Energy Cane

Creative Component for MS in Agronomy
Iowa State University

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USDA – ARS

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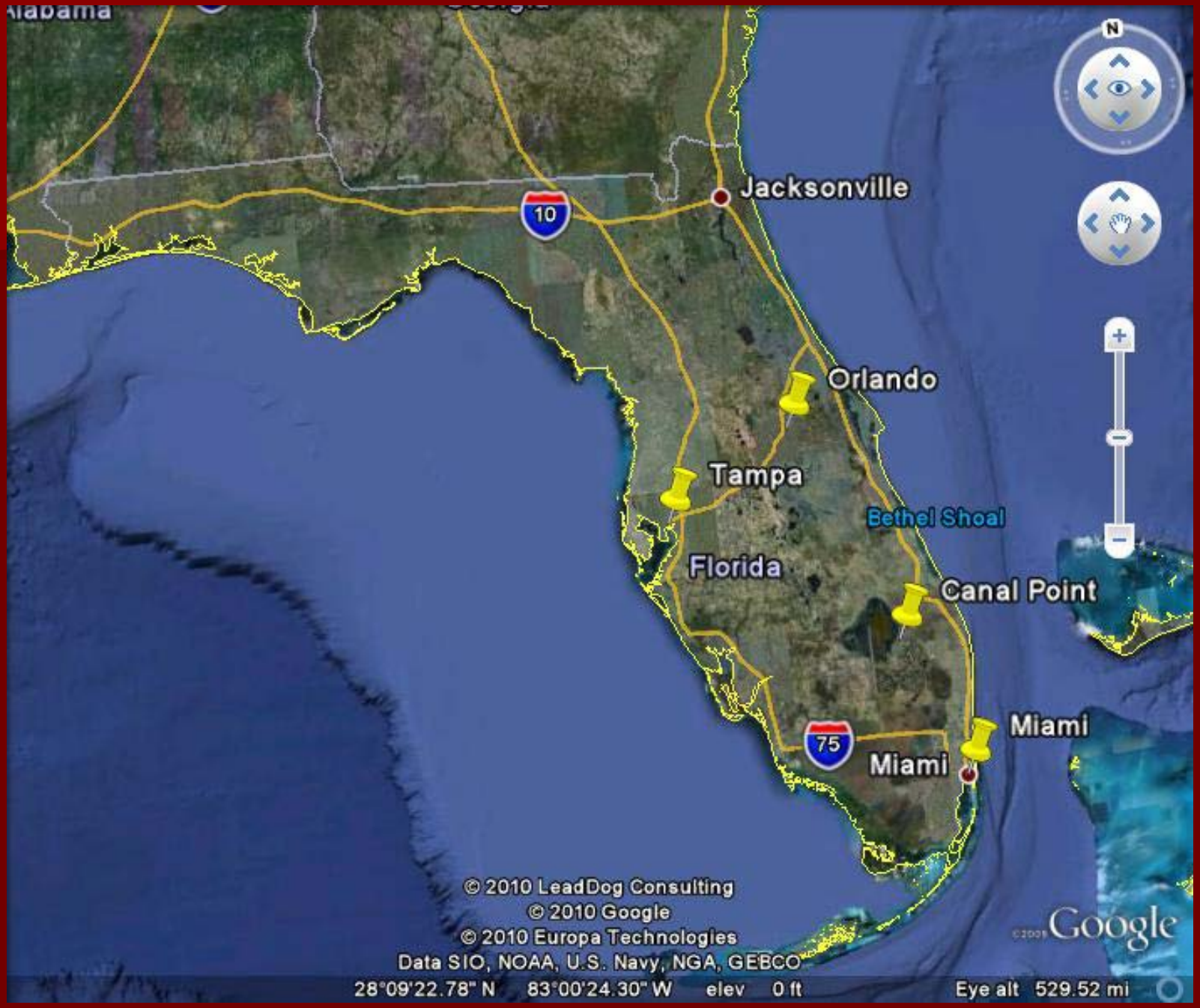
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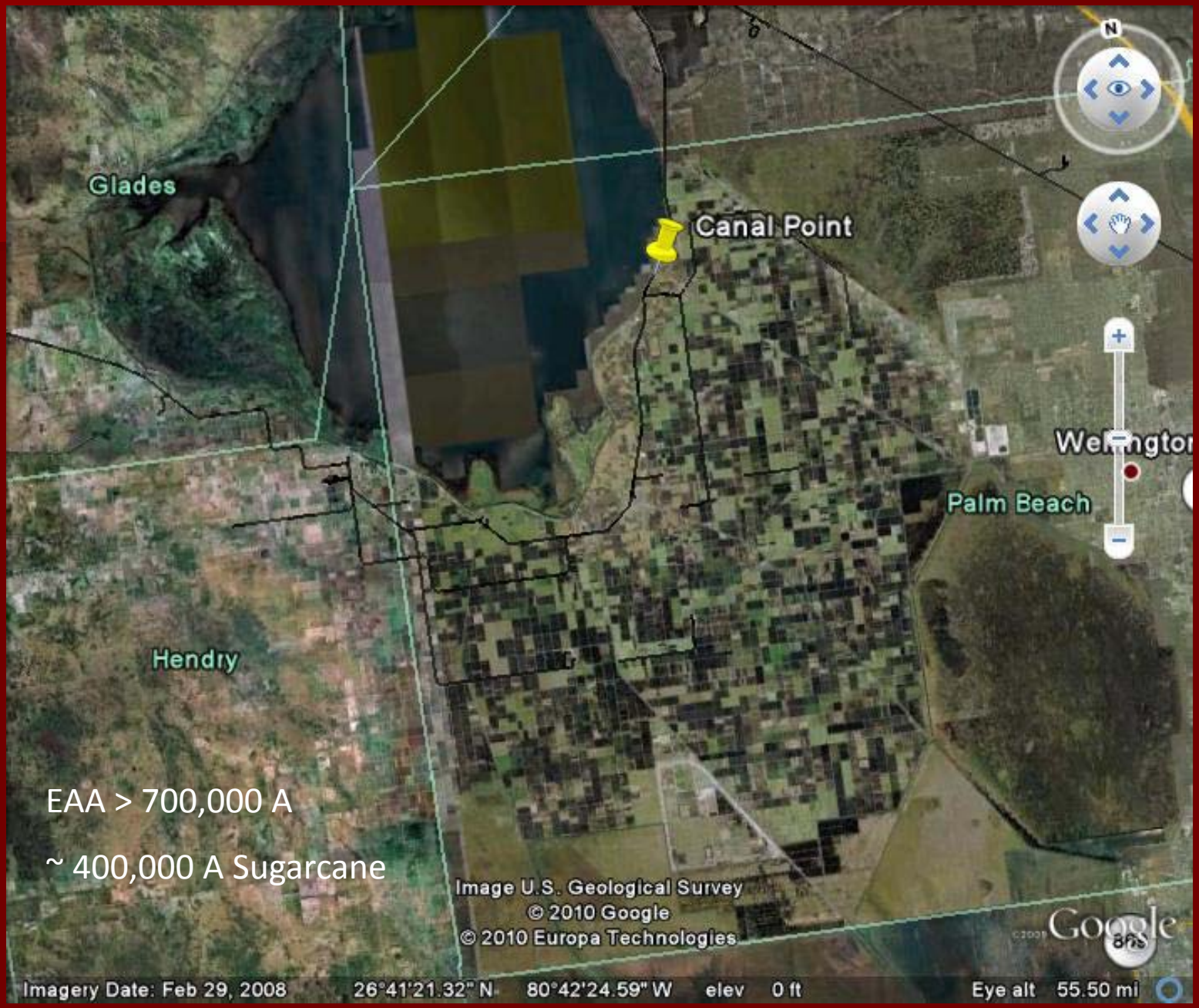


EAA > 700,000 A

~ 400,000 A Sugarcane

Sugarcane Field Station

The USDA –ARS Sugarcane Field Station was established at Canal Point, Florida in 1920.

MISSION

To develop high-yielding, disease and stress-tolerant sugarcane cultivars, and also new pathology, soil, crop, and water management technologies that result in improved production efficiency and soil conservation.

The station currently has 120 acres of farm land used for research plots, population nurseries and active parental clones.


08.11.2008

Why a CAI Module ?

- Opportunity to provide information to an audience unfamiliar with sugarcane.
- Help stimulate interest in sugarcane as an energy crop.
- Provide information about utilization of sugarcane as an energy crop.

Energy Cane

Course Index

Cane field on Maui. http://activerain.com/blogsview/315146/sugar-cane-fields-in-bloom-maui-in-december

Introduction

Demand for alternative energy is being driven by increasing energy prices and projections of diminishing crude oil supplies. This demand has resulted in rapid development of a starch based ethanol industry centered in the upper Midwest. It is evident this ethanol production system will be unable to fully meet ethanol mandates in the near future.

The renewable fuel standard (RFS2) has helped generate a burgeoning cellulosic ethanol industry. The perceived idea of a trade off between food supply and ethanol production makes cellulosic ethanol attractive. Economic factors may play a larger role in development of the emerging cellulosic ethanol production system than perceived food vs. fuel issues.

Elephant grass *(Pennisetum purpureum)* in South Florida. (Abbott)

Introduction

Any organic source of cellulose can be used to produce ethanol making cellulosic ethanol widely adaptable and provides opportunities for production of dedicated “energy crops”.

In the Southeastern United States sugarcane (*Saccharum officinarum* L.) and closely related grasses are being evaluated for use as dedicated energy crops and for their adaptability to other regions of the United States.

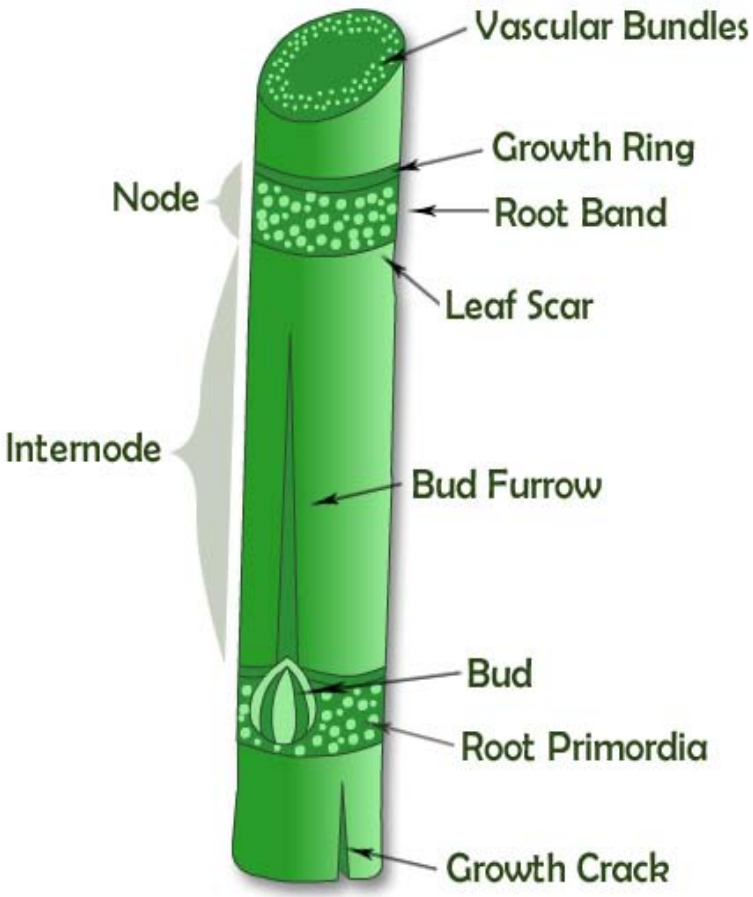
This module examines fundamental processes in conversion of lignocelluloses [structure] to ethanol and agronomic aspects of sugarcane and related grasses in a dedicated energy crop production system.

http://aq48.dnraq.state.ia.us/prairie/Biomass_En.htm

Sugarcane Physiology

The Stem

Sugarcane is a true grass with a solid stem or cane. Sugarcane is asexually propagated by cutting and planting whole stalks of cane or by cutting cane stems into seed pieces called billets. Each billet consists of two or three buds. Buds are located on alternating sides of the stem at each node. The new plants grow from the buds as roots develop from the root primordia.



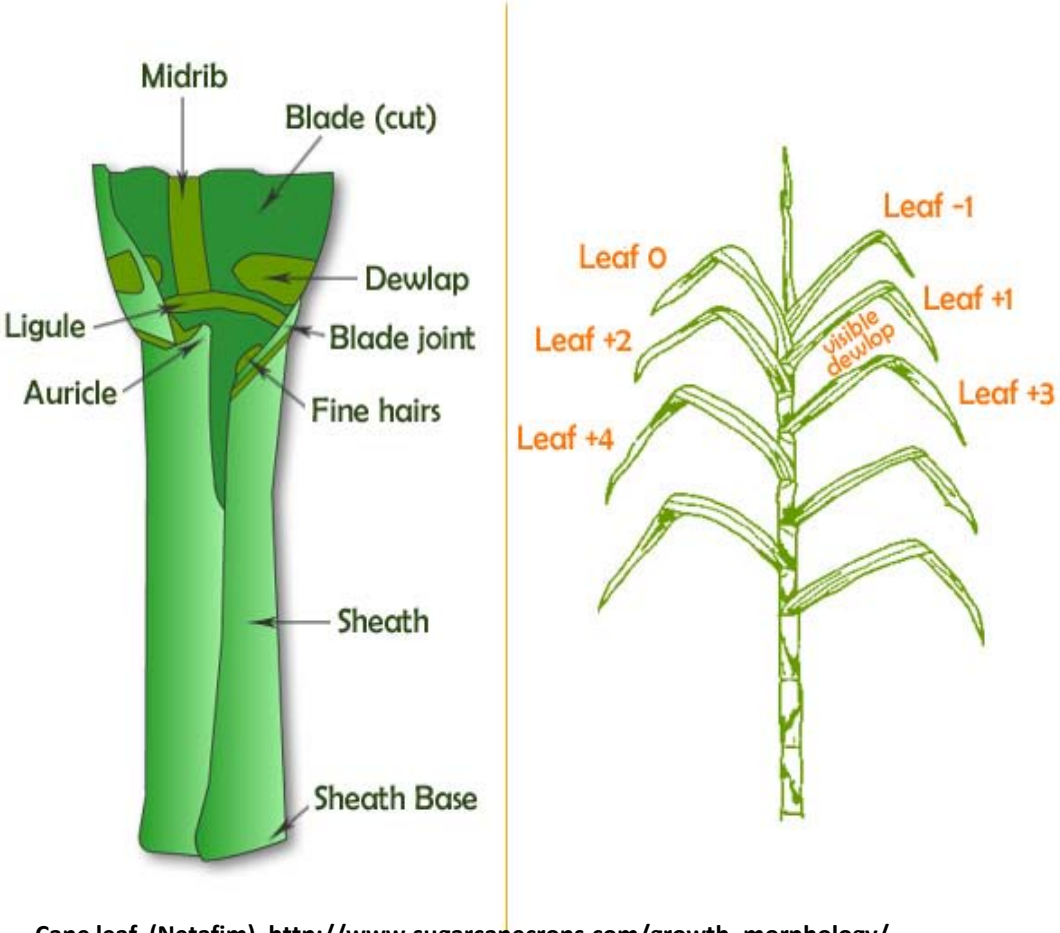
Cane stalk (Netafim) http://www.sugarcanecrops.com/growth_morphology

Sugarcane Physiology

The Leaf

Cane leaves consist of the blade and sheath. Leaves are in an alternate arrangement along the stem. Environmental conditions, cultivar, and cultural practice affect the number of leaves per plant; however, most plants sustain at least ten green leaves during the growing season.

The first visible dewlap is an important morphological feature used as an indicator of maturity, for growth measurements, and in tissue analysis.

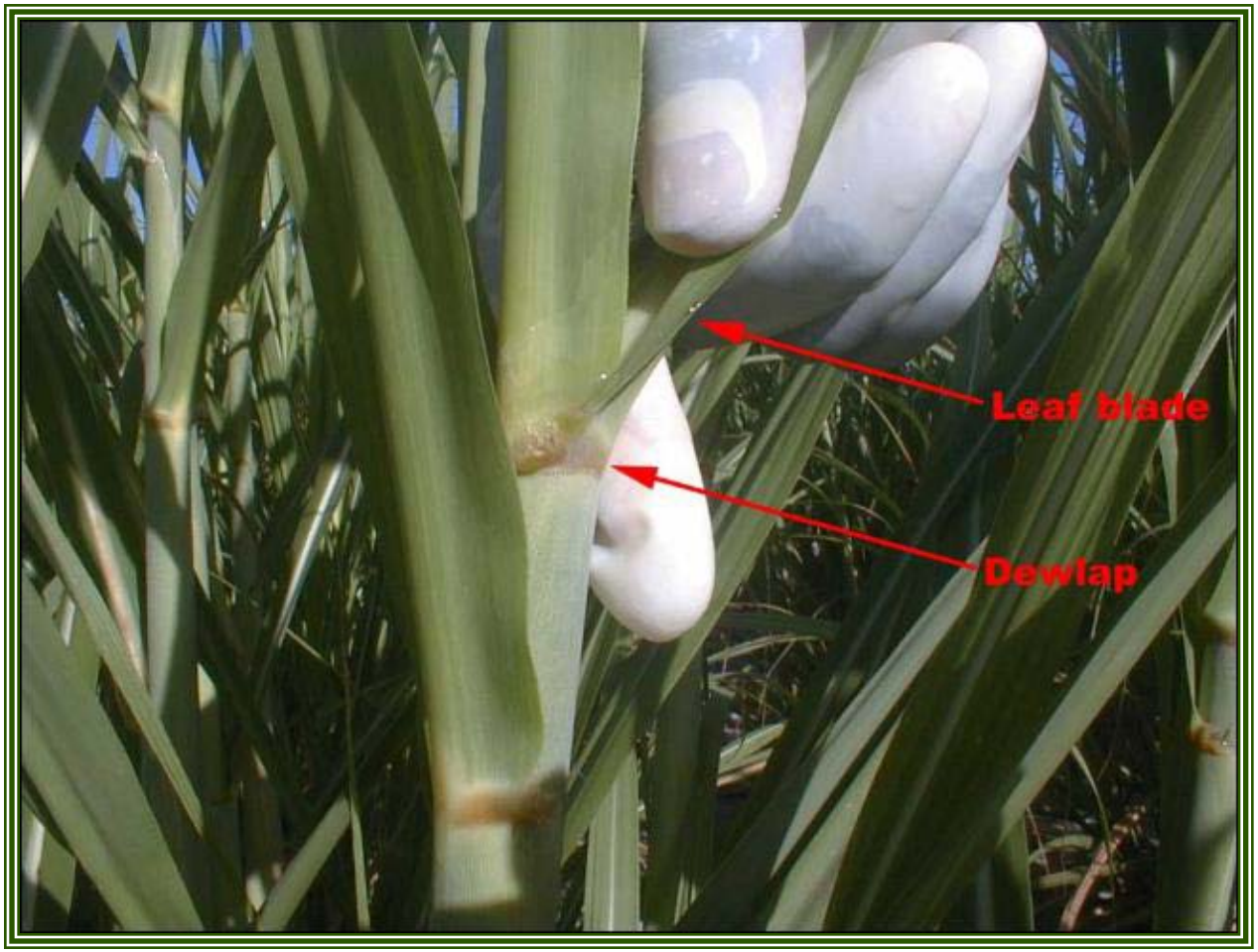


Cane leaf (Netafim). http://www.sugarcanecrops.com/growth_morphology/

Dewlap

The Top Visible Dewlap (TVD) leaf is the uppermost fully expanded leaf that has a visible dewlap or distinct collar, a band of membranous tissue between the leaf sheath and the leaf blade.

The TVD leaf blade is the plant tissue often used for sugarcane foliar analysis. The TVD leaf blade is also an important reference point for growth measurement.



Dewlap **on first expanded leaf. (IFAS)**

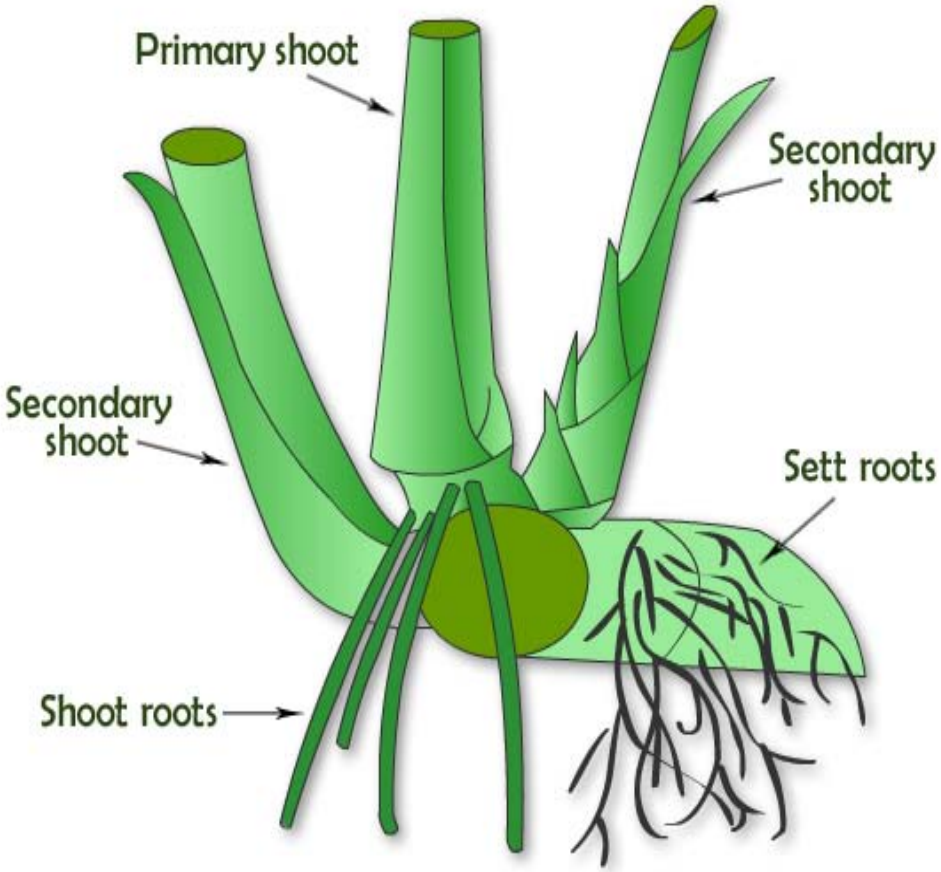
Sugarcane Physiology

The Root

After the billet is planted the first roots to emerge are the sett roots. These roots emerge from the root primorida at the node.

Primary shoot roots emerge within 5-7 days depending on cultivar and growing conditions. Sett roots senesce and play little part in plant growth once the primary shoot establishes its roots.

Secondary shoots develop their own roots as the plant stools out before entering the grand growth stage.



Root system (Netafim) http://www.sugarcanecrops.com/growth_morphology/

Sugarcane Physiology

The Flower

Sugarcane produces inflorescence (inflorescence types) containing several hundred small flowers. Under proper day length and temperature regime the flowers will produce viable seed.

The seed is very small approximately 250 seeds/ gram or 113,500 seeds/ pound. Under carefully controlled conditions plant breeders produce true seed from which new cultivars are developed. Clones of these cultivars are used for commercial sugar production.

Sugarcane is a polyploid and is capable of self pollination (flowers contain stamen and pistil) so each seed produces a unique individual plant with a wide variation of phenotypic characteristics.

Sugarcane flowers **with anthers open. (USDA)**

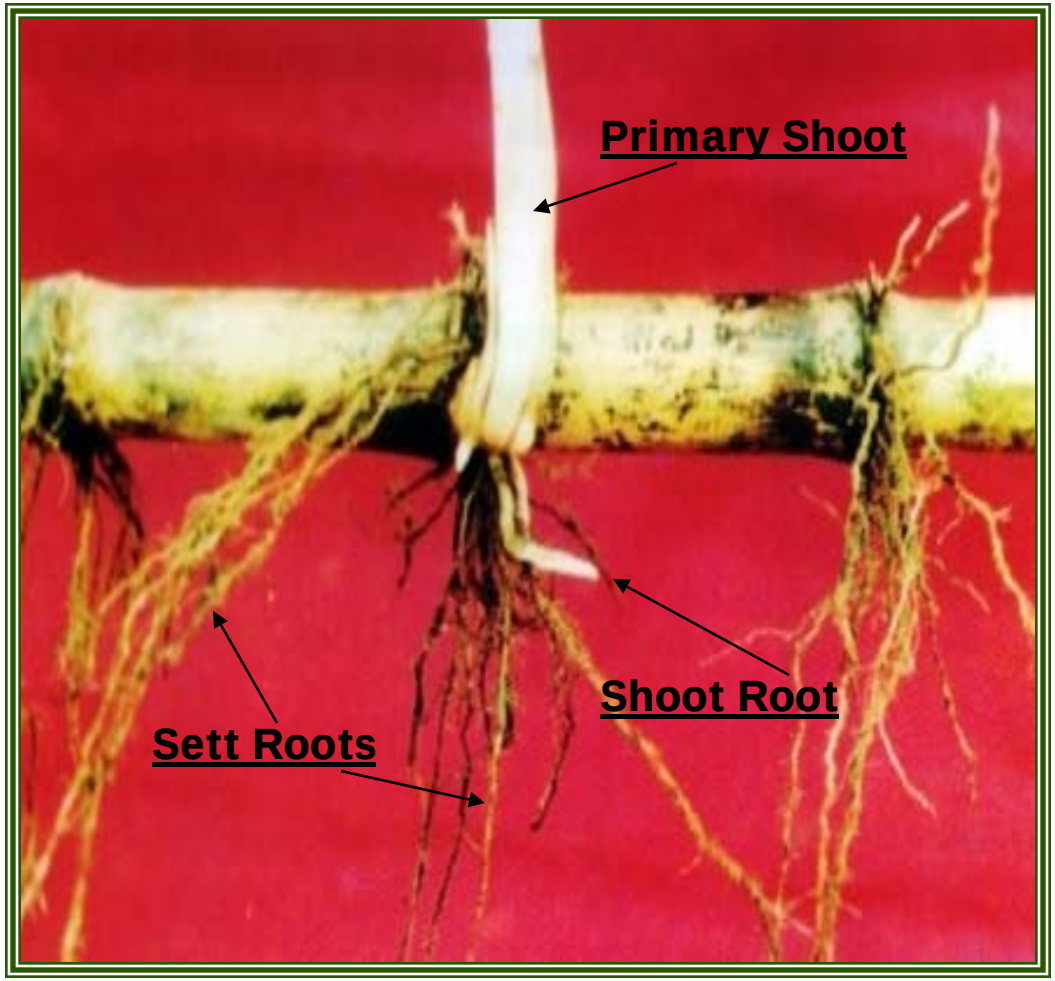
Sugarcane Growth Stages

Germination

Germination takes place after the billet is placed in the soil and the bud sprouts. Bud sprouting begins in as little as 7 days and may continue for up to 30 days.

Soil temperature, moisture conditions, and billet vigor influence germination rate.

Optimum conditions for germination are moist soils, temperature of 85 to 90° F. Good soil aeration is needed because vegetative seed respires rapidly.



Germinating seed piece. Note: Primary shoot, shoot roots, and sett roots. (http://stg2.kar.nic.in/ksi/agro.htm).

Sugarcane Growth Stages

Establishment

After germination a single plant emerges from each bud while establishing shoot roots. A seed piece with several buds often produces multiple shoots along the length of seed piece.

Establishment begins in approximately 10 days after planting and continues for about 30 days. Weather, soil moisture, nutrition, and vegetative seed conditions influence establishment.

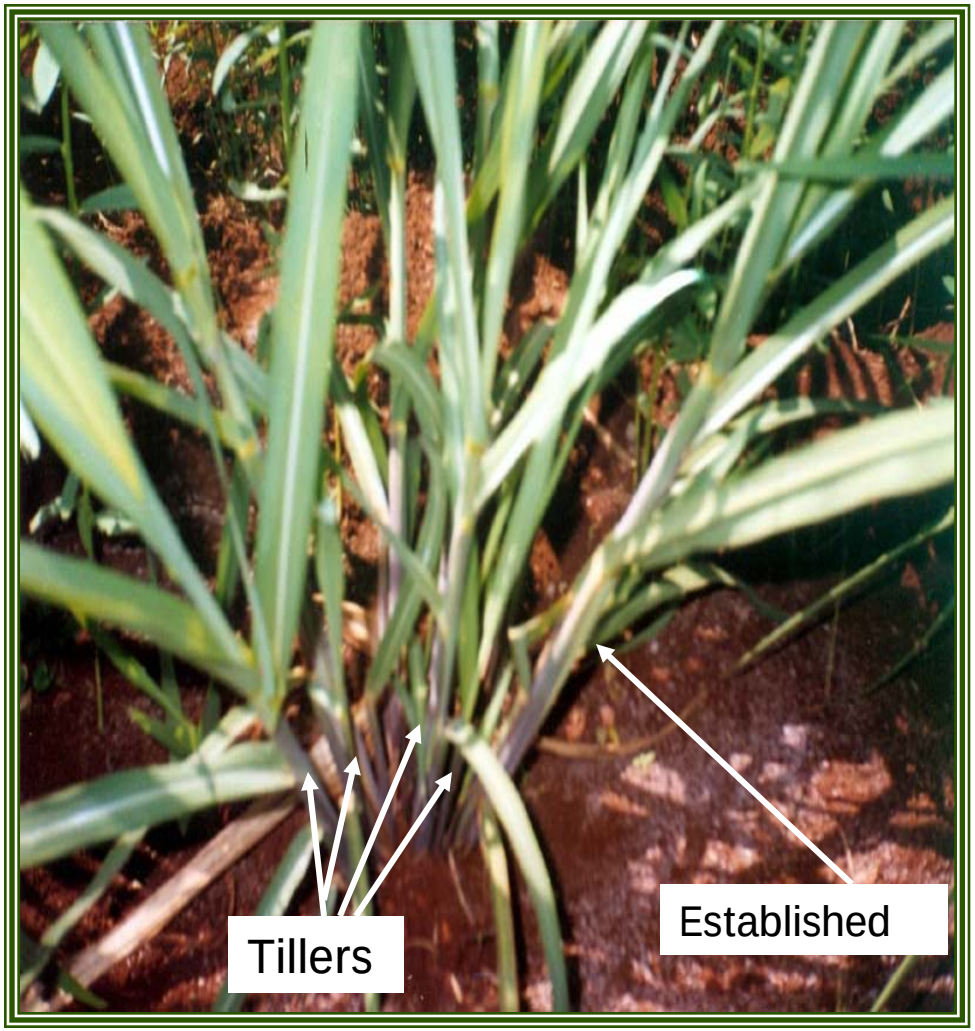
New cane plant well established. (*Courtesy, Netafim*)
http://www.sugarcanecrops.com/crop_growth_phases/

Sugarcane Growth Stages

Tillering

Tillers or secondary shoots arise from the node of the primary shoot. Tillering starts about 35 days after planting and continues for 120 days. Maximum tiller number is reached by 120 days, but by 180 days about 50% of the tiller shoots die back.

Environmental factors, especially light and cultural factors i.e., water, fertilizer, and cultivar (clone), influence tillering. It is important to establish good tillering early so a stable dense stalk population can be established.



Tillering of new plant. (*Courtesy, Netafim*)
http://www.sugarcanecrops.com/crop_growth_phases/

Sugarcane Growth Stages

Grand Growth

Grand growth begins about 120 days after planting and continues until maturation, which could be as long as 270 days. During this stage internodes elongate and overall biomass production increases.

Peak growth occurs when day-time temperatures reach 90° F and night-time temperatures are about 75° F with humidity levels around 80%.

Growth measurements established during peak growth show canes may grow as much as 1 inch per day. Canopy development is rapid with leaf area index (LAI) reaching 6-7.

Stool at mid grand growth. (*Courtesy, Netafim*)
http://www.sugarcanecrops.com/crop_growth_phases/

Sugarcane Growth Stages

Ripening

Ripening of the cane plant is dependent upon the length of the growing season. Flowers may appear, plant growth slows or stops, and sucrose rapidly accumulates from the base of the plant up toward the top.

This is a critical stage to monitor for sugar production. In a cellulosic ethanol production system in the subtropical areas of the United States plant ripening may not be as critical.

Mature cane stalks. **(*Courtesy, Nettfim*)**
http://www.sugarcanecrops.com/crop_growth_phases/

Sugarcane Culture

Planting

Cane crops, whether grown for sugar production or as dedicated energy crops, remain in the same field for multiple years. In Florida, a given field will produce three crops of sugarcane before that field is replanted. Dedicated energy cane fields may remain productive for more than three crops, but supporting data is not available at this time. Longevity of biomass production remains an area where research data is needed.

The multiple year production cycle of cane has given rise to crop nomenclature which is unique to cane production. It is important to identify the point of the production cycle each field is in because this can effect expected yield, cultural practices, timing of harvest, and replanting considerations.

Sugarcane Culture

Planting

In Florida sugarcane is produced in the same field for six years.

1st crop
Plant Cane
1st year
Plant in fall.
Harvest in 14 – 16 months

2nd crop
1st ratoon
2nd year
Begins after plant cane is harvested.
Harvest in 12 - 14 months

3rd crop
2nd ratoon
3rd year
Begins after 1st ratoon is harvested.
Harvest in 10 – 12 months

4th crop
Successive plant
4th year
Planted after last ratoon.
Harvest in 14 – 16 months

5th crop
1st successive ratoon
5th year
Begins after plant cane is harvested.
Harvest in 12 - 14 months

6th crop
2nd successive ratoon
6th year
Begins after 1st ratoon is harvested.
Harvest in 10 – 12 months

After last successive ratoon is removed the field may be rotated to rice, vegetables, fallowed, or a combination of these before starting the cane production cycle again.

If 3rd crop 2nd ratoon yields high enough it may be held as 3rd ratoon. In this case this field would produce seven cane crops before planting rotational crops.

Sugarcane Culture

Planting

Successive planting is the immediate removal of the last ratoon crop after harvest so a “new” cane crop can be planted in the field. This field was harvested in early October and will be ready for successive planting before mid November.

Harvested **cane field.**

Large disc used to turn soil and destroy old cane stubble.

Cattle egrets feasting on soil insects.

Sugarcane Culture

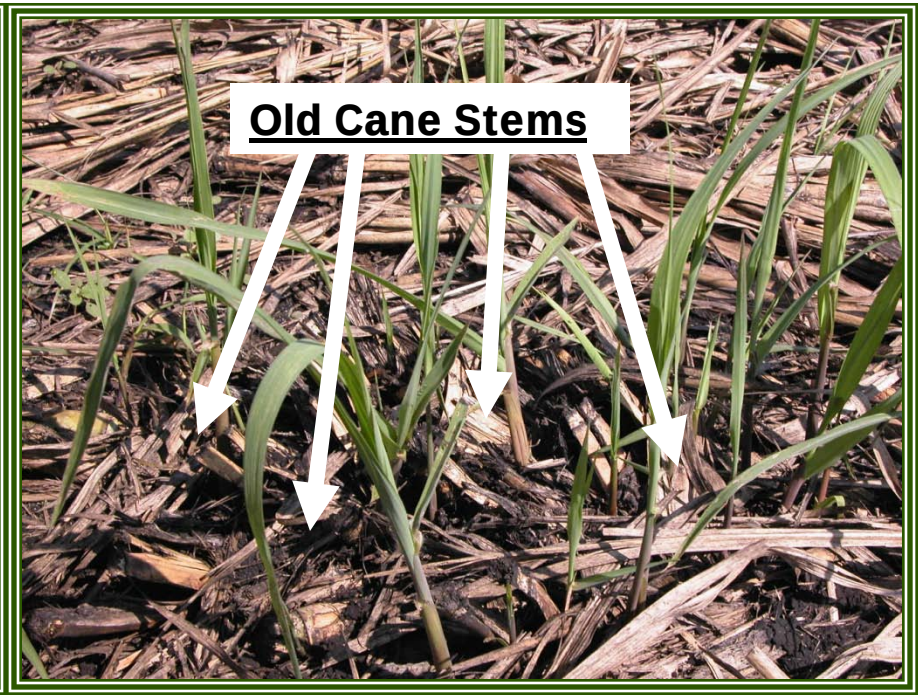
Planting

Plant cane fields in South Florida.

The plant cane fields in these images and ratoon fields look distinctively different. Note the clean drill row and row middles. This field was planted in late August and is now approximately five weeks old. Good moisture conditions and warm temperatures encouraged good emergence and stand establishment. This field is off to a very good start and is in the tillering growth stage.

Sugarcane Culture

Planting



Stubble cane field in South Florida

Note the trash in the row middles of this ratoon field that was cut two weeks earlier. The picture was taken in early October, warm temperatures encouraged vigorous regrowth. Buds at the base of the primary and secondary shoots of the stool produce the new shoots. The buds are located at or slightly below ground level.

Sugarcane Culture

Planting

In many respects successful planting of sugarcane is no different than planting any other crop. All crops require proper seed bed preparation, good quality seed, adequate moisture, proper temperature, and balanced nutrient level.

Sugarcane and related biomass crops differ from “traditional” agronomic crops because they are propagated vegetatively. The term “seed” in cane culture refers to live plant material, the cane stalk and buds from which new plants develop.

Seed cane cut and piled ready for loading.

Seed cane most be handled and processed much differently than “traditional” seed. Seed cane should be planted as soon as possible after it is cut, within 24 hours if possible. Allowing seed cane to desiccate greatly reduces vigor and germination.

Seeds of agronomic crops. http://www.pacificseed.com/

Producers should visit fields from which seed cane will be harvested and inspect them for signs of insect damage, disease, and overall health of the cane before planting.

Sugarcane Culture

Planting

Two methods of planting are common in the United States:

•Hand planting sometimes referred to as **whole stalk planting**

•Mechanical planting sometimes referred to as **billet planting**

Each method has its strengths and weaknesses.

Whole stalk planting requires less seed but is very labor intensive. Billet planting is mechanized but requires almost three to four times the quantity of seed cane.

Seed cane cutter turning at end of row. Single row of cane is fed through center of the machine, seed is topped and dropped at rear of cutter.

Sugarcane Culture

Planting

The whole stalk seed harvester cuts the mature cane stalks at the base of the plant and removes the immature vegetative growth (tops).

The resulting seed cane is approximately six to eight feet long with mature buds (eyes).

Topping, removal of the immature portion and apical bud, stops apical dominance and encourages buds (eyes) to sprout.

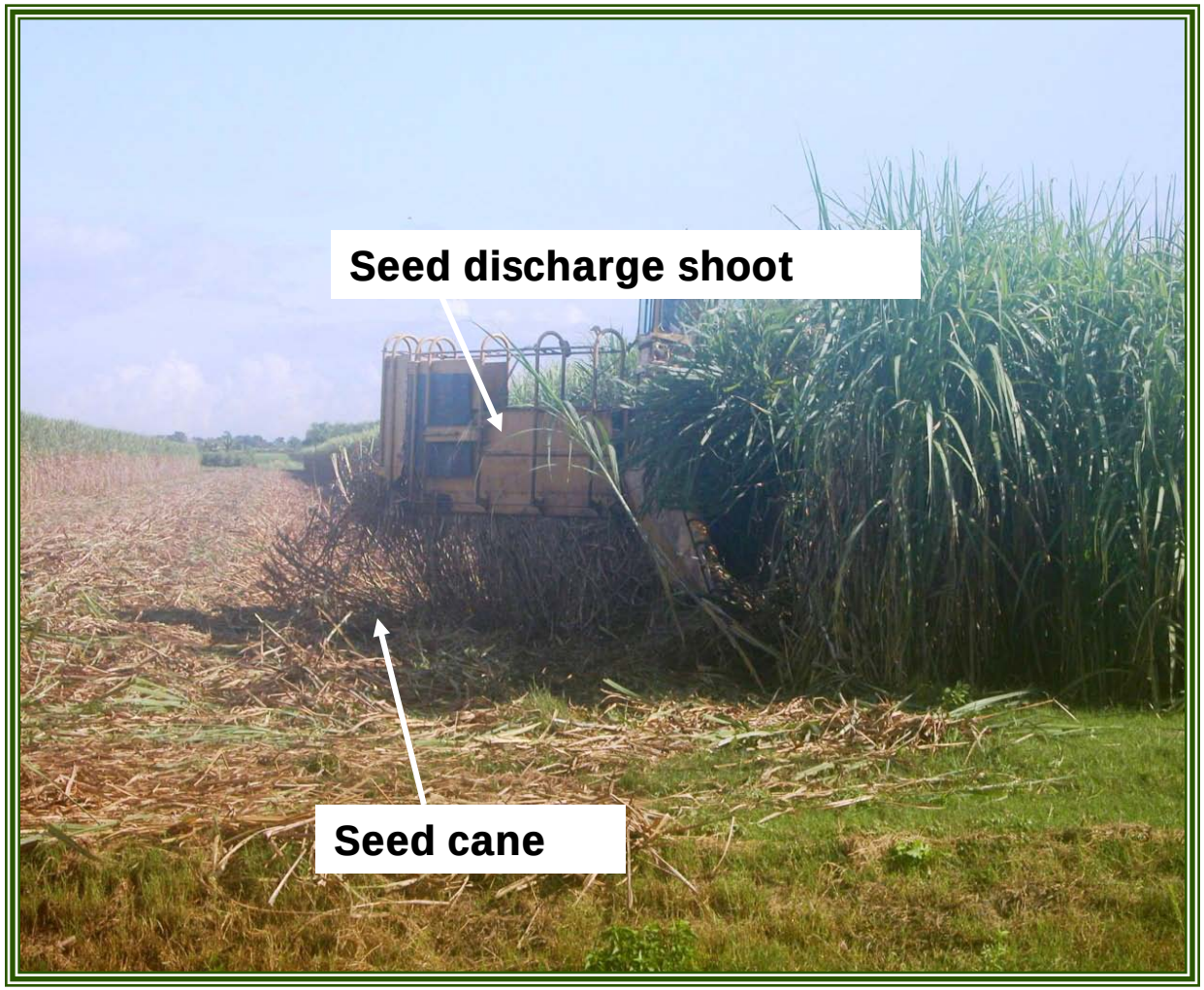
Seed harvester entering field.

Planting

Seed cane is carried through the discharge shoot by a conveyer chain giving rise to the name “soldier harvester”. The seed cane stalks resemble marching soldiers as they are transported through the shoot and dropped on the pile.

Topped seed cane is delivered and dropped in an orderly pile to the side and behind the cutter.

The seed discharge shoot is hydraulically moved out away from the cutter. This allows each row of seed cane to be dropped on the same pile as the cutter moves into the field.



Seed harvester at end of row.

Sugarcane Culture

Planting

Whole stalk seed cane is loaded onto wagons by pushing up piles of seed and picking the pile up with the grapple arm.

Any cane field that is free of weeds, diseases and insects can be used as a seed source.

It is common practice to choose seed fields based on the cultivars' previous years yield, projected performance of the cultivar, and proximity to new planting location.

Whole stalk seed loader pushing up pile of seed cane.

Planting

Furrow depth is dependent on soil type, area of the country, and to some extent size of cane stalks. In South Florida, furrow depths of 11 to 12 inches are common.

In Louisiana, soils are heavier and temperatures are cooler; planting depth is accordingly shallower. Standard row spacing is 60 inches in the United States.

Research in Louisiana has demonstrated correlations between yield and width of furrow bed. Yields were increased with a 15 to 18 inch wide furrow bed vs. a traditional V-shaped furrow.

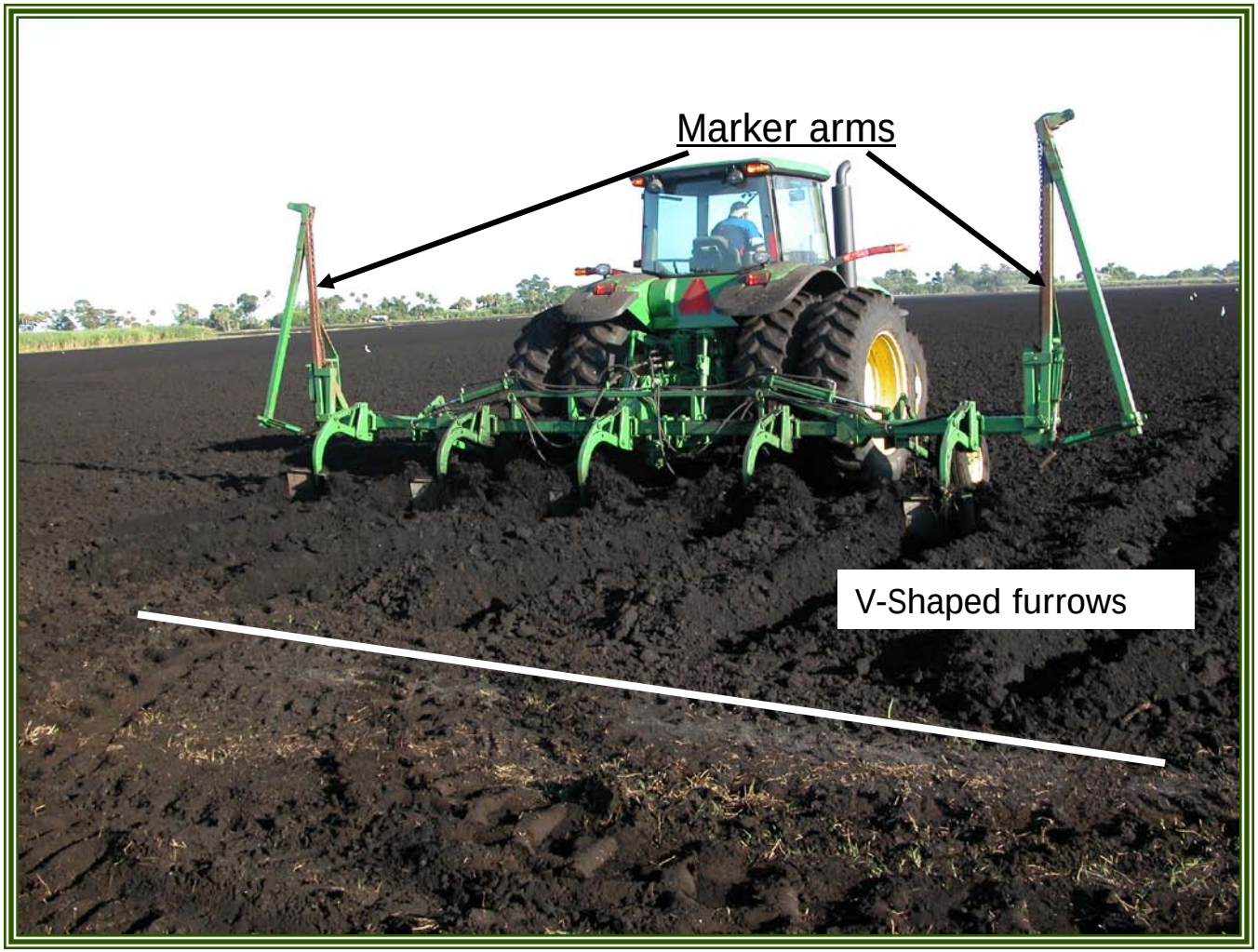
Three row disc type furrow opener shaping furrows in Louisiana.

Sugarcane Culture

Planting

Plow tip depth is approximately 10 to12 inches which will result in a furrow approximately 8 to 10 inches deep.

Note: marker arms are not used and the uniformity of the start - stop point of the furrow ends is controlled by GPS.



Opening rows in South Florida.

Sugarcane Culture

Planting

Plant nutrient levels for dedicated energy cane have not been established so more research is needed in this area. It is well established that on organic soils in South Florida nitrogen applications will be very low or not necessary.

Nutrient recommendations are dependent on soil tests, stage of production cycle, and soil type. The recommendations vary greatly with nitrogen often applied in split applications.

Filling dry fertilizer applicator.

Soil type	Nitrogen	P_2O_5	K_2O
Organic	0-30 lb	40-75 lb	0–250 lb
Mineral	30-180 lb	40-75 lb	0–250 lb

Sugarcane Culture

Planting

Nutrient removal by a sugarcane crop yielding 50 tons/acre (T/A) has been estimated to be approximately 74 lb/A nitrogen, 33 lb/A phosphorus, and 149 lb/A potassium.

Micronutrients are often applied at planting in soils with pH > 6.6. In addition, application of silicon (Si) in the form of Ca-silicate slag has increased yields and improved ratoon crops.

Appling fertilizer in row.

Sugarcane Culture

Planting

Each planting crew consists of eight to ten people including the tractor driver. Four people on the wagon drop cane in one of four furrows and three to four people arrange and chop the cane in the furrows.

Uniform spacing of stalks and smooth spreading of chopped seed pieces insure maximum utilization of water, nutrients, and sunlight.

Dropping and chopping whole stalk sugarcane.

Sugarcane Culture

Planting

After chopping, stalks should be arranged as shown in the two pictures at the right. At least two stalks side by side with no gaps between ends of stalks.

After covering, these rows should have good uniform emergence and develop the maximum number of new plants per foot of row.

Good seed distribution.

Sugarcane Culture

Planting

Soil insecticide may be applied if wireworms (*Limonius* spp.) are a known problem.

This field has a history of wireworm infestations. Accordingly, proper insecticide is being applied.

Appling soil insecticide in South Florida.

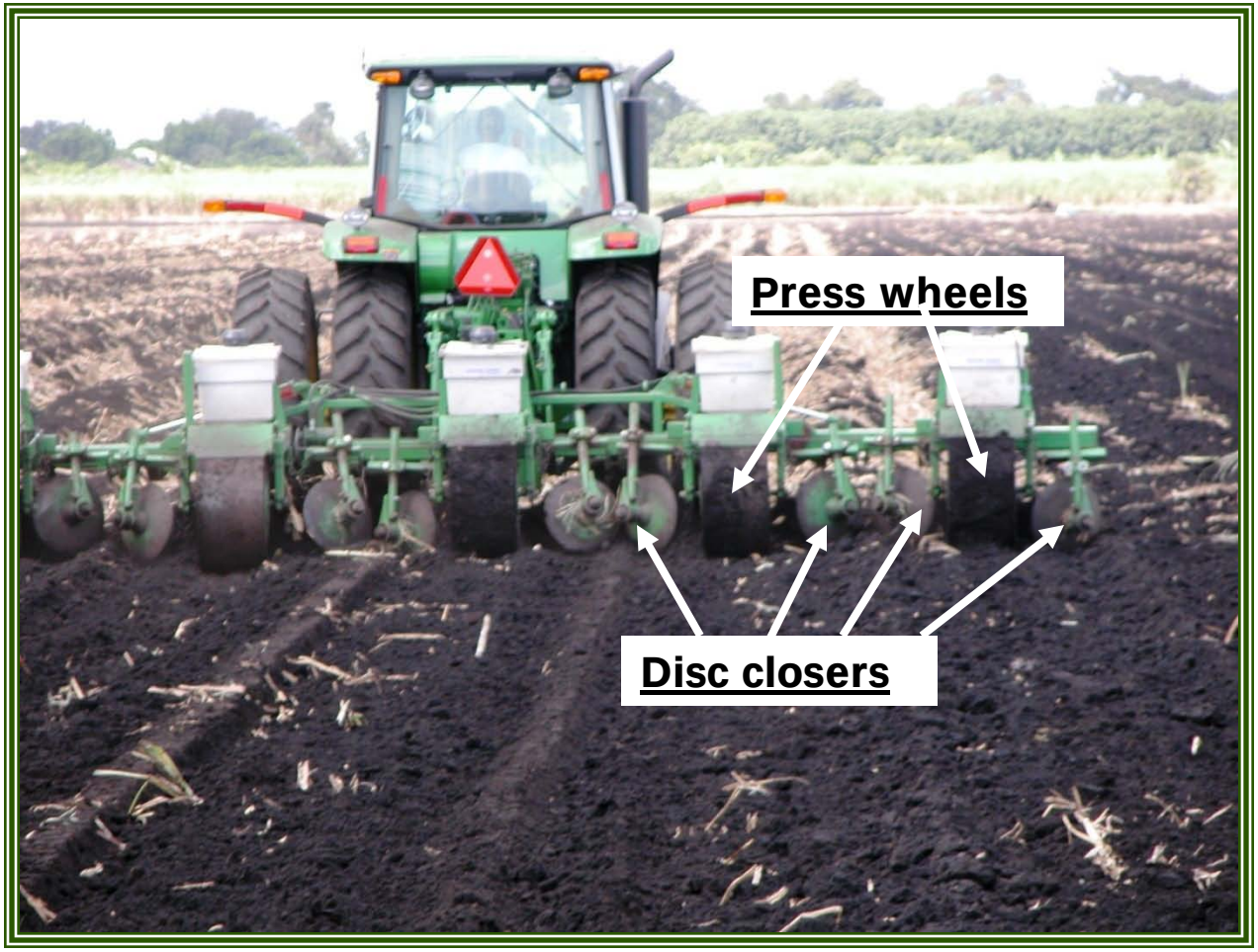
Sugarcane Culture

Planting

The amount of soil covering cane can be as little as two inches or as deep as six inches.

In areas of heavy soil and cool temperatures, shallower covering is recommended.

In South Florida, planting begins in mid-September and continues through December. In Louisiana, mid-August through September is the preferred time for planting.



Closing rows In South Florida.

Sugarcane Culture

Mechanical Planting

Seed for mechanical planting is cut with a commercial cane harvester rather than a solider harvester as in whole stalk planting.

In most situations, billets are loaded into a high dump wagon and hauled to the planting site rather than loading the planter directly in the seed field as depicted in this image.

Damage to buds caused by the planters has caused concern in the cane industry but improvements to harvesting and planting equipment continue to reduce seed damage.

Distribution of seed billets in the row has been a challenge for some planters.

Machine **harvesting of sugarcane billets to be used in planting.**

Sugarcane Culture

Planting Summary

	Mechanical planting	Hand planting	Notes
Labor required for one crew	Four equipment operators	Eight laborers, two equipment operators	
Seed required	Approximately four tons per planted acre	Approximately one ton per planted acre	Energy cane values have not been established
Emergence	May be a little slow Weather influenced	Generally good	Small billets in mechanical planting provide less energy / eye
Crop establishment	May have “gaps” or “clumps” due to poor drop	Generally good	Mechanical planters may drop cane billets in piles or cause skips
Timing	Early fall best	Any time before frost	Warmer temperatures in fall aid emergence and establishment

Sugarcane Culture

Pest Management

Pest control is essential for successful production of all crops. In commercial sugarcane, weeds, diseases, and insects present challenges. In early large plot trials energy cane does appear to compete very well against weed pressure.

Insect pests, such as cane borer (*Diatraea saccharalis*), and diseases, especially rust (*Puccinia melanocephela* and *P. kuehnii)*, will be a challenge for energy cane production.

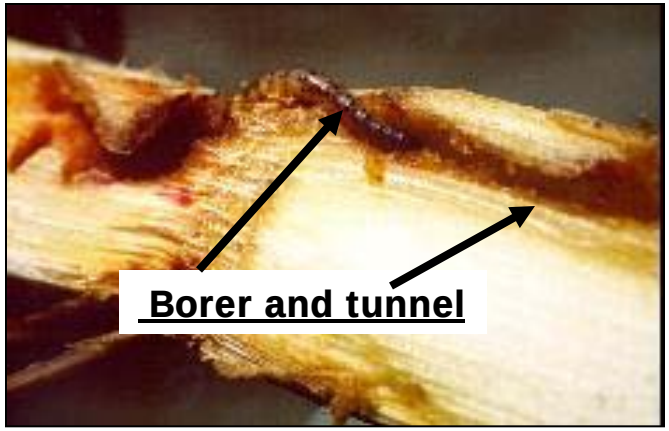
The following section is not designed as a comprehensive pest management guide. It is an introduction to the most economically important pest challenges of South Florida. As cane production moves into other areas, the pest profile may change according to environmental conditions.

Sugarcane Culture

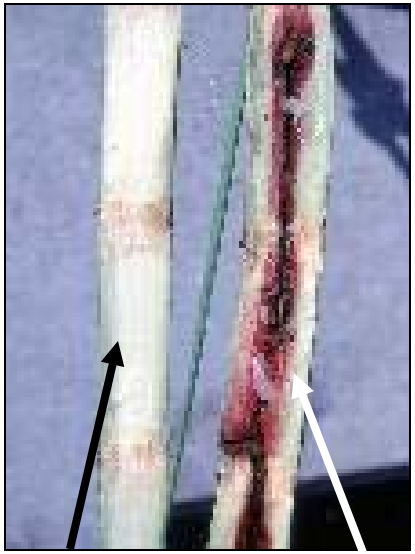
Pest Management - Insects

Sugarcane borer (*Diatraea saccharalis*) is the larva stage of a small moth. These insects go through complete metamorphosis – egg, larva, pupa, and adult. The larvae damage cane stalks by tunneling through the stalk. The damage reduces stalk weight (tons/A) and sucrose content. Secondary infection of fungi, bacteria, and viruses may occur at cane borer entry point.

Adult moth with egg mass. (LyraEDISServlet)



Bore damage at node. (LyraEDISServlet)



Undamaged **Damaged**

Damaged and undamaged stalk. (LyraEDISServlet)

Cane borer larva. (LyraEDISServlet)

Sugarcane Culture

Pest Management – Insect control

The list of insects below represents a short list of economically damaging insect pests of sugarcane and is not a comprehensive study. These three insects may present challenges for energy cane as production increases.

Imported fire ant (*Solenopsis invicta*) attacking borer.

Pest	Cultural Control	Chemical Control
Cane borer	• Plant resistant cultivars. • Use borer free seed cane. • *Alabagrus stigmatera* and *Cotesia flavipes* are important wasp parasitoids of the sugarcane borer larvae.	• Several insecticides are available. • Read and follow label directions. • Resistance management practices should be followed.
Wireworm	• Include rice in crop rotation. • Fallow field flooding.	• Soil-applied insecticides at planting if field has history of wireworm.
White grub	• Include rice in crop rotation • Flooding • Fallow discing	• Not recommended.

Sugarcane Culture

Pest Management - Disease

Ratoon stunting disease (RSD) is considered by many to be the most important disease affecting sugarcane production worldwide. It can cause a 5 to 15% loss in crop yield without the grower even knowing the field has been infected.

The disease is caused by a bacterium *Clavibacter xyli* subsp. *Xyli.*

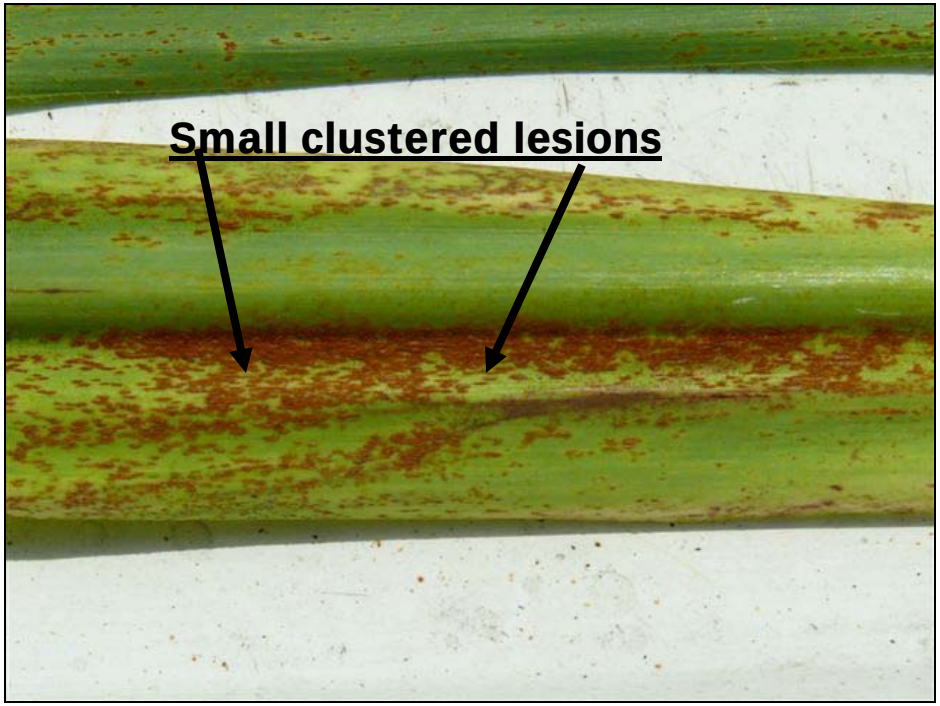
Although there may be no conspicuous symptoms of the disease, internally there is usually an orange-red discoloration of the vascular bundles containing the water-conducting tissues (xylem) at the basal nodes of the stalk.

Sterile meristem tissue has been used to produce disease free clones but this is expensive and only offers temporary disease control. The disease is spread as contaminated equipment moves through the field.

Discoloration of sugarcane vascular bundles caused by ratoon stunting disease.

Sugarcane Culture

Pest Management - Disease



(USDA)

Orange rust caused by *Puccinia kuehnii* is a new rust disease to the United States first found in 2007. This fungal disease tends to attack the plant later in the year when conditions for brown rust are less favorable.

(USDA)

Brown rust (USDA) caused by *Puccinia melanocephela.* Temperatures between 15° to 30° C (60° to 85° F) favor development of this fungal disease. The lesions produced are elongated and narrow.

Pest Management - Disease

Severe orange sugarcane rust damage. (USDA)

Brown sugarcane rust on young ratoon crop. (USDA)

Control of both orange and brown sugarcane rust has focused on development of host resistance. Fungicides are effective but have proven uneconomical for control except in severe outbreaks. These rust diseases are spread by wind and like many fungal diseases are favored by moist conditions.

Sugarcane Culture

Pest Management - Weeds

Sugarcane and energy cane are grown in the same field for several years which can presents weed management challenges that annual crops do not encounter.

Weeds that mimic cane or vine weeds that emerge and grow later in the season can be very challenging.

Napier grass (*Pennisetum purpureum* Schumach.), also called elephant grass, looks like and competes well with sugarcane. It is a strong competitor with energy cane.

This plant was introduced into the United States as a forage crop but is now considered an invasive species. It has been evaluated as an energy feedstock, however it does not produce enough biomass to make it a good candidate.

Napier grass. http://www.hear.org/starr/images/full/starr-031108-0226.jpg

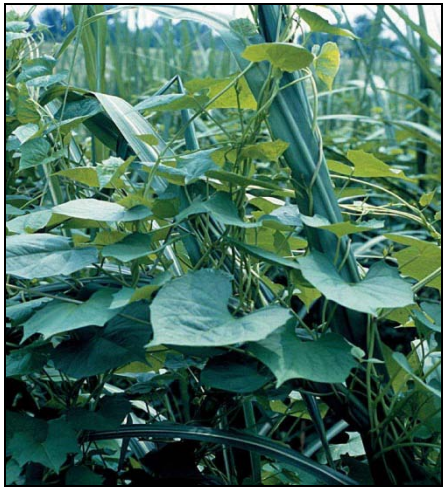
Sugarcane Culture

Pest Management - Weeds

Several species of creeping vines such as **sweet potato** (*Ipomea batatas* (L.) Lam.), **Balsampear** (*Momordica charantia* L.), and **common morningglory** (*Ipomoea purpurea* (L.) Roth) can become serious problems if not controlled early. Sugarcane's multi-year production cycle and long growing season makes control of vines challenging.

Sweetpotato (*Ipomea batatas).*
erec.ifas.ufl.edu/weeds/

Cane overgrown by morningglory.



Morningglory. LSU AgCenter.
Courtesy of James L. Griffin.

Balsampear (*Momordica charantia).*
erec.ifas.ufl.edu/weeds/

Sugarcane Culture

Pest Management - Weeds

The next two tables describe herbicide options for weed management in sugarcane. In combination with timely mechanical cultivation good weed control can be maintained.

Common Name	Pre-emergent	Post-emergent	Notes
Glyphosate	X		Fallow land management and with care can be used with hooded sprayers in row middles.
Atrazine	X	X	Pre in plant cane. Post in ratoon if weeds are small < 3 expanded leaves.
Pendimethalin	X		Good control of annual grasses and broadleaves. Good incorporation important.
Diuron	X	X	Better on broadleaves. Directed post application prolongs control.
Flumioxazin	X	X	Grass and broadleaf control. Post applications should be made when weeds are small.
Metribuzin	X	X	Directed post application before weeds are six inches tall.
2,4-D		X	Good broadleaf control.

Sugarcane Culture

Pest management - Weeds

Common Name	Pre-emergent	Post-emergent	Notes
Dicamba		X	Good broadleaf control alternative for 2,4-D.
Asulam		X	Control of difficult grasses in cane > than 14 inches tall. Tank mixing reduces control.
Trifloxysulfuron-sodium		X	Good control of several difficult grasses and broadleaves. Works well in tank mixes.
Halosulfuron-methyl		X	Good nutsedge control.
Ametryn		X	Apply as directed spray only, good control of difficult grasses < 3 inches tall.

As with all crop protection chemicals always read and follow label directions. Several of these products work well combined in tank mixes and addition of non-ionic surfactants may improve performance and weed control. This is not an endorsement of any products but only a reflection of products used in cane production.

Sugarcane Culture

Harvesting

In Florida, cane harvest begins in October and continues through March. Bagasse is burned at the mill to produce electricity for mill operation and excess electricity is sold to the grid.

Energy cane can be harvested with existing commercial cane harvesters as in the images to the right. The billets produced by these harvesters must be further processed for efficient cellulosic digestion and fermentation.

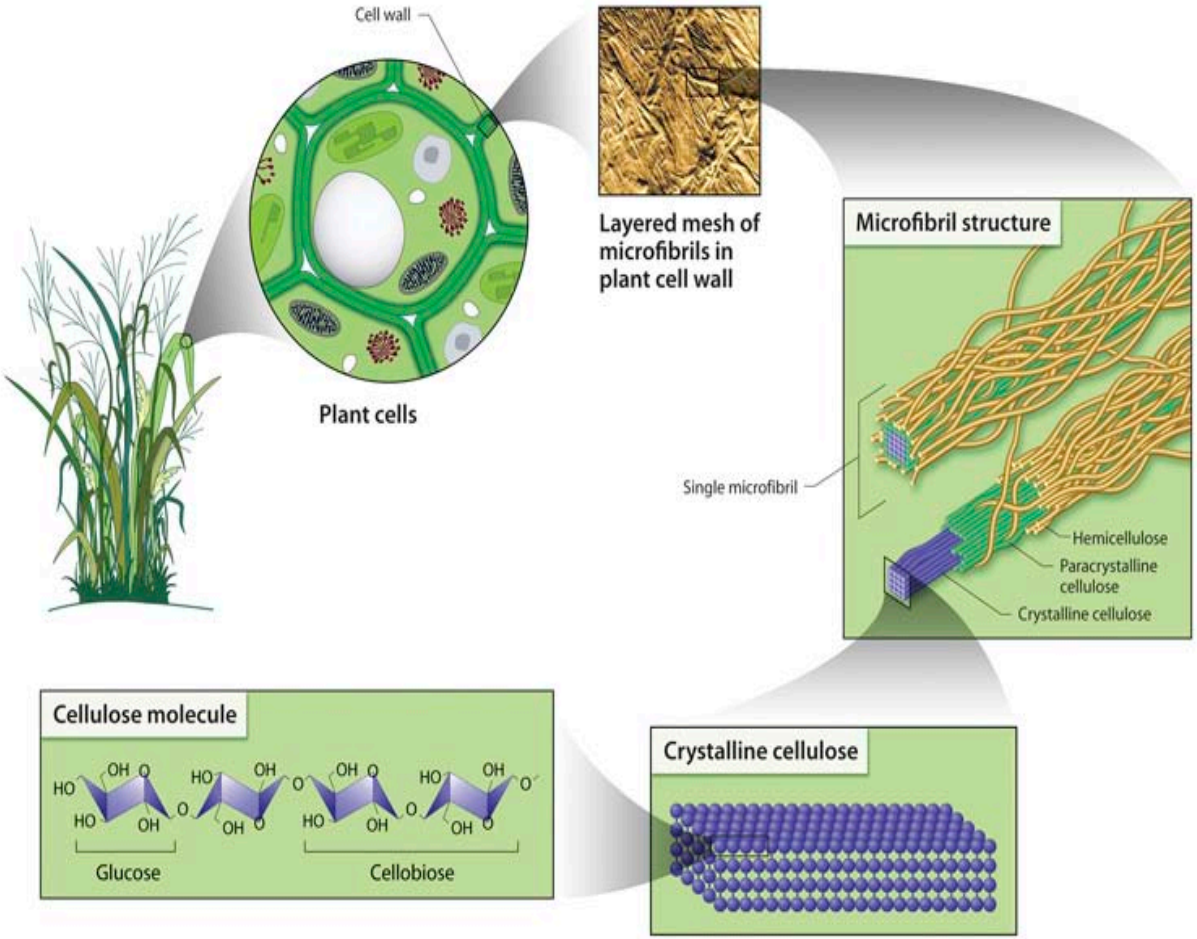
Large plot trials have demonstrated forage harvesters are capable of harvesting and chopping energy cane into acceptable sized feedstock. Equipment modifications are required to allow the forage chopper head to handle the large volume of biomass.

Sugarcane Energy Utilization

Cellulose is contained in the structural microfibrils of the cell wall. It is constructed from chains of pentose and hexose sugars which can be converted to ethanol through fermentation.

Processing of biomass begins by physically reducing the size of the feedstock then chemically breaking the bonds of the cellulose and hemicellulose to release the sugar chains.

The sugar can then be converted to ethanol by fermentation.



http://genomicsgtl.energy.gov/benefits/cellulosestructure.shtml

Sugarcane Energy Utilization

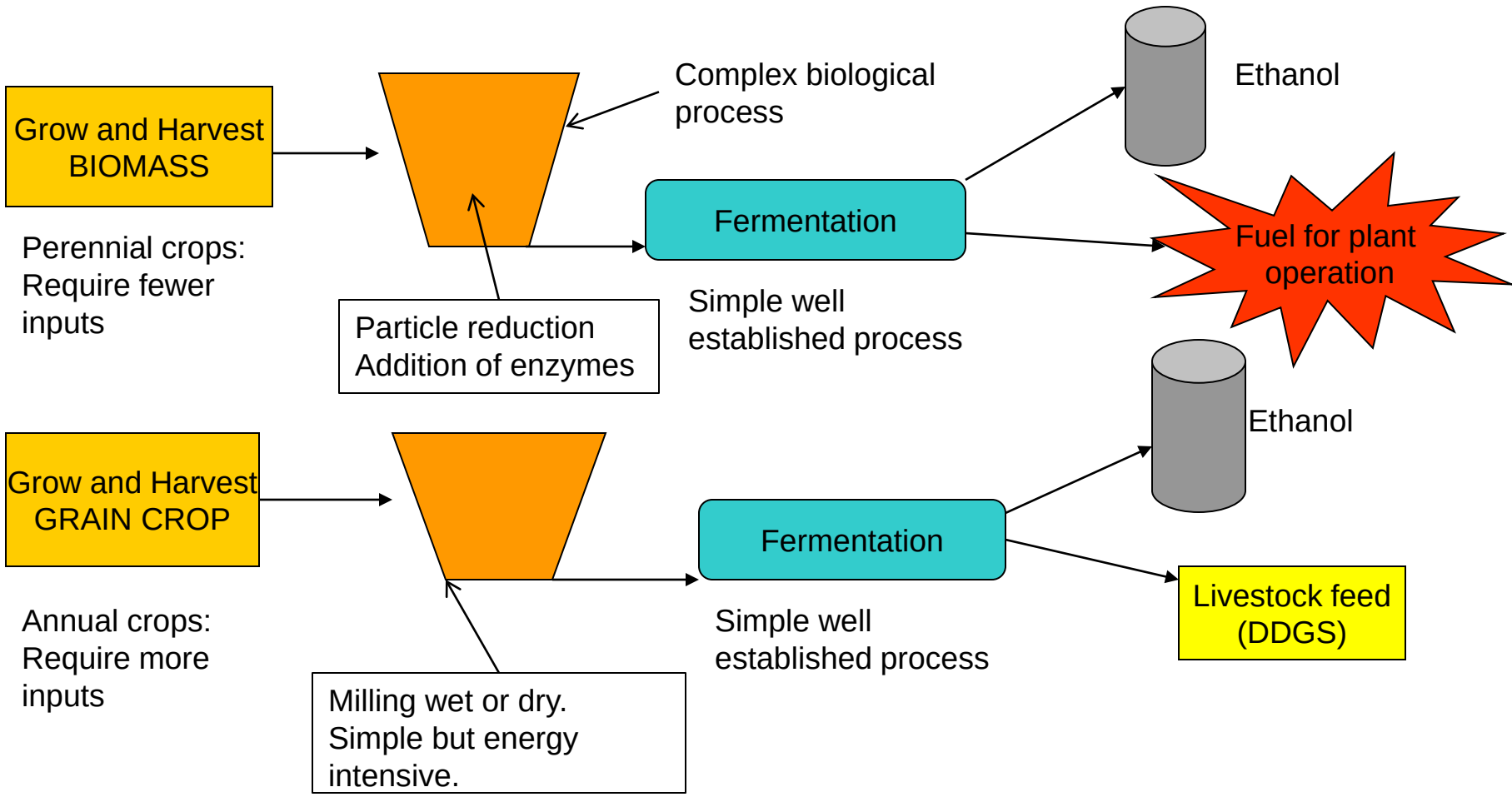
Bagasse is the term used to describe the remains of the cane plant after milling. Mills burn the bagasse to produce steam that generates electricity for mill operation. Excess power is sold to the power grid and helps power homes and businesses in the area.

Bagasse provides a ready source of cellulosic material for ethanol production. Energy cane will not be processed by a sugar mill for sucrose so particle size reduction will be accomplished in a separate operation.

Sugarcane plants after milling, ready for combustion or cellulosic conversion to ethanol. http://www.rise.org.au/info/Res/biomass/image004.jpg

Sugarcane Energy Utilization

In a very simplified comparison of production of ethanol using grain or biomass as the feed stock one can see the energy advantage biomass has over grain. All of the energy to operate the conversion plant can be derived from the byproduct of cellulose fermentation, grain requires additional energy from outside the system.



Sugarcane Energy Utilization

Brazil has been using sugarcane juice, not the bagasse, to produce ethanol for over thirty years. The process of fermentation and distillation of the cane juice results in about 10 gallons of waste water produced for every gallon of ethanol. This water is referred to as vinasse and contains high levels of potassium, calcium, and organic material. Several methods of handling vinasse have been proposed and utilized.

Brazilian sugar mill http://en.wikipedia.org/wiki/Ethanol_fuel_in_Brazil.

Processing of vinasse requires large amounts of energy to dehydrate and concentrate the byproducts. Contamination of potable water supplies, rivers, and lakes is also a concern when processing the large amount of waste water generated by juice fermentation and distillation. Additionally, the U.S. sugar industry can not afford to convert the juice and molasses to ethanol production. Bagasse is a ready economical source of cellulose for combustion and conversion to ethanol for the U.S. sugar industry.

Energy Cane Development

Cultivar development in commercial sugarcane is a ten to eleven year process of selection and field trials. Because researchers are selecting energy cane plants for a more limited set of traits, selection has been reduced to six years. This selection system has the advantage of rapid development of high biomass yielding feedstock in a relatively short period of time. This table is a brief summary of the selection process and is adapted from Rob Gilbert of the University of Florida EREC and Jack Comstock USDA–ARS.

Year	Stage	# 0f Plants	Location	Trait
1	Seedling	7000 2500	S. Florida N. Florida	Visual biomass, disease, cold tolerance, and brix (sugar value)
2	1	110-150 30	S. Florida N. Florida	Visual biomass, disease
3-4	2	~15	S. and N. Florida	Biomass yield, disease, fiber characteristics, genotyping in plant cane and first ratoon
4-5	3	~5	S. and N. Florida	Biomass yield, disease, fiber characteristics, genotyping in plant cane and first ratoon
4-6	4	~5	S. and N. Florida GA and Al	Mechanical harvesting, disease, and cold tolerance

Energy Cane Development

Energy canes are developed from wide crosses between high fiber, low juice “wild type” canes and *Saccharum* spp. The resulting plants yield high biomass with high fiber content. These are tropical grasses that are not widely adapted to cooler climates so cold tolerance is a key evaluation trait during selection.

Dr. Peter Tai, USDA retired, was an early advocate for development of cold tolerant cultivars and developed many of the foundation plant material that are now being used for energy cane.

Dr. Peter Tai examining early cold tolerant canes. USDA.

Energy Cane Development

Development of new sugarcane and energy cane cultivars begins by crossing individual plants to produce “true” seed. If you recall from the beginning of the module, cane flowers only produce viable seed under a controlled environment. Each seedling is a unique individual plant with characteristics similar to its siblings.

Tray with seedlings ready for transplanting.

Individual seedling ready for transplanting . USDA.

Seed from the crosses, referred to as ‘fuzz’, is planted and grown in a greenhouse for approximately 90 to 120 days and produces seedlings as pictured above. These plants are then transplanted to field plots.

Energy Cane Development

Transplanting seedlings with mechanical transplanter. Each flat contains seedlings produced by a specific cross so each seedling within a tray is from the same parents or “family”.

Loading mechanical planter with seedling. USDA

Planting seedling plots.

Seedlings are sorted and planted in field plots by family as indicated by the white stakes in the picture to the left. In approximately nine months these seedlings will be evaluated, individuals selected, harvested, and placed in the stage 1 phase of the development program. Each stalk selected produces a unique clone.

Energy Cane Development

Stage one clones are grown for approximately twelve months, selected based on the criteria set in the biomass development program, and planted in stage two plots.

Growers at energy cane field day looking at early stage two plant cane clones.

Growers evaluating progress of stage three 1st ratoon energy cane at energy cane field day.

Stage three plots are mechanically harvested for yield data and fiber analysis. The plant cane and ratoon crop are used to determine selection for advancement to stage four plots.

Energy Cane Development

This video shows mechanical harvesting of stage three plant cane plots. Three replicated plots of each clone are harvested with a weigh wagon and averaged together to determine total biomass produced by the clone.

In early trials dry matter ranged between 23.5% and 33.7% with dry matter yields of 8.7 to 13.3 tons per acre. The highest yielding clones will be advanced to stage four if the ratoon crop yield is good and disease or other unforeseen problems do not arise.

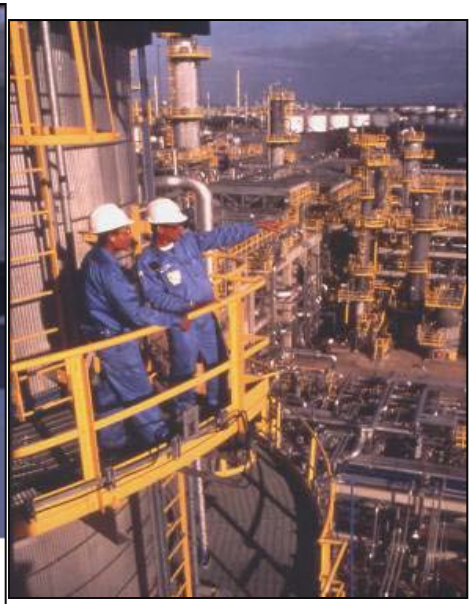
Conclusion

Escalating petroleum prices, increasing crude oil imports, dwindling domestic oil supplies, and concerns about the impact of burning fossil fuels are driving a search for a renewable clean energy source.

While there are several options for generation of electrical power for “the grid”, i.e. wind, solar, and nuclear, there are limited options for motor fuel. While hydrogen powered engines and electric automobiles are still years from development and require development of new infrastructure, biofuels are a reality today.

In the long term bioenergy will not be able to meet the increasing demands of a growing population but it can be part of an integrated supply system that increases national security, increases incomes in rural areas, and helps provide a cleaner environment.

Photo courtesy: National Renewable Energy Laboratory (NREL)



Conclusion

Ethanol is not a new idea. It has been used in the past and is used today as part of the fuel supply in Brazil and the United States. The mandates of the renewable fuel legislation have set goals that make development of ethanol from biomass part of an overall strategy to move toward energy independence and a cleaner environment. Development of a cellulosic ethanol industry promises to help invigorate the economic growth in rural communities and provide agriculture with an opportunity to develop a new income source.

Energy cane is one of several crops that can be grown as dedicated biomass feedstock for cellulosic ethanol production. At present, cultivation of energy cane is limited to subtropical environments of the Southeastern United States, but with continued development of cold tolerant cultivars production areas can be expanded. Biomass yield of energy cane is superior to other biomass feedstock crops which equates to great potential for providing economical cellulosic ethanol production.

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