent (Fig. 9d). When the inflorescence matures, an anemochoric (by wind) dispersion of the propagules begins. The propagules consist of the coma, some floral clusters and the spikelet (Fig. 9a). The flowers (Fig. 9e) consist of two lodicules, the androecium and the gynoecium. The pollen grains are spherical when fertile and prismatic when sterile. Sugarcane fruit, called thecaryopsis (Fig. 10), is dry, indehiscent and one-seeded, and it cannot be separated from the seed. The fruit can only be distinguished from the seed when viewed with scanning electronic microscopy.

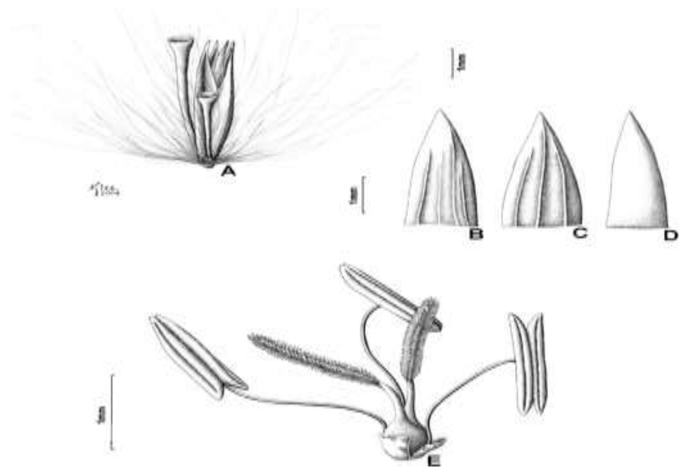


Fig 9: Diagram of a sugarcane propagule: a evident propagule, cupulate coma, empty pedicel and rachilla plus sessile spikelet. The other figures depict the different parts of the spikelet. b Glume I. c Glume II. d Palea. e Flower with two lodicules, three stamens, and gynoecium with ovary and two feathered stigmas (Illustration: Klei Sousa)

Fig 10: Sugarcane caryopses. Note the presence of the remains of styles at the tip of the caryopsis and the differentiated embryo region (at the opposite extremity of the style remains) (Photograph: Alellyx)

The Botanical description given below briefly:

Root

The root system is fibrous and are of two types namely 'sett roots' and 'shoot roots'. When the sugarcane sett is planted in the soil, the root primordials situated at the base of every cane joint is activated and produce roots. These roots are 'sett roots' and are mostly temporary. Sett roots can emerge within 24 hours of planting. The shoot roots arise from the root rings of the lower nodes of tillers. These roots are thick, fleshy, white and less-branched. These are permanent roots which are continually produced from tillers. Shoot roots emerge from the base of the new shoot, 5 -7 days after planting.

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.

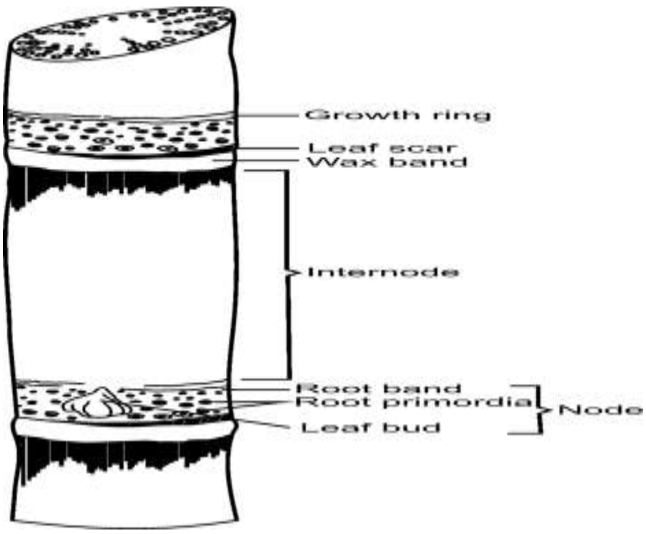


Fig 11: Shoot and Root emergence from Sugarcane Bud (Eye)

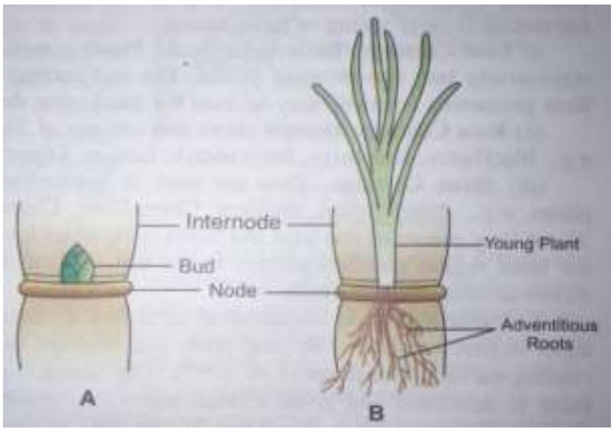
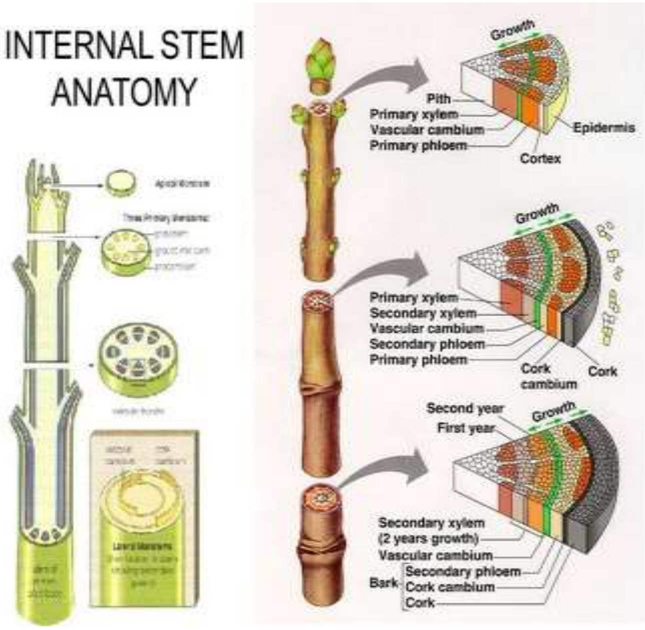


Fig 12: Shoot and Root emergence from Sugarcane Bud (Eye)



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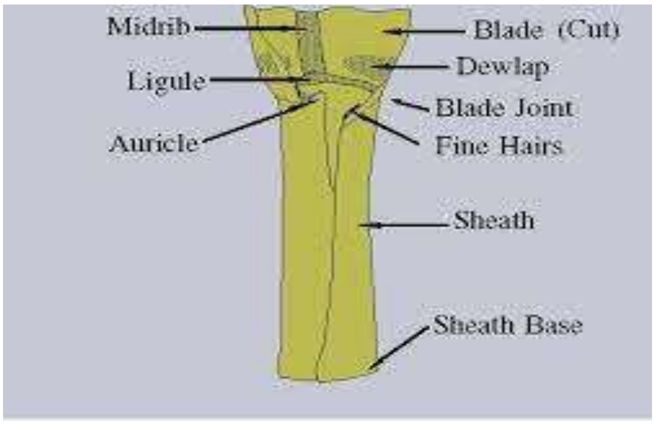
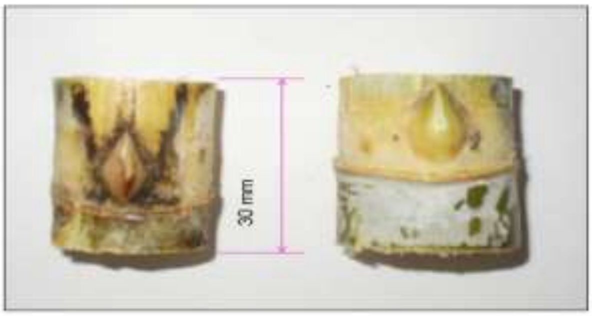


Fig 13: Different parts of the sheathe Blade
(Blade and the sheath, separated by a leaf joint)

Stem

Sugarcane is propagated vegetatively with stem cuttings /Bud (Eye) sapling. 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.



Achievable Bud Dimension Details

Fig 14: Sugarcane crops developed by Bud (Eye) transplanting

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.

Hybridization and Introgression
Modern sugarcane cultivars are the products of crosses between species of the genus *Saccharum* that were made by breeders in the late 19th century (Matsuoka, *et al.*, 1999). The most important species contributing to modern sugarcane varieties were *S. officinarum*, which was widely cultivated for its ability to accumulate sucrose in its stalks, and *S. spontaneum*, which is a vigorous, widely adapted wild species which contributed genes for disease and stress resistance. The species *S. sinense*, *S. barberi* and *S. robustum* also provided minor contributions toward the development of some modern sugarcane varieties.

S. officinarum L. is generally known as the noble cane because it is stout and produces abundant sweet juice. Culms are thick (normally over 3.5 cm in diameter) and soft due to low fiber content. Assessions of this species display long, wide leaf blades (1 m long × 5 cm wide) and a relatively small, shallow root system (Scarpari and Beauclair, 2008). *S. officinarum* is highly demanding in specific climate conditions, high soil fertility and water supply. *S. officinarum* accessions are generally susceptible to diseases such as mosaic, gummosis, leaf scorch, root rot and Fiji disease (Martin, 1961; Ricaud and

Autrey, 1989; Ricaud and Ryan, 1989), but they tend to be resistant to sugarcane smut (Segalla, 1964). *S. officinarum* includes all old traditional sugarcane varieties that were cultivated throughout the world prior to the introduction of hybrid varieties (Segalla, 1964).

Known as wild sugarcane, *S. spontaneum* L. is highly polymorphic, with plant stature ranging from small grass-like plants without stalks to plants over 5 m high with long stalks. Leaf blades vary in width from very narrow mostly restricted to the mid-rib or up to a width of 4 cm (Matsuoka, *et al.*, 1999). Plants show highly adaptive plasticity and are found in different environments. *S. spontaneum* is the species that has contributed to the improvement in sugarcane vigor, hardness, tillering, ratooning ability and resistance to biotic stresses (Mohan Naidu and Sreenivasan, 1987). These plants tend to be immune to most diseases, including 'Sereh' and mosaic, but they are susceptible to sugarcane smut (Segalla, 1964). In some regions of the world, such as the United States, *S. spontaneum* is considered a harmful invasive species (USDA, 2008).

In Brazil, it is considered an exotic and non-invasive plant (Instituto Horus, 2008; Global Invasive Species Database, 2008). *Saccharum sinense* Roxb. and *Saccharum barberi* Jesw. are known as Chinese or Indian canes, as they were initially grown in China and India before the spread of modern varieties (Mohan Naidu and Sreenivasan, 1987). Some taxonomists consider them a single species (Matsuoka, *et al.*, 1999), and according to more modern studies, they are natural hybrids between *S. officinarum* and *S. spontaneum* (Irvine, 1999; D'Hont, *et al.*, 2002). Stems from both species are long (up to 5 m), thin (approximately 2 cm in diameter) and fibrous, presenting long, fusiform internodes. The plants have a vigorous, well-developed root system and good tillering, which enables adaptation to poor and dry soil and allows the production of large volumes of biomass. However, both species have medium sugar content and early maturation. *S. sinense* and *S. barberi* tend to exhibit resistance to root diseases; some individuals are resistant to mosaic, immune to 'Sereh' disease, resistant to sugarcane borers and susceptible to sugarcane smut (Segalla, 1964). Due to poor flowering and sterility of most genotypes of these species, they are rarely used in sugarcane breeding programs (Roach and Daniels, 1987), although they may have contributed to the development of some modern varieties (Mohan Naidu and Sreenivasan, 1987; Dillon, *et al.*, 2007). *S. robustum* Brandes and Jeswiet ex Grassl represents wild sugarcanes adapted to broad environmental conditions. It possesses a high fiber content and vigorous stalks that are 2.0–4.4 cm in diameter and up to 10 m high, but like *S. officinarum*, it does not have rhizomes. The culms are hard and have little juice, are poor in sugar content and have a hard rind, a characteristic that is exploited to build hedges (Matsuoka, *et al.*, 2005; Mozambani, *et al.*, 2006). *S. robustum* tends to be highly susceptible to mosaic (Segalla, 1964). Few current commercial cultivars have received a contribution from this species. However, there are reports of a successful program to broaden the genetic basis of the current varieties by introgressing *S. robustum* into Hawaiian sugarcane varieties (Mohan Naidu and Sreenivasan, 1987).

Cultivation Practice

Soil: Well drained alluvial to medium black cotton soils with neutral pH (6.0-7.0) and optimum depth (>60 cm) are good for sugarcane growth. But can also be raised on lighter soils and heavy clays provided there is adequate irrigation available in the former type of soils and drainage is good in the latter type of soils.

Climate: Sugarcane is grown under wide range of climate, ranging from sub-tropical to tropical.

Conditions: Temperatures above 50°C arrest its growth, house below 20°C slow it down markedly and severe frost proves fatal.

Variety: C0-86032, CO-86002, CO-0238, CO-0239, CO-671, CO-5071, CO-5072 varieties etc.

Seed Material: Healthy seed material, free from pests and diseases and having high viability is essential for establishing the crop in the first instance. 4000-4500 plants per acre required for sugarcane SSB.

Season of Planting: October (autumn), February-March (Spring) and July (Ads All), but major seasons are autumn and spring season.

Planting: Give light irrigation in furrows and for planting put whole plant with net pot in pit. Cover pit with soil.

Spacing: 1m x 1m for Sugarcane SSB plants.

Planting Material Preparation:
For setts the seed cane from nursery crops are harvested at appropriate age (7-8months).
The trash and green leaves are hand stripped to avoiddamage to the buds.
The setts with either two / three eye buds are cut using a sharp knife placing the cane on a small wooden log.
2 budded setts are found to be more appropriate.
The cuts should be slanting.
It is desirable to prepare the setts just before plantingmay be a day before.
A two budded sett is usually 20 to 25 cm long.
To prevent the seed setts being attacked by fungal diseases and also to improve germination, the seed setts are dipped into 0.5 per cent solution of Agallol (3%) or 0.25 percent solution of Aretan (6%) or Tafasan (6%) or In 300 lt of water 150 g bavistin and600 ml malathion of solution in 15 min. before planting.
Under normal planting, if the quality of setts is good about 60,000 two-bud setts or 40,000 three-bud-setts would be sufficient to plant one hectare of land and raises a good crop.

Harvesting and Yield
Sugarcane yield is largely influenced by various yield attributing factors such as plant stand, millable cane per clump and weight of single cane. Weight of cane is highly influenced by the length and girth of the cane. To obtain desired yield from the crop, it is necessary to enhance the yield attributes during various stages of crop growth. Bud chip method of planting has direct effect on various yield attributing factors of sugarcane. Sugeerthi, *et al.,* (2018) reported that wider spacing in SSI method enables the seedlings for better interception of solar radiation for enhanced production of photosynthates, which ultimately contributes to the storage in the cane stalk. Under Madurai situation, Bhanupriya, *et al.,* (2014) obtained the highest cane length of 1.91 m and cane girth of 13.27 cm at harvest with planting of single chip bud seedlings. Under Odisha situation, Mohanty, (2013) obtained more millable canes (9.6/clump) in SSI technology than conventional method (5.2/clump) of planting because of better availability of air, water, sunlight and nutrition under wider spaced (120 cm x 60 cm) crop grown with SSI technology. Besides, there was longer (205.2 cm), thicker (3.1 cm) and heavier (1.12 kg/cane) canes in SSI technology as compared to conventional method of planting. Sugeerthi, *et al.,* (2018) recorded heavier canes (1.80 kg/cane) with planting of chip budded seedlings as compared to other methods of planting. But, Iqbal, *et al.,* (2002) did not find any difference between bud chip planting and planting of three bud setts with respect to single cane weight.

Yield is the most important factor for profitable cultivation of any crop. Yield of sugarcane is affected by varietal characteristics, physical factors and agronomic management practices. Yield of sugarcane grown with traditional planting method is adversely affected due to poor plant stand. Adoption of bud chip method of planting ensures adequate plant stand thereby resulting in higher yield. Bhanupriya, *et al.,* (2014) recorded the maximum cane yield of 101.85 t/ha with plantingof single chip bud seedlings under Madurai situation. Mohanty, *et al.,* (2015) from Nayagarh in Odisha reported higher caneyield of 105.0 t/ha in SSI method as compared to 89.0 t/ha under traditional method of three bud setts planting. Sugeerthi, *et al.,* (2018) from Cuddalore in Tamilnadu recorded the highest seed cane yield of 98.32 t/ha with chip budded seedlings planting as compared to other methods of sugarcane planting. But, Mote, *et al.,* (2016) did not find any superior in cane yield by planting single bud setts over planting of scooped bud chips. On the contrary, Selvan and Nadanam, (1999) obtained maximum cane yield with conventional planting method, which was higher than the yield obtained with chip bud planting method. Several workers have validated the SSI technology in the real farm situation under farmers' field.

Loganandhan, *et al.,* (2013) recorded 20% higher yield of cane from SSI method than conventional methods of sugarcane planting. Similarly, Mishra, (2019) obtained higher cane yield (122.6t/ha) in bud chip method of planting than conventional method (89.3t/ha) underfarmers' field situation. Results from on-farm trials in farmers' field by Patnaik, *et al.,* (2017) resulted in 13.86% more cane yield by planting with bud chip technology than the traditionally planted crop. Mohanty, (2013) also reported that the cane yield under SSI technology was 40.95% more than the yield obtained from conventional method of sugarcane cultivation under farmers' field situation. Yield varies and mainly depends on varieties, states, soil condition etc. In tropical and states of high productivity the yield varies between 70 tonnes to 100 tonnes. In sub-tropical region it varies between 50 tonnes to 70 tonnes per hectare.

Brix Value of Sugarcane

The brix value of sugarcane plays an important role in deciding the marketability of the harvested cane. Planting methods, as reported by various researchers, have marked influence on sucrose content of the cane. Bhanupriya, *et al.,* (2014) recorded higher brix value (18.50%) and higher juice weight (1.68 kg/cane) at harvesting stage with planting of single chip bud seedlings. Similarly, Selvan, (2000) observed the highest CCS of 16.09% at harvesting stage with planting of 40- day old chip bud seedlings grown in polybags. Economics of cultivation plays a critical role for sustainability of sugarcane crop. Higher profit encourages cane farmers to grow the crop in more areas with adoption of innovative technology. But, sugarcane production faces severe challenge due to increased cost of cultivation, especially the cost of seed material. To address the issue, various researchers have advocated bud chip method of planting to obtain higher profit from sugarcane cultivation. Narendranath, (1992) mentioned that use of seedlings raised from bud chips for planting of sugarcane was three times more cost-effective than use of conventional planting materials. Parajuli, *et al.,* (2019) recorded a saving of 60-70 per cent of the seed cost when single bud seedlings were raised in nursery as compared to conventional method of planting.

Mohanty, *et al.,* (2015) recorded higher net return of Rs 84,300/ha under SSI technology of sugarcane planting as compared to conventional method of planting (Rs.30, 950/ha). Similarly, Arthi, *et al.,* (2016) reported that the net return (Rs 123739/ha) obtained under SSI method was more than that of conventional method (Rs 87473/ha). Under farmers' field situation, Mishra, (2019) obtained higher gross return, net return and benefit-cost ratio by planting bud chips as compared with conventional method of planting. Sugeerthi, *et al.,* (2018) opined that in spite of involvement of higher input cost, the economic benefit obtained from chip budded seedlings was much higher. They have reported the maximum net income of Rs.1,83,040 /ha and the highest B:C ratio of 2.63 with planting of chip bud seedlings. As reported by Patnaik, *et al.,* (2017) from Odisha, bud chip technology realized 32.63% higher net profit than conventional method of sugarcane cultivation. The research findings obtained by various workers across various agro-climatic situations indicated that the bud chip method of sugarcane planting is superior to conventional method of planting with respect to crop establishment, plant growth, yield and economics. These findings were also validated in the real farm situation by various researchers.

Sugarcane Simple Bud Implantation Methods:

Choose Seeds: first will choose high yield and high sugar before plantation, growth is normal, without the breeding of damage by disease and insect as the kind of planting.

Sugarcane Leaf is Shelled: first peelled off by the leaf sheath of sugarcane kind before cutting kind after choosing kind, cut down the afterbody of growing point bottom medicine 4 ~ 5cm and the old stem of liftoff 80-100cm, by the use of the sugarcane stem in the middle of major part as sugarcane kind.

Kind is cut: the quality must noting ensuring sugarcane bud when to cut kind, discards bad bud, worm bud. The cutter to cut kind is sharp, and the edge of a knife is thin, and rebasing plank outline is thick, preferably becomes dome-shaped, conveniently cuts kind; Will exert oneself when to cut kind, namely a cutter breaks, and notch is level and smooth, does not cut and splits sugarcane kind, and when to cut kind, the bottom internodes of seedling will stay longer, and account for 2/3 of internodes, the internodes on top stays shorter, about go up 1/3 of internodes, is conducive to improving germination rate and promotion growth of seedling.

Seed Soaking Sterilization: Medicament soaked seed mainly refers to by topsin 800 ~ 1000 times of immersion kinds, requires whole submergence kind face, because liquid is suspension, will plant bud after should first stirring again and immerse, and immerse and pick up for about one minute, liquid can be reused after stirring. But time liquid need increase water not, dosing be continued when stirring into milky (being 800 ~ 1000 times), seed soaking sterilization could be continued.

Pendulum Kind: the kind that tillering ability is strong, every meter of pendulum 4 buds (namely often putting a bud apart from 25cm), kind every meter pendulum 5 buds (namely every 20cm puts a bud) that tillering ability is weak, during pendulum kind, sugarcane bud should upwards or both sides, must guard against bud not to be flapped toward down (being short of seedling because easily causing) downwards and to affect emergence rate.

Basal Dressing: set after planting and evenly spread fertilizer over the fields base manure immediately in plantation ditch, mu executes the old sugarcane Special basal fertilizer of health (including the medicine of insect-pest) 50 kilograms, and ditch of being namely expert at after executing spray atrazine adds Acetochlor weed killer herbicide (consumption is identical with the method for general planting).

Lid Mulch Film: after row ditch herbicide spraying, carries out row operculum colpi mulch film immediately, builds both sides fine earth compacting after film, guarantees the quality of epiphragma, improves the bud ratio of sugarcane.Require before epiphragma to check that can soil moisture content guarantee the normal growth of sugarcane seedling, namely the mud of row bottom of trench is grabbed with hand, one grab agglomerating, decontrol earth namely to scatter, namely show that soil can be planted, as soil is too arid, when ditch bed mud is grabbed not agglomerating, this shows that soil is excessively arid, answers trickle to plant and maybe wouldn't plant.

Look into Seedling: when after sugarcane tidy seedlings output, look into seedling immediately, all be obstructed in film namely with finger seedling is broken out, cut soil blocks.

Other cultivation step is identical with general planting, as long as conscientiously implement by above requirement, normal time sugarcane per mu yield all can reach more than 8 tons.

The foregoing is only the preferred embodiments of the present invention, be not limited to the present invention, although with reference to previous embodiment to invention has been detailed description, for a person skilled in the art, it still can be modified to the technical scheme described in foregoing embodiments, or carries out equivalent replacement to wherein portion of techniques feature. Within the spirit and principles in the present invention all, any amendment done, equivalent replacement, improvement etc., all should be included within protection scope of the present invention.

Fig 15: Sugarcane eye ready for transplanting

Summary of the Invention

The technical problem to be solved in the present invention overcomes existing defect, provides a kind of sugarcane simple bud implantation methods. Object of the present invention carrys out specific implementation by the following technical programs:

A kind of Sugarcane Simple Bud Implantation Methods Comprises the Steps:
Choose Seeds;

Sugarcane Leaf is Shelled: first peeled off by the leaf sheath of sugarcane kind before cutting kind after choosing kind, cut down the after body of growing point bottom 4 ~ 5cm and the old stem of liftoff 80-100cm, by the use of the sugarcane stem in the middle of major part as sugarcane kind;

Kind is cut: discard bad bud, worm bud;

Seed Soaking Sterilization: by topsin 800 ~ 1000 times of immersion kinds, whole submergence kind face, immerses and pick up for a minute;

Pendulum Kind: the kind that tillering ability is strong, every meter of pendulum 4 buds, namely often put a bud apart from 25cm; Kind every meter pendulum 5 buds that tillering ability is weak, namely every 20cm puts a bud; During pendulum kind, sugarcane bud upwards or both sides, is avoided bud to be flapped toward down;

Basal Dressing: set after planting and evenly spread fertilizer over the fields base manure immediately in plantation ditch, ditch of being namely expert at after executing spray atrazine and Acetochlor weed killer herbicide;

Lid Mulch Film: after row ditch herbicide spraying, carries out row operculum colpi mulch film immediately, builds both sides fine earth compacting after film, guarantees the quality of epiphragma;

Look into Seedling: when after sugarcane tidy seedlings output, look into seedling immediately, all be obstructed in film namely with finger seedling is broken out, cut soil blocks. Preferably, described step 2) in, when to cut kind the bottom internode of seedling leave account for internode 2/3 length, the internode on top leaves the length of 1/3 of internode.

Sugarcane Associate Insects

The most important sugarcane insect pests in Brazil are the sugarcane borers (*Diatraea saccharalis* and *Diatraea flavipennella*), the giant sugarcane borer (*Telchin licus*), spittlebugs (*Mahanarva fimbriolata* and *Mahanarva* *posticata*), termites (different genera), the migdolus beetle (*Migdolus fryanus*), the sugarcane weevil (*Sphenophorus levis*) and herbivorous ants (*Atta* spp. and *Acromyrmex spp*.). *D. saccharalis* is widely distributed in Brazil, while *D. flavipenella* is restricted to the northeastern region of the country. Both species construct galleries in the stalks, leading to less biomass and sugar production, and an increase in fungal infections and juice contamination. These sugarcane borers are mainly controlled by massive release of the parasitoid *Cotesia flavipes*, which is normally reared in labs at the various mills. Sugarcane borers are also controlled, although by a lesser extent, by the release of the parasitic wasp *Trichogramma galloi*. Currently there is strong evidence that the sugarcane borer population has been increasing due to the expansion of cane into new areas, the cultivation of susceptible varieties, and the failure to use biological control. The increase in borer populations has been causing an increase in the use of pesticides to control these insects (Dinardo-Miranda, 2008a).

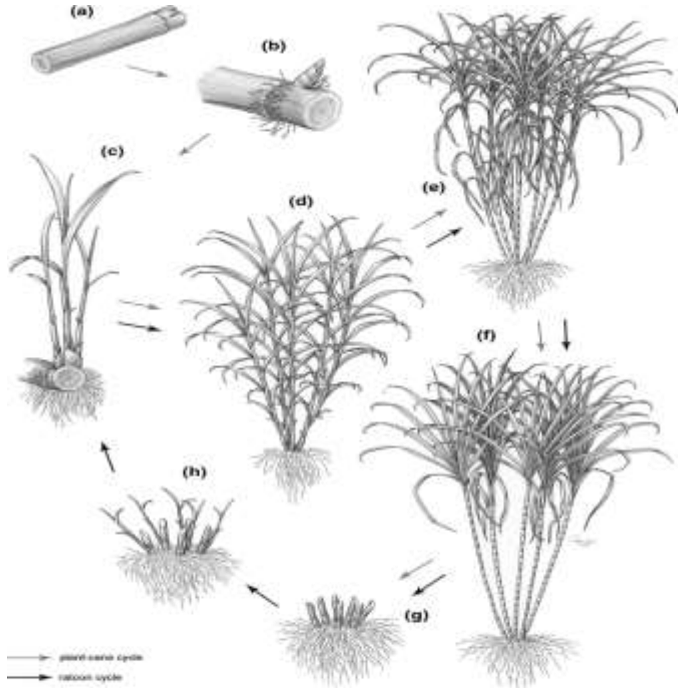


Fig 16: Sugarcane phenological cycle. a Stalk pieces used in planting; b Beginning of bud sprouting and rooting; c Tillering initiation; d Intense tillering; e Beginning of maturation; f Manufacturable stalks in optimal sucrose concentration; g Harvesting; h Ratoon sprouting. Illustration: Rogério Lu-po

The giant sugarcane borer (*T. licus*) is another lepidopteran pest that attacks the crop. *T. licus* was considered to be restricted to northeastern Brazil, but there have been recent reports of its occurrence in São Paulo State, Brazil's main sugarcane producing state. *T. licus* also construct galleries in the stalks, but they more easily outright kill the ratoons due to the extensive damage caused by their large size (Dinardo-Miranda, 2008a). Biological and chemical control mechanisms against *T. licus* are not effective, and the economic impact of the pest, if it spreads throughout Brazilian sugarcane-producing regions, has yet to be assessed. The root froghopper (*M. fimbriolata*) has become an important sugarcane pest since Brazil started to abolish crop burning. Crop damage is caused by the young insect (nymph), which sucks water and nutrients from plant roots and injects toxins into them, leading to a decrease in root function and, consequently, a loss of productivity. Release of the fungus *Metarhizium anisopliae* results in good biological control, which can be complemented or replaced by pesticide spraying (Dinardo-Miranda, 2008a). The leaf spittlebug (*M. posticata*) is more predominant in northeastern Brazil; this insect sucks leaf sap, causing leaf drying; it can be controlled in the same way as *M. fimbriolata*.

There are many species of termites that attack sugarcane in the the country. Among these species, *H. tenuis* is the most harmful. These underground insects attack the stalks used for planting, leading to low bud germination and the need for replanting (Dinardo-Miranda, 2008a). Farmers control termites by spraying pesticides over the stalks in the furrow during planting. The migdolus beetle *Migdolus fryanus* is a native Brazilian insect that attacks the roots of many crops, including sugarcane, coffee, eucalyptus and beans (Bento, *et al.*, 1985). The insect can destroy the root system, leading to an early need for field replanting. Control of *M. fryanus* is difficult because the larvae live deep within the soil so that pesticide application during planting is not very effective. Recently, the use of pheromone traps has been shown to be very promising for controlling this pest (Nakano, *et al.*, 2002). The sugarcane weevil (*Sphenophorus levis*) is another beetle that attacks the sugarcane root system, leading to damage similar to that caused by the migdolus beetle. *S. levis* has low dissemination ability so its spread is linked to human activities (Dinardo-Miranda, 2008a). Consequently, one of the more effective control practices for this pest is to avoid planting cane that is harvested from infected areas.

Ants that behave as pests in the sugarcane crop belong to the genera *Atta* and *Acromyrmex*. The species *Atta bisphaerica* and *Atta capiguara* cause most of the losses, but *Atta sexdens* and *Atta laevigata* also cause damage. Studies have shown that the ants of one anthill can reduce sugarcane productivity by 3.2 ton ha^{-1} (Dinardo-Miranda, 2008a). Control of these pests is accomplished using pesticides that must be applied very carefully because the pesticides could kill predator ants that are beneficial to the crop. Many species of nematodes are found in association with sugarcane, but in Brazil, most of the damage is caused by five species: *Meloidogyne incognita*, *Meloidogyne javanica*, *Pratylenchus zeae*, *Pratylenchus brachyurus* and *Helycotylenchus dihystera*. These nematodes are mainly controlled with chemical pesticides because nematode-resistant varieties have not been developed in the Brazilian sugarcane breeding programs (Dinardo-Miranda, 2008b). Nematicide application during sugarcane planting can increase productivity up to 30% in some infested areas (Copersucar, 1982). It is also possible to use nematocides in ratoon cycles, but the control of nematodes on ratoons is not as effective (Dinardo-Miranda, 2008b).

Sugarcane Diseases

Most commercial sugarcane varieties are genetically resistant to most sugarcane diseases. In addition to genetic resistance, use of pathogen-free planting material is commonly used to avoid spreading of diseases. The Brazilian sugarcane industry does not usually control sugarcane diseases in commercial fields, but recently, coinciding with the first detection of the Orange rust (*Puccinia kuehnii*) in the country, the Agriculture Department has registered a product (azoxystrobin and ketoconazole) to control fungal disesases at sugarcane fields (Santos, 2008; Agrofit, 2010). Additionally, the Triazole fungicides triadimefon and triadimenol are registered to treat sugarcane stalks before planting to prevent smut contamination caused by *Ustilago scitaminea* (AGROFIT, 2010). Sugarcane smut disease is also contolled by destroying contaminated plants in the field (roguing) when varieties having intermediate resistance to the pathogen are planted.

Industrial Processing (Sugar, Ethanol, Vinnase, Filtercake, and Biomass)

The objective of industrial sugarcane processing is to obtain highly purified sugar and ethanol. The process involves pressing of the sugarcane to obtain juice, which goes through several phases of purification and concentration, followed by crystallization (in the case of sugar production) or fermentation and distillation (in the case of ethanol production). Sucrose and ethanol, which are pure and chemically defined substances, are obtained at the conclusion of both processes. The byproducts are vinasse (also called vinhoto) and bagasse (biomass). Figure 8 illustrates the phases involved in the industrial production of sugarcane products and byproducts.

Use of Sugarcane in Natura

Unprocessed sugarcane is used as human food and animal feed. As a food item, sugarcane may be consumed *in natura* or as juice (*garapa*). *In natura* consumption is common in Brazilian rural areas, but juice consumption is much more common. Sugarcane juice is a nutritious energy drink that is very popular in Brazil where it is consumed by people of all ages and social strata, especially during the summer. The juice is extracted in electric or manual presses, sieved and served with ice, either pure or mixed with fruit juice (Lubatti, 1999; Soccol, *et al.*, 1990; Oliveira, 2007). Because this is an almost entirely informal activity, there is virtually no literature or reliable statistics on the sugarcane juice market (Oliveira, 2007). Studies conducted on samples collected from the product sold in cities of São Paulo State have shown poor hygienic conditions (Oliveira, 2007).

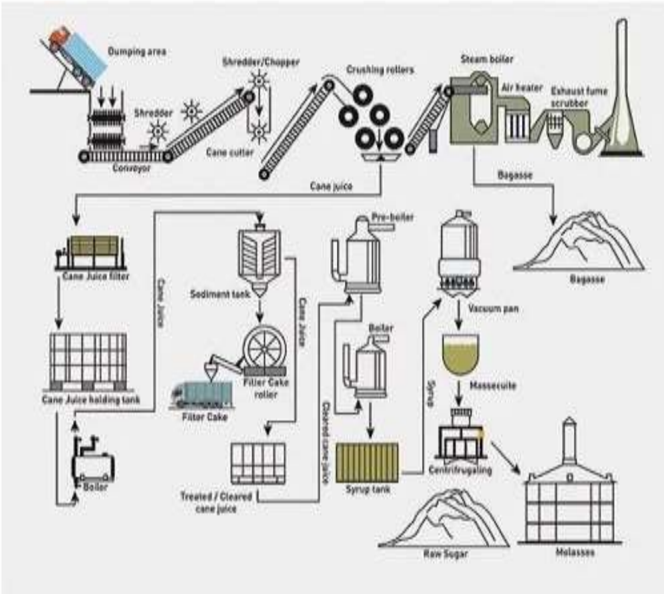


Fig 17: Sugarcane industrial processing

Sugarcane bagasse is the fibrous residue of juice extraction, consisting of water (49%), fibers (48.7%) and a small quantity of soluble solids (2.3%) (Paturau, 1969). Bagasse fiber is a water-insoluble mixture that is mainly composed of cellulose, hemicellulose, pentosanes and lignin (Valsechi and Oliveira, 1964; Paturau, 1969; Delgado and Delgado, 1999; ICIDCA-GEPLACEA-PNUD, 1990). Due to its high fiber content, sugarcane bagasse has been used as part of ruminant feed. Although its digestibility is low (approx. 25%), digestibility can be increased to 65% through chemical, biological or thermomechanical treatments (Allen, *et al.*, 1997; Pate, 1982; de Medeiros and Machado, 1993; de la Cruz, 1990). *In natura* sugarcane is an economically feasible alternative to forage especially during the drought season, when pastures are not sufficient to feed herds (Embrapa Gado de Leite, 2008).

Chemical Industry

Biopolymers are polymeric-based materials that are structurally classified as polysaccharides, polyesters and polyamides. The basic raw material for production is a source of renewable carbon. The most important biopolymers are polylactate (PLA), polyhydroxyalkanoate (PHA), starch polymers (PA) and xantane (Xan). According to Pradella, (2006), of all raw materials that are available for biopolymer production, sugarcane has one of the best profiles as a carbon source. The lignocellulosic fiber content of bagasse give sugarcane a unique competitive advantage compared to other carbon sources since bagasse may also be used to generate the energy used in biopolymer production.

Biotechnical Development

The sugarcane genome is among the most complex of cultivated crops. This complexity has hindered our understanding of sugarcane genetics and our ability to improve the crop using biotechnology tools (D'Hont, *et al.*, 2008). In the late 1990s, in situ hybridization studies helped clarify how the sugarcane genome is organized. A series of studies described part of its complexity and clearly established the ploidy level of the species, while revealing the coexistence of two distinct genome organization modes in modern varieties (D'Hont, *et al.*, 1996; D'Hont, *et al.*, 1998; Ha, *et al.*, 1999). Tomkins, *et al.*, (1999) built a bacterial artificial chromosome (BAC) library for the genome with over 100,000 clones, which facilitated beginning stages of physical mapping of sugarcane chromosomes and comparisons with other grasses. In the same period, several research groups started EST (expressed sequence tags) sequencing projects in South Africa (Carson and Botha, 2000), Australia (Casu, *et al.*, 2001) and Brazil (Vettore, *et al.*, 2001). Up to present, Brazilian sequencing project, called SUCEST, was the project with greater sugarcane EST sequence contribution, responsible for sequencing 238,000 ESTs from 26 different cDNA libraries. Methods for the genetic transformation of sugarcane were reported decades ago. The first experiments in sugarcane genetic transformation were conducted in the late 1980 s (Chen, *et al.*, 1987) when a kanamycin-resistance gene was introduced into protoplasts through electroporation and polyethylene glycol treatment. Transformed plants were produced through particle bombardment (biolistics) of cell suspensions and embryogenic calli (Bower and Birch, 1992).

Sun, *et al.*, (1993) obtained plants that were resistant to the herbicide amonium-gluphosinate through biolistics using the *bar* gene, which encodes phosphinothricin acetyltransferase. Gambley, *et al.*, (1994) bombarded meristematic tissues with microprojectiles and regenerated plants that expressed the luciferase gene. Later, Arencibia, *et al.*, (1995) reported a procedure for the stable transformation of meristematic tissues using electroporation. Gallo-Meagher and Irvine, (1996) described the development of plants of the commercial cultivar NCo 310 containing the *bar* gene, which was transformed through biolistics. Currently, many studies have demonstrated *Agrobacterium*--mediated and particle bombardment transformation of sugarcane with sufficient efficiency to produce commercial varieties (Bower and Birch, 1992; Birch and Maretzki, 1993; Bower, *et al.*, 1996; Birch, 1997; Irvine and Mirkov, 1997; Joyce, *et al.*, 1998a, b; Arencibia, *et al.*, 1998; Enriquez-Obregon, *et al.*, 1998; Elliott, *et al.*, 1998; Moore, 1999; Nutt, *et al.*, 1999; Elliott, *et al.*, 1999; Manickavasagan, *et al.*, 2004). Additionaly, several genes of commercial interest have been introduced into sugarcane by genetic transformation, conferring herbicide tolerance, resistance to diseases and pests, tolerance to drought, increased sucrose content, and improvements in sugar quality and color (Falco, *et al.*, 2000; Braga, *et al.*, 2001; Braga, *et al.*, 2003; Zhang, *et al.*, 2006; Molinari, *et al.*, 2007). Sugarcane has also been transformed with genes with the intention of using the plant as a biofactory, producing high-value-added products such as bioplastics (Lakshmanan, *et al.*, 2005) and high-value isomers of sucrose (Wu and Birch, 2007). In Brazil, the National Biosafety Commission (CTNBio) has approved more than 40 applications to conduct field trials of genetically modified sugarcane that contain genes conferring higher sucrose content, herbicide tolerance, insect resistance and drought tolerance. Field trials have also been conducted or are ongoing in South Africa, Australia and the United States. These trials will almost certainly result in biotechnology products. At present, however, transgenic sugarcane cultivars have not been commercially released in Brazil, or elsewhere in the world.

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