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Sugarcane Culture and Syrup Production

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This publication gives the basic information needed by growers of syrup sugarcane. It includes descriptions of the sugarcane plant, characteristics needed in syrup varieties, the best varieties, cultural requirements and practices, and the diseases and insect pests of sugarcane. Also described are typical equipment needs, the process of making syrup, and various techniques for obtaining the best product.

KEYWORDS: Sugarcane, sugarcane culture, sugarcane diseases, sugarcane insect pests, sugarcane syrup, syrup production.

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This publication supersedes Agriculture Handbook No. 209, "Culture of Sugarcane for Sirup Production."

Sugarcane Culture and Syrup Production

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Sugarcane for syrup production is grown on farms ranging from a fraction of an acre to 10 or 20 acres. A few farmers have larger acreages. Syrup is usually manufactured on a small scale, although there are a few large factories. It is sometimes made in the neighborhood for home use only; otherwise, it is produced primarily for the market. In many communities, a group of farmers has the syrup manufactured at a privately or cooperatively owned plant.

Sugarcane syrup is usually light colored and mild and has a good flavor. It is favored by many as a table syrup. Since market potential and production cost are affected by such variables as locality, size of operation, and quality of product produced, each grower should research these matters carefully for the particular operation.

Most sugarcane for syrup is grown in Georgia, Alabama, Mississippi, and Louisiana. These States—the sugarcane-syrup belt—produce about 90 percent of the sugarcane syrup manufactured in the United States. Louisiana and Georgia have been the largest producers for many years. Some sugarcane is also grown for syrup in Florida and Texas. The northern limit (fig. 1) for growing sugarcane for commercial production of syrup is

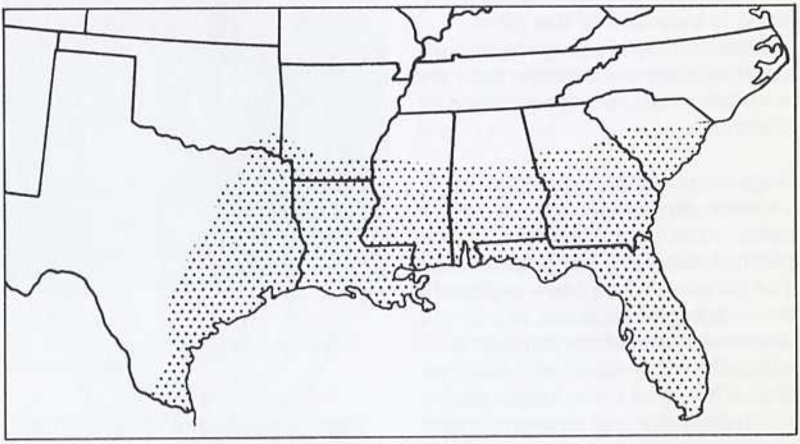

Figure 1
Successful sugarcane culture for syrup production is restricted to shaded area. (Source: Stokes et al. 1961.)

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where the crop remains immature, imparting objectionable qualities to the syrup; gives a prohibitively small yield because of the short season; or fails to produce a stubble crop (Brandes et al. 1940).

Sugarcane is propagated by means of "seed cane," which is sections of the stalk containing one or more buds. True seed is not suitable for growing a commercial crop of sugarcane. It is exceedingly small, germinates very poorly, and requires much longer to develop into full-grown plants than do the shoots from buds, or "eyes," on the seed cane. Plants grown from true seed are not true to type and are usually inferior to the parent varieties. However, the production of true seed is essential to the plant breeder for developing sugarcane varieties that are disease resistant and that produce high yields of good syrup.

Sugarcane varieties propagated vegetatively, that is from seed cane, do not change when planted over long periods of time. The older varieties have gradually been replaced because of diseases, particularly mosaic, to which they are especially susceptible. Throughout the sugarcane-syrup belt, disease-resistant, high-yielding varieties are now used almost exclusively.

Sugarcane Plant

Description

Sugarcane, a member of the grass family, belongs to the genus *Saccharum*. Syrup varieties are complex hybrids from crosses of several species. Sugarcane is best adapted to tropical conditions. Little or no growth occurs during the winter in the syrup areas of the Southern United States. Under favorable conditions a new crop will normally be produced from stubble of the previous crop.

Early growth above the surface in the spring consists mostly of leaves. However, the stalk is developing during this period, at first mainly by the formation of nodes situated very close

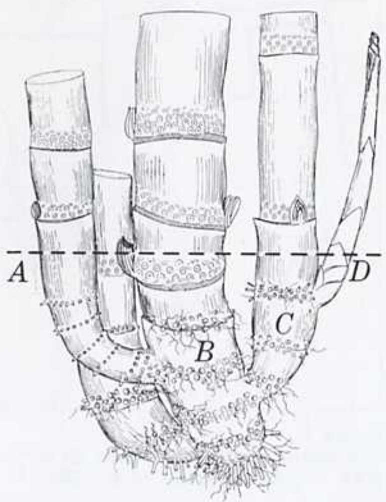

Figure 2
Part of sugarcane stool: *A*, Ground level; *B*, primary, *C*, secondary, and *D*, tertiary stems.
(Source: Artschwager 1925.)

Figure 3
CP 36–111 sugarcane consisting of several stalks.

together. After the stalk emerges, the internodes grow more rapidly and become much longer. Tillers develop from buds below the surface. The entire plant is called a stool (fig. 2). A mature plant usually has several stalks growing together in a cluster (fig. 3). The stalks, which consist of fully

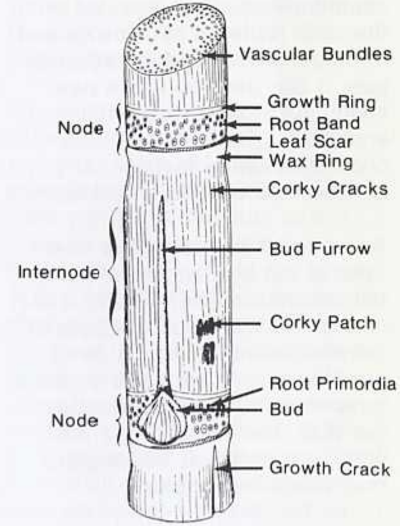

Figure 4
Node and internode of sugarcane.
(Source: Artschwager 1940.)

expanded nodes and internodes, vary from 6 to 10 feet high at harvest. They range from light green or yellow to red or purple.

The node is tough, fibrous tissue with four essential structures—root band, growth ring, bud, and leaf scar (fig. 4). The root band is a small section of the node just above the leaf scar. It usually differs in color from the internode and has many small dots. Under proper moisture conditions, a root may develop at each dot. Just above the root band, and usually not clearly distinct from it, is a transition area known as the growth ring. Elongation and growth of the internodes occur in this area. At each node is a bud on the root band. Buds are arranged in two rows, usually alternately on opposite sides of the stalk. When a bud is exposed to proper moisture and temperature, it can develop into a new shoot. A slightly protruding, encircling area is visible at the node. This is the leaf scar or point of attachment of the leaf sheath.

As its name suggests, the internode is the section of the stalk between the nodes. Usually a thin film of wax covers the outside of the mature internode. Its outer area, or rind, is hard and contains numerous fibers that strengthen the stalk; the inside of the internode is mainly soft tissue (pith) that stores sweet juice.

A leaf of the sugarcane plant consists of the sheath and the blade. The sheath completely encircles the stalk, forming a close-fitting cover for the bud. It usually extends the full length of the internode. The blade of syrup varieties varies from 1 to 3 inches wide at the point of attachment to the sheath and tapers to a sharp point. Leaf blades are usually 4 to 5 feet long.

The primary feeding roots originate from nodes at a point slightly beneath the surface of the soil. They grow downward into the soil; secondary, tertiary, and smaller roots branch out and penetrate the soil in all directions. The plant obtains its moisture and mineral nutrients largely from the upper foot of soil. Some of the roots, however, extend down 3 to 4 feet or more.

Characteristics of Syrup Varieties

The desirable characteristics of sugarcane varieties grown for syrup production are the ability to produce a high yield of medium-to-large stalks; a high percentage of extractable juice with a high total soluble-solids content, mostly sugar (expressed as degrees Brix); the ability to mature in a comparatively short growing season; disease resistance; the ability to produce high-quality syrup; desirable germination and stooling; good stubbling; strong, erect plant growth that resists lodging; and resistance to cold injury. Varieties differ greatly in these characteristics and in their adaptation to soil and climatic conditions. The grower should carefully consider all these qualities in selecting a variety.

A high yield per acre of medium-to-large (1.0- to 1.5-inch diameter) stalks is essential to the economical production of sugarcane syrup. Yields of cane per acre are affected by cultural and fertilizer practices. Large-stalk varieties are cheaper to harvest and easier to handle in the small mills normally used throughout the syrup-producing areas of the United States. The stalks should be soft and easily processed in these small mills. A suitable variety should yield a high percentage of extractable juice. Each 100 pounds of stalks should yield about 60 pounds of juice when processed in an efficient mill.

Syrup yield per ton of cane is determined by the degrees Brix (soluble solids) of the extracted juice. A suitable variety should produce juice with a high Brix (15–18 percent) reading. To avoid excessive crystallization or sugaring in the finished syrup, the soluble-solids content should not contain more than 50 percent sucrose.

Since most of the sugarcane for syrup production is grown on the northern fringe of the area adapted to the culture of sugarcane in the United States (fig. 1), it is essential that the variety mature as early as possible. Maturity is determined by the Brix reading of the juice (15–18 percent soluble solids). A suitable variety should be mature or have acceptable juice Brix for harvest in October to avoid cold injury later in the season.

Sugarcane diseases are economically important throughout the sugarcane-syrup belt. To control losses, which can range from a slight reduction in yield and quality of syrup to loss of the entire crop, the farmer should plant a variety with resistance to these diseases.

A suitable variety should produce a high-quality syrup with the following characteristics: Light amber color; mild, sweet flavor typical of sugarcane syrup; no colloidal sedimentation, or sediment confined to a trace of small particles near the top of the container; and no crystallization or, if present, limited to a few small crystals.

The yield of cane and syrup per acre and the quality of the juice for syrup production at harvest are affected by the ability of the variety to germinate and to produce an adequate number of tillers per stool early in the spring. Tillers produced late in the season often die before harvest. They sap the growth of primary stalks and tend to delay the maturity of the crop. Delayed maturity, coupled with early harvest, results in low-quality juice for syrup production. A suitable variety should germinate early in the spring and produce a stand of mature stalks by harvest.

In the syrup area, three crops of sugarcane are usually produced from one planting. Since early harvesting of a crop generally reduces the stand of cane produced from the stubble the following year, a suitable variety should produce a satisfactory stand from stubble even when the previous crop was harvested as early as October 15.

Lodged and entangled stalks at harvest greatly increase the harvesting costs and reduce the profit from the crop. Lodging may degrade juice quality, especially when the lodging is associated with stalk breakage and uprooting. A suitable variety should not lodge readily even under severe conditions of rain and high winds.

Figure 5
Stalk characteristics of three sugarcane varieties: *A*, CP 36-111; *B*, CP 52-48; *C*, CP 67-500.

Since sugarcane is normally a tropical plant, it has very little resistance to cold injury. Cold injury may reduce the quantity and quality of syrup produced. A suitable variety should not be greatly damaged for syrup production by light frost injury.

Syrup Varieties
The variety grown is one of the most important factors in the production of syrup. Most of the older varieties have been replaced for commercial production because the newer varieties are better adapted, have better yield, and are more disease resistant.

Through plant explorations and exchange with other sugarcane-growing areas, the best varieties of the world have been assembled in the United States as valuable breeding material for use in improving varieties. They are crossed and their progeny studied so that better varieties for syrup, adapted to the specific requirements of each locality, can be selected and made available to farmers.

We recommend 'CP 36-111', 'CP 52-48', and 'CP 67-500' (fig. 5) as the best varieties for syrup production. CP 36-111, a variety bred by the U.S. Department of Agriculture, has consistently given good yields of syrup (table 1), though somewhat less than 'CP 29-116' (table 2) in some tests at Cairo, GA (Stokes et al. 1951). It has the same parentage as CP 29-116. Stalks of CP 36-111 are pale green to greenish yellow, with faint reddish-purple markings developing lengthwise as the internodes mature. A purplish color appears when leaves and sheaths are removed and the stalk is exposed to the sun. Under favorable growing conditions, the internodes are long and the stalks straight, about the same as those of CP 29-116 in diameter and

Table 1
Yields of 3 varieties of sugarcane at 4 locations, 1966–69

	Yields at—											
	Meridian, MS			Poplarville, MS			Brewton, AL			Cairo, GA		
Crop and variety	Cane per acre (tons)	Syrup per ton of cane (gallons)	Syrup per acre (gallons)	Cane per acre (tons)	Syrup per ton of cane (gallons)	Syrup per acre (gallons)	Cane per acre (tons)	Syrup per ton of cane (gallons)	Syrup per acre (gallons)	Cane per acre (tons)	Syrup per ton of cane (gallons)	Syrup per acre (gallons)
Plant cane:												
CP 36-111	34.5	15.0	508	51.4	18.4	946	23.8	18.7	450	34.5	18.5	635
CP 52-48	39.8	15.8	671	63.2	16.8	1,062	34.0	19.2	645	46.3	17.9	830
CP 67-500	33.1	15.7	572	50.2	18.9	949	25.9	19.7	503	39.5	20.4	804
1st-year stubble:												
CP 36-111	32.9	15.7	523	52.1	19.9	1,037	37.5	21.1	784	23.2	17.9	416
CP 52-48	36.4	15.7	562	56.6	17.8	1,025	44.6	19.9	873	37.4	18.2	682
CP 67-500	29.8	16.4	497	50.2	20.5	1,029	23.5	22.2	789	32.6	19.6	645
2d-year stubble:												
CP 36-111	25.4	15.9	401	...	...	...	39.5	18.7	740	15.7	17.4	274
CP 52-48	28.4	16.0	454	...	...	...	47.9	18.3	879	21.2	18.2	383
CP 67-500	25.9	17.0	459	...	...	...	40.2	0.0	816	22.8	20.3	464
Average for 3 years:												
CP 36-111	30.9	15.5	477	51.8	19.2	992	33.6	19.5	658	24.5	17.9	442
CP 52-48	34.9	15.8	562	60.4	17.3	1,044	42.2	19.1	799	35.0	18.1	665
CP 67-500	29.6	16.4	509	50.2	19.7	989	29.8	20.7	703	31.6	20.1	638

Table 2
Yields of 2 varieties of sugarcane at Cairo, GA, 1955–59

Crop and variety	Cane per acre (tons)	Syrup per ton of cane (gallons)	Syrup per acre (gallons)
Plant cane:			
CP 29-116	28.3	19.5	552
CP 52-48	36.3	19.4	704
1st-year stubble:			
CP 29-116	23.3	17.4	405
CP 52-48	33.9	19.1	647
2d-year stubble:			
CP 29-116	16.3	20.2	329
CP 52-48	33.6	19.6	659
Average:			
CP 29-116	22.6	19.0	429
CP 52-48	34.6	19.3	668

weight. CP 36-111 has given excellent stands as first- and second-year stubble in most areas. The leaves are fairly easily stripped from the stalks at harvest. Milling operations are greatly facilitated by the straight stalks. The percentage of juice obtained in milling is about the same as from CP 29-116. Although CP 36-111 has not been damaged severely by mosaic or other diseases, it is not immune to them.

CP 52-48 was released for commercial culture in southwest Georgia. This variety, bred by the U.S. Department of Agriculture, has consistently given higher yields (table 1) of cane and syrup per acre than CP 29-116 (table 2). It is a selection from a cross between 'CP 36-105' and 'CP 38-34' (Freeman and Lyons 1960). Like 'Co 290', the long leaves of CP 52-48 tend to droop. Since the variety shades the row early, it is highly competitive with weeds. Stalks of CP 52-48 are pale green when the grayish to pinkish wax is removed. This variety is highly resistant to lodging because it has a stiff stalk and an extensive root system. Under favorable growing conditions, the internodes are long. The stalks are straight and of about the same diameter and weight as those of CP 29-116. They are harder and more difficult to cut by hand than those of CP 29-116, but they are well adapted for machine harvest because of their erectness. This variety does not strip as cleanly and easily as CP 29-116, but stripping is not particularly difficult. CP 52-48 germinates early in the spring and develops a satisfactory stand 2 to 3 weeks earlier than CP 29-116 or CP 36-111. It is superior to them in tillering and in producing a good stand in first- and second-year stubble crops in southern Georgia. Milling operations are greatly facilitated by the straight stalks of CP 52-48. The percentage of juice extracted and the Brix reading are about the same as for CP 29-116. The juice clarifies well, and the syrup is equal in quality to that of CP 29-116.

CP 67-500, a sugarcane variety with superior lodging resistance, was bred by the U.S. Department of Agriculture and selected in the cooperative sugarcane breeding program of the U.S. Sugar Crops Field Station, Meridian, MS, and the Mississippi Agricultural and Forestry Experiment Station (Coleman and Broadhead 1968). It is a selection from the progeny of a cross between 'CP 50-11' and 'CP 51-30'. CP 67-500 grows erect and has heavy wax on the bluish stalks. The stalks are shorter but larger in diameter than those of CP 36-111. CP 67-500 is equal to CP 36-111 in yield of cane per acre (table 1). It is slightly better than CP 36-111 in yield of syrup per ton of cane and syrup per acre and is better in resistance to lodging. It usually remains erect during storms, whereas CP 36-111 tends to lodge, making harvesting more difficult and expensive. CP 67-500 is resistant but not immune to infection by strain B of sugarcane mosaic virus.

Growing Sugarcane for Syrup Production

Fertilizer Practices

Most of the land used for growing sugarcane requires fertilizer. The amount for optimum growth depends largely on soil type, rainfall, crop history, and previous applications of manure and fertilizer (Stokes and Ashley 1947, Lyons 1954). Heavy soil may produce a good crop with little or no fertilizer added. Sandy soil is less fertile and usually requires fertilizer. Some upland soils of intermediate types, such as sandy loam, produce low yields without fertilizer, as shown in table 3. When legume cover crops are used for green manure, the need for fertilizer, especially nitrogen, is less. This is also true for land that has been well manured in the past or for land just plowed out of improved pasture.

Fertilizer may be applied in the off-bar furrow on each side of the row in April or early May with the first spring cultivation. The fertilizer is covered with 4 to 6 inches of soil. Subsequent applications of fertilizer, usually nitrogen, should be made during June. Applications later than this may retard maturity of the cane and lower the yield and quality of syrup. In a fairly fertile soil, a small application of fertilizer in the off-bar furrows to help the early growth may be all that is necessary for the entire season. But on most soils, the quantity applied should be greater than that needed for a starting effect only. Also, more fertilizer may be added later.

Table 3
Effect of fertilizer on syrup yield for 2 locations and soil types, 1966–69

Fertilizer[1] per acre (pounds) N	P_2O_5	K_2O	Syrup yield in gallons per acre from— Plant cane	1st-year stubble	2d-year stubble	Average yield (gallons)	Increase in yield from fertilizer (gallons)
			Cairo, GA, on Tifton fine sandy loam				
0	0	0	333	328	236	299	...
	72	0	361	346	251	319	20
	0	72	415	413	315	381	82
	72	72	422	422	339	401	102
36	0	0	390	367	241	333	34
	72	0	404	394	251	350	51
	0	72	502	513	367	461	162
	72	72	518	535	420	491	192
72	0	0	396	369	232	332	33
	72	0	428	406	241	358	59
	0	72	537	568	438	514	215
	72	72	528	597	467	531	232
			Poplarville, MS, on Ruston fine sandy loam				
0			393	423	305	374	...
20			537	498	479	505	131
40	0	0	571	572	530	558	184
60			561	621	595	592	218
80			480	608	571	553	179
20			454	508	447	470	96
40			532	692	472	599	225
60	20	0	661	605	584	617	243
80			530	538	622	563	189
20			516	516	426	486	112
40			585	610	513	569	195
60	40	0	609	642	686	646	272
80			596	572	627	598	224
80	...	20	534	658	674	622	248

[1]N = nitrogen, P_2O_5 = phosphorus pentoxide, K_2O = potassium oxide.

Each grower should have the soil tested and obtain current fertilizer recommendations based on soil tests from the nearest experiment station or the county extension agent. Most of the fertilizer used for sugarcane is a mixture of nitrogen, phosphorus, and potassium. The ratio varies in different localities, depending on local requirements or practices. Nitrogen is particularly needed in most soils and is generally considered first. Most soils are usually not deficient in phosphorus. Potassium is needed in some soils (table 3).

It is not possible to recommend one fertilizer practice for all farm conditions. Lacking specific information about the needs of a particular farm, the grower should use a standard fertilizer formula that is recommended for the area, such as 6-8-8 or 8-8-8 (N, P_2O_5, K_2O), at 500 to 700 pounds per acre. Where fertility is low, it may be advisable to make a second application, or sidedressing, of 20 to 30 pounds of nitrogen; the total amount is 50 to 80 pounds of nitrogen and 30 to 60 pounds each of phosphorus and potassium.

It was once believed that nitrogen supplied by an organic fertilizer, such as cottonseed meal or tung meal, gave better syrup. Current information indicates that a syrup of good quality can also be produced by using inorganic nitrogen in ammonium sulfate, sodium nitrate, ammonium nitrate, or anhydrous ammonia (Ashley et al. 1956). Under some conditions, these inorganic sources produce slightly higher yields of syrup per acre than organic sources such as cottonseed meal and tung meal (fig. 6). Anhydrous ammonia is equal to ammonium nitrate in its effect on yield of sugarcane syrup (fig. 7). The cost per unit of nitrogen is usually lower in inorganic sources.

Nitrogen should be applied during early growth, but not later than June, in amounts not exceeding the requirements of the crop. Avoid applying a high-nitrogen fertilizer as a sidedressing after June. Organic fertilizer should be applied in March or early April. If manure is used, apply it to the previous crop instead of directly to the sugarcane crop. When heavy applications of manure are applied to the sugarcane crop, a syrup of poor quality may result.

Tractor-propelled distributors are generally used to apply fertilizer in the off-bar furrows. Distributors can be adjusted to apply the quantity needed at the depth desired. Later, during cultivation of the crop, the same equipment can be used to apply a sidedressing along the row. Liming is recommended if the soil pH is below 6.0.

Soil Requirements

Many types of soil are used to grow sugarcane, ranging from the heavy silt loam of Louisiana to the light sandy soil of Mississippi and Alabama. But a soil with good physical characteristics and high fertility produces the best results. In general, loam and sandy loam

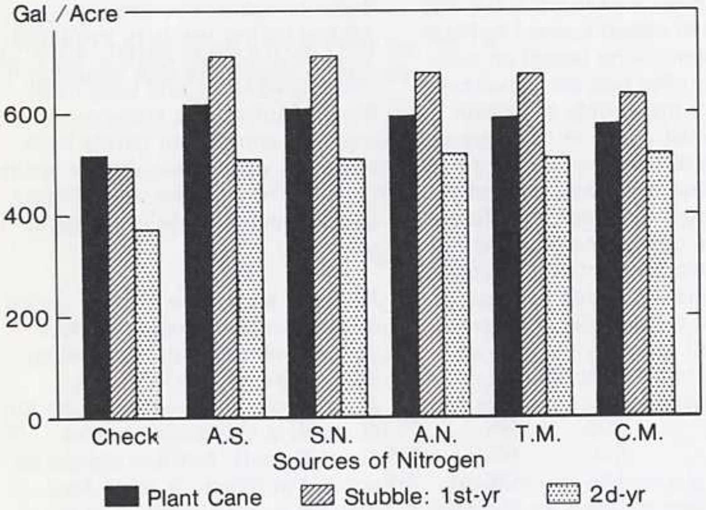

Figure 6
Effect of five sources of nitrogen on yield of sugarcane syrup when applied in March in a 6–8–4 mixed fertilizer at 1,000 pounds per acre. (A.S. = ammonium sulfate, S.N. = sodium nitrate, A.N. = ammonium nitrate, T.M. = tung meal, C.M. = cottonseed meal.) (Source: Stokes et al. 1961.)

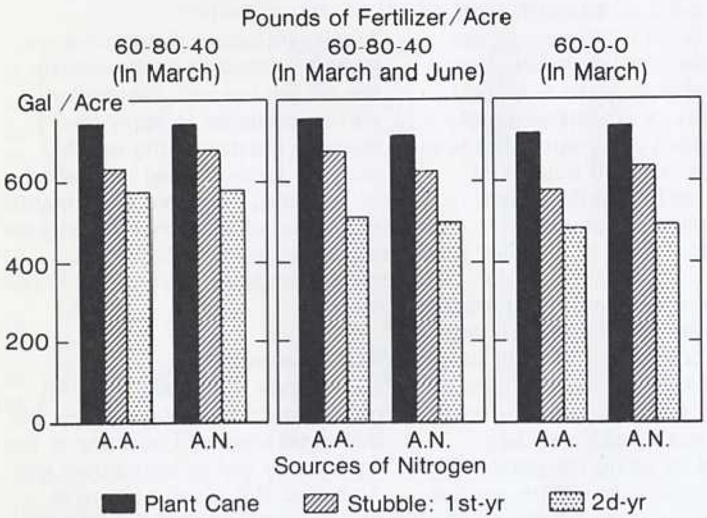

Figure 7
Effect of anhydrous ammonia (A.A.) and ammonium nitrate (A.N.) on yield of sugarcane syrup. (Source: Stokes et al. 1961.)

are best for growing sugarcane for syrup production. Poorly drained, heavy soils usually result in sparse stands, low yields, and a poor syrup quality.

Soils rich in organic matter may degrade syrup quality, but not necessarily. If cultural practices are satisfactory, syrup of good quality is frequently made from sugarcane grown on soils rich in organic matter supplied by green manure crops.

Cultural Practices

Not only are yield and quality of sugarcane syrup and the economy of handling the crop affected by soil type and fertilizer practices but also the growth, uniformity in maturity, erectness of stalks, weed control, and ability to withstand deterioration after harvest. The following cultural practices affect these factors.

Crop rotation. Sugarcane is usually grown on the same land for 3 years. The rotation should provide for one or more interim crops such as corn, cotton, or soybeans. Clean cultivation of the interim crop is desirable to reduce the weeds in sugarcane. Addition of the residue from all crops to the soil will help maintain adequate organic matter and capacity for water retention. To avoid damage to the stand, thoroughly chop the residue from corn, cotton, or soybeans into the soil several weeks before planting the sugarcane. A winter cover crop may be grown in the rows after corn, cotton, or soybeans to add organic matter preceding the sugarcane crop. But during many seasons, a cover crop cannot be planted early enough in the fall after sugarcane or the interim crop to produce a satisfactory growth before cold weather. Since the cover crop must be turned under early in the spring to avoid damage to the succeeding interim crop, it does not usually have time to produce a satisfactory yield of green manure. Planting soybeans in May on land to be used for sugarcane in October is usually a good practice. The growth is turned under in late August or early September and allowed to deteriorate partially before sugarcane is planted. After this treatment, the land usually has enough organic matter to remain in good condition during one plant cane and two stubble crops of sugarcane.

Land preparation. Since plant cane and succeeding stubble crops occupy the same land for 3 to 4 years, it is necessary to have a well-prepared seedbed. The land should be "flat-broken" to a depth of 6 to 8 inches at least a month before planting. Use disk or moldboard plows to prepare the seedbed, and plow the land so that it will drain properly.

Just before planting, disk and bed the land into rows. Furrows between the beds may be used for planting seed cane on well-drained soil. On land with slow drainage, the beds can be opened to provide a furrow for seed cane.

Table 4
Effect of row spacing on yield[1] of CP 36–111 sugarcane at 2 locations

Row spacing (feet)	Yields at— Meridian, MS[2] (1959–61 and 1965–67): Cane per acre (tons)[3]	Meridian: Syrup (gallons) per— Ton of cane	Meridian: Syrup (gallons) per— Acre	Poplarville, MS[4] (1958–61): Cane per acre (tons)[3]	Poplarville: Syrup (gallons) per— Ton of cane	Poplarville: Syrup (gallons) per— Acre
3	31.3a	17.6	551	40.6a	19.1	775
4	30.8a	17.7	544	35.8b	19.4	695
5	25.8b	18.2	470	29.2c	19.3	594
6	23.1b	17.7	408	23.9d	18.6	445

[1]Average of 6 crops (2 each for plant cane, 1st-year stubble, and 2d-year stubble).
[2]Soil type: McLaurin loamy sand.
[3]Means with same letter are not significantly different at 1 percent level by Duncan's multiple-range test.
[4]Soil type: Ruston fine sandy loam.

Table 5
Effect of planting date on stalk yield of CP 36–111, CP 52–48, and CP 67–500 sugarcane at Meridian, MS, 1969–75

Date planted	Stalk yield[1] (tons per acre) from— Plant cane	1st-year stubble	2d-year stubble	Average stalk yield (tons per acre)
Sept. 1	42.6a	40.1a	41.3a	41.3
Oct. 1	42.1a	40.5a	40.2a	40.9
Nov. 1	40.1b	40.0a	40.0a	40.0

[1]Average of 10 crops (4 plant cane and 3 each of 1st- and 2d-year stubble). Within columns, means followed by same letter are not significantly different at 1 percent level by Duncan's multiple-range test.

Table 6
Effect of planting rate on stalk yield of CP 67–500 sugarcane at Meridian, MS, 1978–81

Lines planted	Stalk yield[1] (tons per acre) from— Plant cane	1st-year stubble	2d-year stubble
1	26.1a	17.4a	16.9a
2	32.4b	21.8b	20.0b
3	35.7c	23.6b	21.2b

[1]Within columns, means followed by same letter are not significantly different at 1 percent level by Duncan's multiple-range test.

Row spacing. Most sugarcane in the syrup-producing areas is planted in rows 4 feet apart. The spacing may be varied slightly to suit available tractor equipment (Freeman 1968, Broadhead and Ashley 1969). Table 4 shows average yields with different row spacings of crops from plant cane and first- and second-year stubble. Rows spaced less than 4 feet apart may be satisfactory for the plant cane, but they require more seed cane per unit of area planted and may cause crowding in successive stubble crops in some areas.

Planting. To protect the buds during planting, do not strip seed cane, but remove the tops to make handling easier. Before the buds germinate, leaves and sheaths will deteriorate without hindering the stand.

We recommend planting sugarcane in late September or October (table 5) (Broadhead 1977). However, planting can be done under favorable conditions until March 15. Seed cane for spring plantings must be stored in banks at the time of harvest in October (Stokes 1949). Fall planting requires less labor, and the seed cane usually remains in good condition while dormant.

A satisfactory stand is usually obtained by planting 1.5 to 2 lines of seed cane in a furrow (table 6). The practice of overlapping seed cane about 12 inches helps eliminate gaps in the stand (fig. 8). The small increase in yield obtained by planting three lines of stalks will usually not justify the increased cost of the additional seed cane. Stalks should be cut only to straighten the lines in the furrow. Cutting stalks into short pieces (one or two buds) may give the impression that the stand is improved, but this practice may result in reduced yields (table 7) (Broadhead 1975). About 2,723 six-foot stalks are required to plant an acre at the rate of 1.5 lines in rows 4 feet apart.

Seed cane may be planted 1.5 to 4.5 inches below the soil surface without affecting yields (Broadhead et al. 1963) (table 8). Cover fall-planted seed cane with 7 to 9 inches of soil to protect it from cold injury during the winter (fig. 9). Remove the soil in the spring to within 2 to 3 inches of the seed cane. Cover spring-planted seed cane with 2 to 3 inches of soil. Provide good drainage after planting by plowing out the middle area between beds to a depth of 2 to 4 inches below the seed cane.

Table 7
Effect of seed-piece size on yield and germination of CP 36–111 at Meridian, MS, 1966–68

Seed-piece size (number of buds)	Yield of plant cane (tons per acre)				Plants per acre (mean[2])
	1966	1967	1968	Mean[1]	
2	24.4	49.8	34.8	36.3	9,024
4	30.9	61.0	47.8	46.6	8,432
8	32.7	55.6	43.6	44.0	7,632

[1]Least significant difference at 5 and 1 percent is 3.90 and 5.16, respectively.
[2]Least significant difference at 5 and 1 percent is 504 and 672, respectively.

Table 8
Effect of planting depth on yield of CP 36–111 sugarcane at Meridian, MS, 1955–58

Planting depth (inches)	Yield of cane per acre (tons)	Yield of syrup (gallons) per—	
		Ton of cane	Acre
1.5	23.2	21.3	494
3.0	25.1	21.1	530
4.5	23.1	20.7	478

Figure 8
Two lines of seed cane in furrows before crooked stalks are cut to straighten the lines.

Figure 9
Field of sugarcane showing soil covering to protect stalks from freezing temperature during the winter.

Figure 10
Off-barring sugarcane with disk hiller.

Cultivation. Cultivation should begin in the spring when the buds start to germinate. After the leaves and tops from the previous crop have been burned, off-bar the stubble cane. Off-barring favors germination and early growth during the cool part of the spring. A section harrow can be used to remove the soil within 2 to 4 inches of the planted seed cane. Disk hillers (fig. 10) can be used to off-bar plant or stubble cane. When the cane is 8 to 12 inches high, apply fertilizer in the off-bar furrows and follow by shallow cultivation. Frequent shallow cultivations are needed throughout the season to control weeds and to provide optimum growing conditions.

Weed control. The practice of hoeing sugarcane to control weeds is decreasing because of economic factors and improved chemical and mechanical control. Chemical weed control is desirable in sugarcane grown for syrup production. Where broad-leaved weeds are a problem in the fall, a postemergence application of 2,4-D[2] has provided effective control. This treatment can be followed in the spring by a preemergence spray of diuron[3] (Palmer and Broadhead 1964). Cultivation may be done 1 month after preemergence treatment if necessary.

[2](2,4-Dichlorophenoxy) acetic acid.
[3]3-(3,4-Dichlorophenyl)-1,1-dimethylurea.

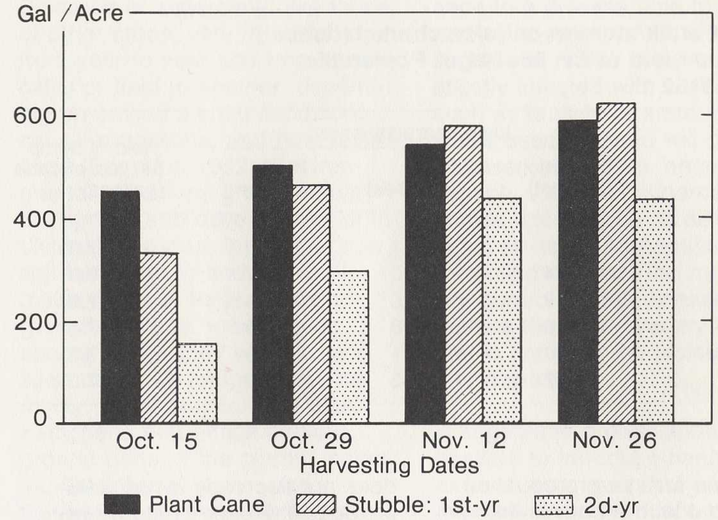

Figure 11
Syrup yields based on nine date-of-harvesting tests of sugarcane at Poplarville, MS. (Source: Stokes et al. 1961.)

Harvesting Sugarcane for Syrup Production

Changes in the composition of the juice as the cane matures affect the quality and quantity of the syrup. In general, harvesting should be delayed as late in the year as possible to permit the maximum accumulation of sugar. But sugarcane should be harvested before it is subjected to severe damage from cold. Early-harvested cane produces less syrup per acre than cane harvested late in the season (fig. 11). Also, the stand and corresponding yield are usually less in succeeding stubble crops following early-harvested cane. The effect of early harvesting on yield depends on the variety and on whether the crop is plant or stubble cane (Stokes and Ashley 1956).

Harvesting practices vary considerably throughout the syrup belt, depending largely on the acreage and local practices. If the leaves are to be removed from the stalks, this is usually done first. Leaves may be struck off with a paddle, a cane stripper, or the knife used to cut the stalks, or they may be pulled off by hand. Stripping and topping should be done while the stalks are standing. Sugarcane can be milled with the leaves attached to the stalks and will produce high-quality syrup without a reduction in yield provided the leaves are dry when the stalks are milled (Broadhead 1964). Burning the leaves on sugarcane stalks will produce an undesirable flavor in the syrup.

Table 9
Effect of stalk storage on juice characteristics and syrup yield of CP 36-111 at Poplarville, MS, 1959-62

Storage time (days)	Juice characteristics Extraction (percent)	Brix (degrees)	Purity (percent)	Yield of syrup per ton of cane (gallons)
0	57.3	14.1	68.0	17.6
3	54.4	15.0	59.7	17.8
7	51.9	15.5	52.8	17.9
14	51.0	15.8	44.0	17.3
21	49.0	16.1	42.9	17.3
28	46.7	16.3	45.0	17.2

Sugarcane for syrup production may be cut with a corn knife, cane knife, hoe, or mechanical harvester, of which there are several types. Generally, the cane is cut near the surface of the soil. If cut higher, losses in tonnage and total production of syrup result because juice from the lower internodes contains more sugar than that from the middle and top internodes.

Since most sugarcane for syrup is manufactured on small-scale equipment, cane that has been cut must sometimes remain in the field or at the mill for several days before it is milled. This practice does not decrease syrup yield provided the cane is stored no longer than 25 to 30 days and is not subjected to freezing temperatures (table 9). Syrup quality is improved and sugaring is reduced when cane is stored for 15 to 20 days (Stokes 1950, Broadhead 1964).

Diseases of sugarcane, like those of other crops, vary in severity from year to year and from one locality or field to another, depending on environmental conditions, causal organisms, and host resistance (Edgerton 1959). Environmental conditions greatly affect the spread and development of individual diseases. In general, low soil temperature and high soil moisture favor soilborne pathogens that attack roots, young shoots before they emerge, and seed cane. Air temperature, humidity, wind, and sunlight affect pathogens that attack aboveground parts of the plants, including the foliage, stalks, and flowers. No disease will occur, however, if its causal organism or pathogen—be it virus, bacterium, or fungus—is absent, even though the environment is favorable for disease development and the host is susceptible.

Disease-causing organisms may vary in virulence as much as the hosts that they attack vary in degrees of resistance. Some pathogens, especially those attacking roots, have little host specificity, and they may attack many plant species besides sugarcane. Others, such as rust or smut, are highly specific. Most pathogens have intermediate host specificity and can attack grasses as well as sugarcane. Disease control in sugarcane is based on planting disease-resistant varieties, planting healthy seed cane, and using crop rotation and clean cultivation. Because it is a vegetatively propagated crop, a sugarcane variety has no genetic resistance to a disease able to attack a particular variety. And when sugarcane plants become systematically infected with a disease, such as mosaic or smut, diseased stalks used for seed will produce diseased plants. So, once a susceptible variety of sugarcane becomes infected with a disease or is known to be susceptible to a prevailing disease, the most effective control for the disease is to replace the entire variety with one that is known to be resistant to that disease.

A sugarcane grower should not hesitate to introduce healthy seed cane of recommended varieties to improve syrup production. But growers should resist the temptation to introduce individual stalks of varieties of unfamiliar background that they may come across in their travels. This type of introduction can bring in new or exotic diseases, such as smut and rust, which are now increasing in the Southern United States.

Several serious insect pests of sugarcane in the continental United States have not yet become established in all areas where it is grown. But in the past, establishment of an insect pest in new areas of sugarcane production has often been associated with infested cane brought from another area. Consequently, transport of sugarcane from one area to another should be kept to a minimum, and precautions should be taken to ensure that it is free of insect pests.

Hot-water treatment of sugarcane at 122°–126°F for 30 minutes will kill all insect stages on the foliage and stalks without seriously affecting germination of vegetative buds (Yoder and Ingram 1923). But some insect stages inside the stalks will survive this treatment, particularly large larvae and grubs. Hot-water treatment that can kill these insect stages (more than 130° for 1 hour) often seriously impairs seed cane germination. Similarly, all chemical fumigants tested to date cause serious problems with seed cane germination at concentrations that kill insect stages found within internodes.

The most workable method of reducing insect-related risk involved in transporting sugarcane is to carefully inspect all pieces of stalks and discard all internodes that contain insect frass, tunnels, or other evidence of internal infestation. Treat those remaining stalks for 30 minutes at 126°F to ensure that no insect stages remain on their surface. This procedure can be accomplished easily and requires no special equipment, but it is only practical for transport of small lots of a dozen cuttings or less. Federal and State pest regulatory agencies should be contacted regarding shipments of sugarcane to other areas.

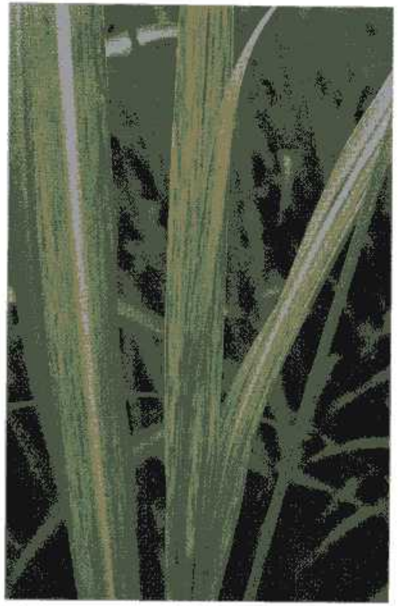

Figure 12
Sugarcane mosaic on CP 52-48 sugarcane at Cairo, GA.

Diseases

Mosaic

Mosaic is caused by a virus that is transmitted from diseased to healthy plants by aphids (Brandes 1919). Mosaic-infected plants show an irregular pattern of yellow or light-green areas interspersed with darker green areas on the upper three to four leaves of syrup varieties (fig. 12). Sometimes the light-green or yellow areas may cover large areas of the upper leaves so that infected plants appear yellow. Mosaic can cause stunting of infected plants and can also reduce germination in planted cane.

At least seven species of aphids can transmit the virus from diseased to healthy sugarcane plants (Ingram and Summers 1936, 1938, Tate and Vandenberg 1939). Included are the corn leaf aphid [*Rhopalosiphum maidis* (Fitch)], rusty plum aphid [*Hysteroneura setariae* (Thomas)], greenbug [*Schizaphis graminum* (Rondani)], sedge aphid [*Carolinia cyperi* (Ainslie)], pea aphid [*Acyrthosiphon pisum* (Harris)], ambrosia aphid [*Dactynotus ambrosiae* (Thomas)], and sow thistle aphid [*Nasonovia lactucae* (Linnaeus)] [*Amphorophora sonchi* (Oestlund)]. These aphids can become infective in less than a minute after feeding on mosaic-infected sugarcane plants and soon after can transmit the mosaic virus by feeding on healthy plants. The aphids remain infective for less than 2 hours after leaving mosaic-infected sugarcane, though they may become infective if they feed again on diseased plants. Since sugarcane is not a preferred host plant for these aphids, they move around looking for a more desired host and as a result spread the virus to healthy plants. Both winged and nonwinged aphids can transmit mosaic (Zummo and Charpentier 1964, 1965a, 1965b, 1969).

The ideal method for mosaic control is to grow resistant varieties of sugarcane. But if adapted resistant varieties are unavailable for an area, the grower can keep mosaic under control by digging out and destroying mosaic-infected plants in the fields that are to be used as sources of seed cane. Roguing may be effective for retarding the spread of mosaic when the infection is confined to a small part of the crop, but it will rarely eliminate the disease. CP 36–111 has good resistance to most strains of sugarcane mosaic and can be grown in most areas without becoming diseased. CP 52–48 also is resistant to many mosaic strains. CP 67–500 is susceptible to mosaic and will require roguing in areas where it is a problem.

Several strains or different forms of the sugarcane mosaic virus occur in the Southern United States (Summers et al. 1948). Strains H and I occur in the commercial sugar areas of Louisiana and Texas, but not in Mississippi and Georgia, and can infect commercial syrup varieties. Strain B occurs generally throughout the syrup area on some of the older varieties such as 'Louisiana Purple', 'Louisiana Striped', and Co 290. Strain B will readily infect CP 67–500 but not CP 36–111 or CP 52–48. Strain L readily infects CP 52–48 in the Meigs, GA, area (Zummo 1974). Another strain of sugarcane mosaic virus, known as maize dwarf mosaic, first appeared in the United States in 1964 on johnsongrass and corn. This virus will also infect the various varieties of sorghum but will not normally infect sugarcane. It is transmitted by the same insect vectors that transmit most other strains of sugarcane mosaic virus.

Figure 13
Red stripe and top rot on CP 67-500 at Grand Bay, AL.

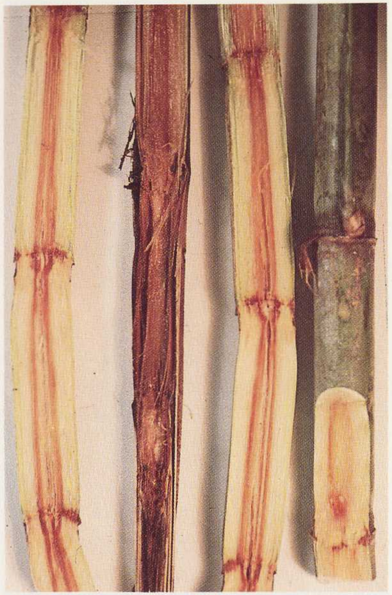

Figure 14
Internal stalk symptoms of red stripe and top rot on CP 67-500 at Grand Bay, AL.

Red Stripe and Top Rot
Red stripe and top rot are two phases of a disease caused by the bacterium *Pseudomonas rubrilineans* (Lee et al.) Stapp. The top rot phase occurs sporadically throughout the syrup belt. The earliest symptom of the disease is bleaching and water-soaking of the uppermost whorl leaves followed by killing of the central whorls of stalks (similar to sugarcane borer injury) so that the tops of the entire stool may be killed (fig. 13). In the red stripe phase, thin red stripes, 0.06 of an inch wide by several inches long near the base of leaves but not extending down in the leaf sheath, are very apparent on affected stalks.

Associated with top rot are large lalas or side sprouts, which often grow from the lower and middle buds. When stalks are split lengthwise, a water-soaked red cylinder extending from the dead top down through the base of the stalk is revealed (fig. 14). The color of the water-soaked cylinder is more intense in the upper part of the stalk. When stalks are cut in cross sections, a red ring is visible around a water-soaked central core. A putrid odor is generally associated with the moribund stalks. In many instances, some stalks from diseased stools will show no external symptoms, but when split lengthwise, they have a red-bordered

Red stripe affects CP 67–500 somewhat more than CP 36–111 or CP 52–48. Roguing of diseased stools is the only control measure recommended.

Sun Spot
Sun spot, caused by a bacterium, *Pseudomonas* sp., occurs during the hot, dry periods in the late fall on the upper leaves of sugarcane and sorghum plants (Zummo and Freeman 1975). On sugarcane, the spots are from 0.17 to 0.8 of an inch long and generally elliptical (fig. 15). There is a yellowish halo around the lesions, and the lesions sometimes have a runner similar to but shorter than runners of eyespot disease, which is incited by *Bipolaris sacchari* (Butler) Shoemaker. On sweet sorghum, the spots are considerably larger (0.8 to 1.6 inches long) and do not have the runner that is sometimes associated with sun spot. Although none of the several thousand commercial and unreleased varieties at Meridian, MS, have remained completely free from the disease, none have suffered yield losses from the disease. Control measures are not warranted.

Rust
Rust, caused by the fungus *Puccinia melanocephala* H. Sydow and P. Sydow, is a relatively new disease of sugarcane in the United States. It was first reported in Florida in 1979 (Dean et al. 1979) and has since been reported in Louisiana, Mississippi, and Texas. It first appears on the leaves as small, elongated, yellowish spots visible on both surfaces (fig. 16). These spots

Figure 15
Sun spot lesions on sugarcane leaves at Meridian, MS.

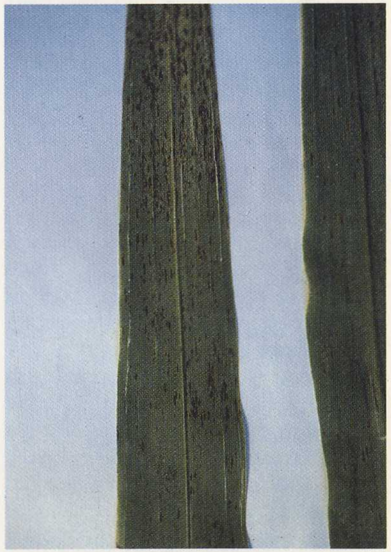

Figure 16
Rust on sugarcane leaves at Meridian, MS.

Figure 17
Sugarcane smut showing typical smut whip.

increase in size to 0.17 to 0.4 inch long by 0.04 to 0.13 inch wide with a pale green halo. The lesions turn orange brown to brown and become raised, usually on the lower surface. They rupture and release the spores (millions can be produced on each plant), which can cause new infections on adjacent plants or on plants in other fields, sometimes miles away, and thus perpetuate the disease. Sugarcane rust, once established in a field of a susceptible variety, can spread very rapidly so that the entire field can be covered with it in a short time.

Sugarcane rust is easily identified in the field because of raised pustules that are readily discernible with the fingertips. Several other sugarcane diseases such as leaf stipple or brown spot at times can resemble sugarcane rust, but they can all be distinguished from it by their lack of raised pustules.

For many years, there have been reports of a rust fungus misidentified as *P. melanocephala* causing rust on bamboo in the Southern United States. But the fungus on bamboo will not attack sugarcane. The effect of rust on sugarcane for syrup and the resistance of sugarcane syrup varieties have not yet been fully determined. There is evidence that sugarcane rust in the syrup areas may not be a major disease. Also, the rust fungus may not be able to survive the winters in many areas of the syrup belt because it must have green sugarcane leaves to survive, and there is a long period from November to April when there is no aboveground sugarcane foliage (Zummo and Broadhead 1983).

Smut

Sugarcane smut, caused by the fungus *Ustilago scitaminea* H. Sydow, is another newly introduced disease in the Southern United States. Like rust, smut's first appearance in the United States was in Florida, from where it has since spread to other sugarcane-growing areas (Todd 1978). Smut-infected sugarcane plants are usually spindly, with extended internodes and small narrow leaves. Smut is easily recognized by the smut whips, which are long, whiplike, and usually curved (fig. 17). These silver-gray-to-black spore-bearing structures are produced at the apex of infected plants. Before the emergence of the smut whips, the shoots usually have a distinct grasslike appearance.

When the membranes covering the smut whips rupture, the spores, which are produced in the millions per whip and look like black soot, fall to the ground or are spread by wind and rain to adjacent plants and fields of sugarcane. These spores land on leaves of standing cane and are washed down behind the leaf sheaths by rain and lodge in or on buds, where they can cause infection. Germinating buds on seed cane planted in soil where spores are present can also become infected. Plants from infected buds have a grasslike appearance and eventually produce new smut whips, and the disease cycle is repeated.

The losses from sugarcane smut on some susceptible varieties can be serious. Smut-infected plants not only produce few millable stalks but have lower sugar content. Losses from smut are greater when diseased stalks are used for seed cane than when infection occurs during the growing season. Losses are also greater in the stubble crop than in plant cane.

Because sugarcane smut has not yet been found in many of the syrup areas, growers should be alert to the possible occurrence of smutted plants and should rogue and destroy them when observed. Currently, roguing is the only control recommended for smut in the syrup area until varieties resistant to the disease can be developed.

Red Rot

Red rot is caused by the fungus *Glomerella tucumanensis* (Spegazzini) von Arx & Mueller and is generally referred to in older literature as *Colletotrichum falcatum* Went (Abbott 1938). Red rot is primarily a disease of seed cane; however, it may sometimes damage the crop before it is harvested for syrup. Red rot can best be observed by splitting suspected diseased stalks longitudinally. The disease can be recognized by the reddened interior of the stalks, which is interrupted by occasional white patches extending crosswise, giving the stalks a marbleized appearance (fig. 18). The extent of damage depends on the susceptibility of the variety and on environmental conditions.

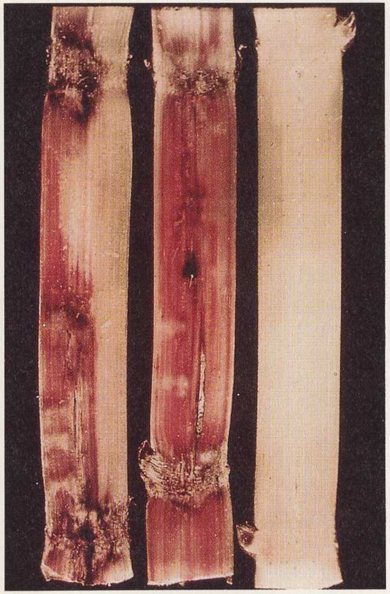

Figure 18
Split stalks of sugarcane showing red rot.

Losses from red rot are usually greatest when a field is planted with banked seed cane or with the older, more susceptible sugarcane varieties such as Louisiana Striped, Louisiana Purple, and Co 290. The fungus invades the buds and nodes of the seed cane, or it may enter through wounds or injury in the stalk, and it reduces germination and stands. Severe infection by red rot before harvest also reduces the sugar content of the cane and lowers the yield and quality of the syrup. Losses from red rot have been negligible in those varieties currently recommended for syrup production, except where seed cane is banked for winter or spring planting.

Control measures include using resistant varieties, fall planting, and discontinuing the practice of banking seed cane. CP 36–111, CP 52–48, and CP 67–500 are highly resistant to red rot. Growers who plant these varieties should not have to be concerned with this disease.

Pokkah Boeng, or Twisted Top
Pokkah boeng, or twisted top, is caused by the soilborne fungus *Gibberella fujikuroi* (Sawada) Wollenweber, which is present in all sugarcane areas where high humidity is prevalent. Although the disease may be conspicuous on some varieties, such as CP 52–48, losses are usually negligible. Pokkah boeng is characterized by deformed or discolored leaves near the top of the plant. In some cases, the leaves become so wrinkled they are unable to unfold properly and result in a plant with a ladderlike appearance. In extreme cases, infection may move from the leaves and sheath into the stalks, killing the tops. In mild cases, symptoms often resemble those of mosaic caused by virus. Pokkah boeng can be differentiated from mosaic by the wrinkled bases and numerous small transverse cuts in the margins of the leaves of infected plants. Sometimes the disease causes stalks to bend, and sometimes the stalks display "knifecut" symptoms, such as narrow, uniform, transverse cuts in the rind, that give the impression the tissue has been removed with a sharp knife. Because they are covered by the leaf sheaths, these lesions may not be apparent when pokkah boeng leaf symptoms are present.

During prolonged wet weather, the fungus grows upward on the outside of sugarcane stalks and may become temporarily established behind the leaf sheaths or in the whorls. Metabolites produced by the fungus cause distortions in the plants. When the wet weather subsides, the fungus dries and the plant resumes normal growth. Pokkah boeng also affects corn, johnsongrass, sorghum, broomcorn, and sudangrass.

Ratoon Stunting Disease
Ratoon stunting disease (RSD) is caused by a bacterium that is transmitted from diseased to healthy plants by knives used in harvesting the crop. Unlike mosaic, no insect vector is associated with this disease. In the field, symptoms of RSD include retarded growth, reduced tillering, and relatively smaller stalks. These symptoms are most pronounced under drought or other stress conditions.

When the basal parts of diseased stalks are split lengthwise, orange dots can sometimes be seen in the nodal areas. These internal symptoms are nebulous and sometimes difficult to see. Losses from RSD are usually greatest in stubble crops.

RSD can be controlled by using disease-tolerant varieties; heat-treating seed cane with hot water, hot air, or aerated steam; or introducing progeny of heat-treated seed cane. The varieties used for syrup production are sufficiently tolerant to the disease so that treatment of the seed cane is not normally required.

Insect Pests[4]

Sugarcane Borer
The sugarcane borer [*Diatraea saccharalis* (Fabricius)] is the most destructive insect pest attacking sugarcane in the United States. Losses in crop yield will average about 13 percent annually in fields where season-long infestations are not maintained below the economic threshold of crop damage (10 percent of the internodes bored). This stalk borer was first introduced into the United States about 1850, apparently in seed cane brought to Louisiana from the West Indies. Its geographical distribution now includes all States where sugarcane is grown primarily for production of refined sugar—Florida, Louisiana, and Texas—and Mississippi where only syrup is produced. Sugarcane borer infestations have not yet been reported in the syrup-production areas of Alabama, Georgia, and northern Florida.

Sugarcane grown as a short-term perennial crop is the principal cultivated host of the sugarcane

[4]Prepared by Sess D. Hensley, entomolgist, U.S. Sugarcane Field Laboratory, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 470, Houma, LA 70361.

Figure 19
Sugarcane borer larvae that have tunneled into stalk internodes.

borer. Heavy infestations are sometimes found on corn, rice, and sorghum but only when these annual crops are grown near sugarcane. Sparse populations are also found on several large-stemmed grasses, including johnsongrass, bullgrass, and itchgrass, especially when they occur as weeds in sugarcane fields. It is not yet certain whether annual cultivated or wild grasses will become permanent hosts of the sugarcane borer in the United States, because they are seldom able to sustain overwintering populations of this pest from one crop season to the next. But infestations on all host crops involved are usually higher when corn, rice, or sorghum is grown on the same farms with sugarcane.

Larvae of the sugarcane borer feed on (scarify) sugarcane leaves and bore within the internodes (fig. 19). They decrease crop yield primarily by retarding development and growth of internodes and thus reduce stalk weight. Severe infestations contribute to lower sucrose recovery by impairing juice quality. Feeding larvae destroy some vegetative buds and thus limit germination of the affected seed cane. Larval tunnels in internodes serve as invasion routes for stalk rot pathogens. Since severely bored stalks break and lodge, heavily infested fields are prone to wind damage and are difficult to harvest. Loss in stalk weight, however, is more important than all other damage caused by this pest.

When first deposited on sugarcane leaves, borer eggs are creamy white, then an orange tint as embryonic development progresses. After egg hatch, the young larvae migrate into the leaf whorls and spindles, where they feed and develop until half grown (about 10 days). They then bore into internodes, complete development, pupate, and emerge as adults. The adult moths exit stalks via tunnels bored by larvae. Most sugarcane borer larvae undergo five stages of development before pupating; however, there can be more. The life cycle from egg to adult emergence is completed in about 30 to 40 days. Fully mature sugarcane borer larvae are about 1.5 inches long, and all larval instars are characteristically cream white with dark spots. The moths are straw colored, with darker stripes on the wings; their wing span is about 1.25 inches.

In the United States, four to five generations of the sugarcane borer occur each year. First-generation larvae infest sugarcane during the spring and destroy by deadhearting young tillers that have not produced internodes visible above ground. The second and third generations occur during the summer and damage internodes that contribute most to crop yield. Fourth- and fifth-generation infestations occur in the tops of stalks during the fall. Larvae of these generations injure immature internodes that are most often cut off and left in the field during crop harvest. Past research indicates that little benefit is derived from suppressing spring and fall borer infestations.

Fully developed larvae enter diapause during the fall and overwinter above ground in sugarcane residues, such as broken stalks and stalk tops, or below the soil surface in stubs and seed cane. Ambient cold temperature has little effect on larvae underground, but 20°F or lower can kill all larvae attempting to overwinter above ground. Hot, dry weather during the summer can kill 50 percent of the first-stage larvae in leaf sheaths, especially when daily temperatures are higher than 100° and dew does not form on the plants. The biology of the sugarcane borer appears to be well synchronized with that of its perennial cultivated host, sugarcane. Weather favorable to rapid growth of this crop, as mild temperature, high humidity, and abundant rainfall, invariably triggers increased infestations.

An integrated pest management program has been used successfully since the mid-1960's to restrict borer populations below crop damage levels, particularly in Louisiana. Major emphasis is placed on host-plant resistance, conservation of natural enemies, especially arthropod predators, and cultural practices as worthwhile tactics for suppressing larval populations. Sugarcane fields are surveyed weekly from mid-June to mid-September, and an economic threshold of 5 percent leaf sheaths occupied by small larvae is used to identify individual fields requiring an insecticide application to avoid crop losses.

Azinphosmethyl[5] has been the only insecticide used extensively for sugarcane borer control since the 1960's. When applied as a spray to sugarcane foliage at 0.75 pound active ingredient in 2 gallons of water per acre, azinphosmethyl provides 80 to 90 percent control, with residual activity persisting for more than 1 week. Serious problems with pesticide residues, destruction of nontarget organisms, pest resistance, and pest resurgence or escalation have not developed with the use of azinphosmethyl for sugarcane borer control.

Resistance in the host variety can contribute significantly to limiting infestations of the sugarcane borer below levels that cause damage to the crop. Varieties with resistance to this pest are now grown on more than 75 percent of the Louisiana cropland devoted to sugarcane production. Conservation of arthropod predators, particularly populations of ants, spiders, and carabid beetles, is also important. Azinphosmethyl applied in a spray formulation does not cause serious mortality of predators and most other ground-related species of arthropods.

Several cultural practices help reduce borer infestations and damage. They include (1) maintaining seed cane fields as free of infestation as possible to improve crop stands; (2) plowing out old stubble fields as quickly as possible after final crop harvest to reduce the number of larvae attempting to overwinter underground in stubs; (3) leaving infested crop residues, particularly stalk tops, broken stalks, and uprooted stubbles, exposed on the soil surface during the winter to obtain maximum kill of larvae by ambient cold temperatures; (4) scrapping (gleaning) heavily infested fields of mill cane during harvest to reduce the number of larvae capable of overwintering; and (5) planting corn, rice, or sorghum as far away from sugarcane as possible to limit infestations. None of these practices require more farm labor than what is expended in routine farm-management programs. During 1970–80, emphasis on variety resistance, conservation of arthropod predators, and selected cultural practices has reduced by more than 75 percent the amount of insecticide used annually for sugarcane borer control.

[5] *0,0*-Dimethyl *S*-[(4-oxo-1,2,3-benzotriazin-3(4*H*)-yl)methyl] phosphorodithioate.

Sugarcane Beetle

The sugarcane beetle [*Euetheola humilis rugiceps* (LeConte)] is normally a minor pest of sugarcane in the United States. It is better known as a pest of corn. The adult beetle is shiny black, about 0.625 inch long, with rugose punctures on the thoracic shield (fig. 20). This species is a scarab of the subfamily Dynastinae, whose immature stages (grubs) feed and develop to adulthood on decaying plant residues. The only stage that injures sugarcane, then, is the adult. Large numbers of sugarcane beetle eggs (seven to eight per foot of row) are sometimes deposited in field soils. But the grubs hatching from these eggs will not live to become adults unless large amounts of decaying plant residues are available as food.

In the spring, the adult beetles tunnel downward through the soil surface of sugarcane rows, where they mate, produce eggs, and destroy young tillers by deadhearting as they germinate and develop from the plant crowns. The beetle chews a jagged hole through the rind of a tiller into the center of the growing point and eats the meristem (fig. 21). Since these adults usually remain below the soil surface during the entire period of crop tillering, damage to the crop stand may not cease until the growing point of all undamaged tillers is above the soil surface.

The beetle rarely reduces stands with sufficient severity to cause economic crop loss. When such losses occur, they are sporadic. Serious damage, however, can occur in some fields or parts of fields, particularly where an excessive amount of rotting vegetation is present during the spring beetle flight. Since heavy beetle populations are reported to develop in pastures and sod land, we suggest that sugarcane be planted away from large areas of turf crops. No insecticides tested have provided satisfactory control when treatments are applied in the furrow at planting or as row treatments before adult activity.

Figure 20
Adult sugarcane beetle attacking young sugarcane plant.

Figure 21
Sugarcane plant injured by sugarcane beetle.

Several farm-management practices are apparently beneficial in avoiding sugarcane beetle damage. They mostly involve procedures that minimize the accumulation of rotting vegetation, which appears to attract ovipositing adults, particularly during the spring. These procedures include avoiding, as much as possible, poor drainage, cold damage, herbicide injury, crop diseases, or other factors that contribute to excessive rot of sugarcane stubs and seed cane; maintaining sugarcane fields relatively free of rotting crop or weed residues; eliminating succession planting of sugarcane after corn; and planting vigorous sugarcane varieties that tiller profusely in the spring to compensate for beetle-related reduction in crop stands.

Wireworms
Several species of wireworms (Elateridae) damage sugarcane at planting time, particularly when this crop is grown on sandy or sandy-loam soils. The immature damaging stages are slender yellow-to-brown larvae that range from less than 0.25 to more than 1.50 inches long. The wireworm adults, or click beetles, are predators of several insect species, including the sugarcane borer. Wireworms damage sugarcane stands by feeding on and destroying the vegetative buds and small germinating tillers. They also feed on the roots, but this injury is much less important than their damage to seed cane.

Wireworm damage occurs infrequently, but stand reductions may be severe enough to require replanting of fields or parts of fields. Several grasses that occur as weeds in sugarcane fields, including bullgrass, crabgrass, itchgrass, and johnsongrass, are also host plants for wireworm larvae. Most wireworm problems can be avoided by maintaining fields free of heavy grass infestations. Carbofuran 10G[6] applied in the furrow at planting time has provided effective control in the few fields that have required protection from wireworm damage; however, before any insecticides are applied for control, obtain current recommendations for insecticide use from the county extension office or other responsible sources.

White Grubs
Several species of white grubs (Scarabaeidae) seriously damage sugarcane in Florida and Texas. They have not yet invaded other areas of sugarcane production in the United States. Large numbers of white grubs of the genus *Phyllophaga* and also heavy wireworm infestations often occur in pastures. We have found carbofuran 10G to be effective when disked into the soil whenever pasture or other land heavily infested with grass is being prepared for sugarcane planting. No further applications have been required provided the fields are maintained relatively free of grass. Again, check with the county extension office.

Lesser Cornstalk Borer
The lesser cornstalk borer [*Elasmopalpus lignosellus* (Zeller)] is a minor pest of sugarcane in all areas of the United States where this crop is grown. The larvae are green with dark brown-to-purple markings and are about 1 inch long when fully developed. They move rapidly and with quick jerking motions when disturbed. These larvae bore into young sugarcane tillers at or slightly below the ground surface and tunnel upward. The injury resembles deadheart damage by the sugarcane borer except that it occurs earlier and the entrance hole into stalks has a tubular silken burrow, extending outward, that contains some grass and soil particles. The larvae pupate in this burrow, and the moth emerges 6 to 8 days later. Deadhearting of young sugarcane tillers by lesser cornstalk borer larvae occurs from March to June but seldom results in economic crop loss. Infestations are often low and may be limited to field parameters. The sugarcane crop, by producing more tillers, usually compensates for stand reductions by this pest and also the sugarcane borer.

Infestations are difficult to control with insecticides. High-volume water sprays containing carbofuran or diazinon[7] directed at the base of the tillers provide the most effective insecticide control available for use on sugarcane. The lesser cornstalk borer also infests corn, peanuts, soybeans, and several wild grass species.

[6]2,3-Dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate.

[7]*0,0*-Diethyl *0*-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate.

The yield and quality of sugarcane syrup are affected by the equipment and process used in manufacture and by the knowledge and skill of the syrup maker. Syrup quality can be improved by variety selection, appropriate harvesttime, settling of juice, control of heat, depth of juice in the evaporator, rapid evaporation, and use of an accurate thermometer near the drawoff opening to determine the desired density (Walton et al. 1938).

Equipment and Plant

Processing Plant

Steam processing. The steam system (fig. 22) for evaporating sugarcane juice to syrup requires considerable investment; therefore, large acreage and high milling and processing capacities are necessary to make this system economical. Steam processing has the advantage over direct-fire processing of better temperature control of juice preheating tanks. It also provides hot water for daily cleaning of juice storage tanks, processing equipment, and work areas. Copper steam coils are more desirable than iron because of their high heat transfer and ease of cleaning with a dilute muriatic acid solution.

Direct-fire processing. Direct heating (fig. 23) for juice evaporation is probably most applicable, efficient, and economical for plants that can process up to 200 gallons of syrup per day. Fuels to heat the evaporator

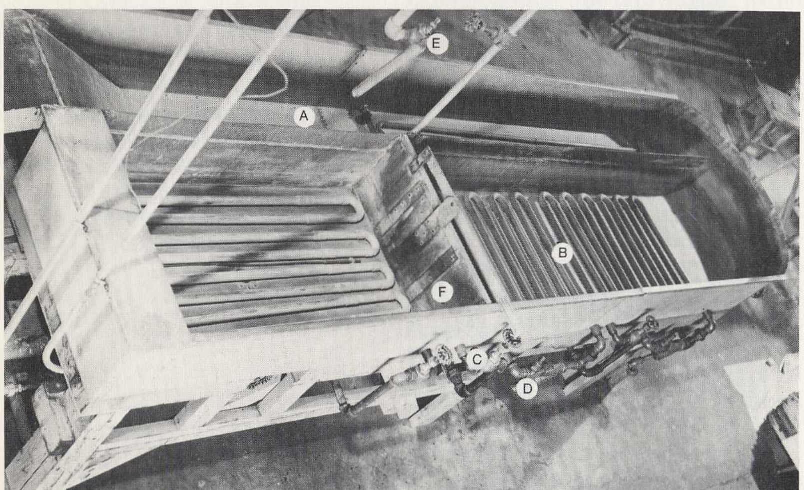

Figure 22
Stubbs-type evaporator: *A,* Side where juice enters; *B,* copper heat coils; *C,* steam-inlet valve for coil; *D,* automatic steam trap; *E,* adjustable valve; *F,* finishing-off compartment.

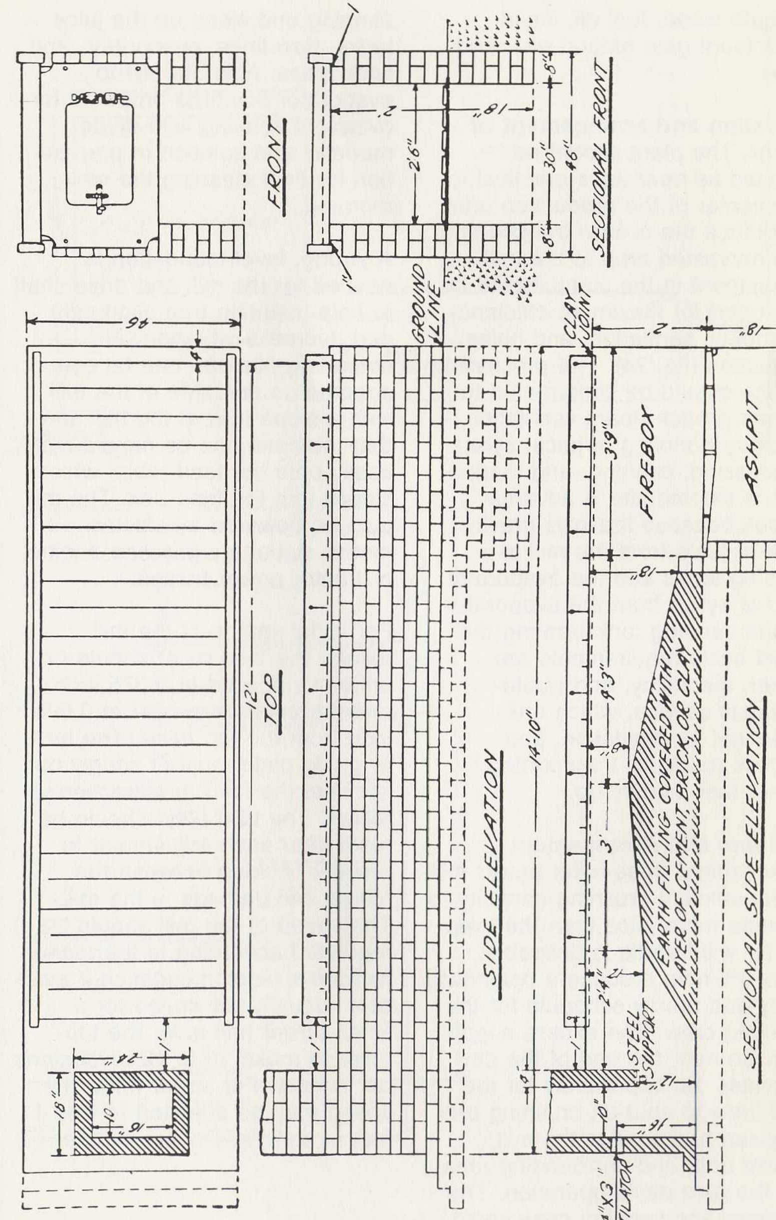

Figure 23
A 12-foot continuous evaporator and furnace. (Source: Walton et al. 1938.)

include wood, fuel oil, liquid-petroleum gas, natural gas, and coal.

Location and arrangement of plant. The plant should be located as near as is practical to the center of the production area to reduce the cost of transporting the harvested crop to the mill. Equipment in the plant should be arranged for maximum efficiency, economy, sanitation, and noise reduction (fig. 24). The processing house should be constructed to permit proper steam ventilation, sanitary handling of juice, syrup processing, canning, and marketing. A sloping site is advantageous because it allows gravity flow of juice from the mill to settling tanks and the evaporator, and of syrup from the evaporator to the canning tank. Among the most basic requirements are water, electricity, and waste-disposal service, which are essential for sanitation, and access roads for transporting cane, fuel, and syrup.

Mill and Mill Arrangement

A horizontal three-roller power mill with sufficient crushing capacity to provide more juice than the evaporator will handle is desirable. This will help produce a balanced daily and hourly schedule for the working crew. The excess supply of juice near the end of the day provides the opportunity for the mill crew to shut off crushing and to clean and service the mill, power unit, and surrounding area for the next day's operation. The cooking and canning crew could complete their processing and canning and clean up the juice tanks, flow lines, evaporator, and floor areas. Also, the syrup evaporator could be prepared for overnight soaking with dilute muriatic acid solution in preparation for final cleaning the next morning.

A strong, level foundation is needed for the mill and drive shaft to help maintain true alignment and decrease vibration. An unloading platform can be constructed on one side of the mill with a slope toward the mill so that the cane can be moved more easily onto the feed table, which slopes into the feed box. The mill may be powered by electric motor, stationary gasoline engine, or tractor power takeoff.

For initial setting of the mill rollers, the feed roller should be uniformly spaced at 0.375 inch and the extraction roller at 0.625 inch from the top roller. The turn or guide plate must fit snugly but not bind the feed or extraction rollers. The turn plate should be reset after each adjustment to prevent choking between the rollers and damage to the mill. The speed of the mill should be regulated according to the manufacturer's recommendation if available. Usually the speed for a small power mill is for the top roller to make 10 to 12 revolutions per minute. For larger mills, the speed may be adjusted to 9 to 11 feet of stalk intake per minute.

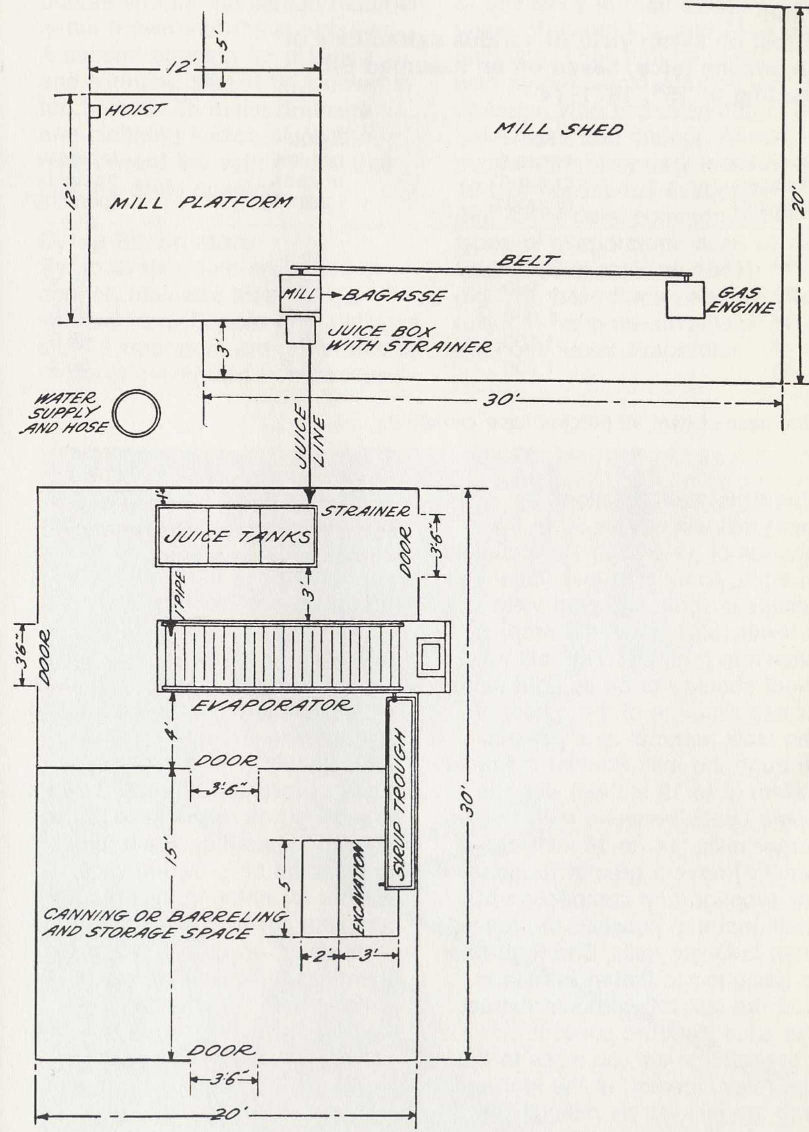

Figure 24
Plan of a typical syrup plant. (Source: Walton et al. 1938.)

Table 10
Effect on syrup yield of various extractions of sugarcane juice, based on an assumed Brix reading of 15°, 1971–74

Extraction of juice (percent)	Juice per ton of cane (pounds)	Syrup per ton of cane (gallons)	Increase in yield (percent)[1]
40	800	12.1	. . .
45	900	13.7	13.2
50	1,000	15.2	25.6
55	1,100	16.7	38.0
60	1,200	18.2	50.4

[1]Increase of over 40 percent juice extraction.

Under normal conditions, an efficient mill will deliver 50 to 60 pounds of juice from 100 pounds of cane. Extracting less juice results in reduced syrup yield and a lower return from the crop, as shown in table 10. The mill adjustment should not be so tight as to create slippage of the rollers on the stalk material as it passes through the mill. Smaller diameter rollers (9 to 12 inches) with the same space between rollers as in larger mills (14- to 18-inch diameter) have a greater tendency for slippage and compaction of stalk material between the rollers than in larger mills. The first roller is designed to flatten the stalks and the last roller should extract the juice from the cane. If the front roller is set too close to the top roller, feeding of the stalks into the mill will be difficult. An even feed of stalks into the mill should be maintained to provide better juice extraction. If the crop has been harvested during a prolonged drought stress, the extraction percentage decreases even if the rollers are properly set.

Juice Settling Tanks

The number and capacity of juice settling tanks are best determined by the milling capacity. Settling tanks should hold juice from 3 hours of milling and allow 2 hours of settling before the juice is run into the evaporator. Each juice tank should be provided with a strainer for entering juice and a complete cover to keep out insects, dust, and trash. Metal or fiberglass tanks are generally preferable to wood because of their light weight per volume, relatively low cost, and ease of cleaning.

The opening for drawing off the juice to the evaporator should be located about 1 inch above the bottom so that the settled material is not drawn into the evaporator. A second opening for draining and cleaning should be located in the bottom. To make drainage and cleaning easier, slope the tank toward the side or end that has the drain opening.

Syrup Evaporators

Syrup evaporators are made of copper, stainless steel, or galvanized iron. Copper and stainless steel evaporators are preferable to those of galvanized iron because of efficiency in heat transfer, more years of useful life, and ease of cleaning. They can be cleaned with muriatic acid solution without damage, whereas evaporators of galvanized iron cannot. Although evaporators may vary in size, the 12-foot continuous evaporator (fig. 23) is most common. Other types of evaporators, such as the Stubbs (Stokes et al. 1961) (fig. 25), have been used successfully but have no advantage over the continuous evaporator.

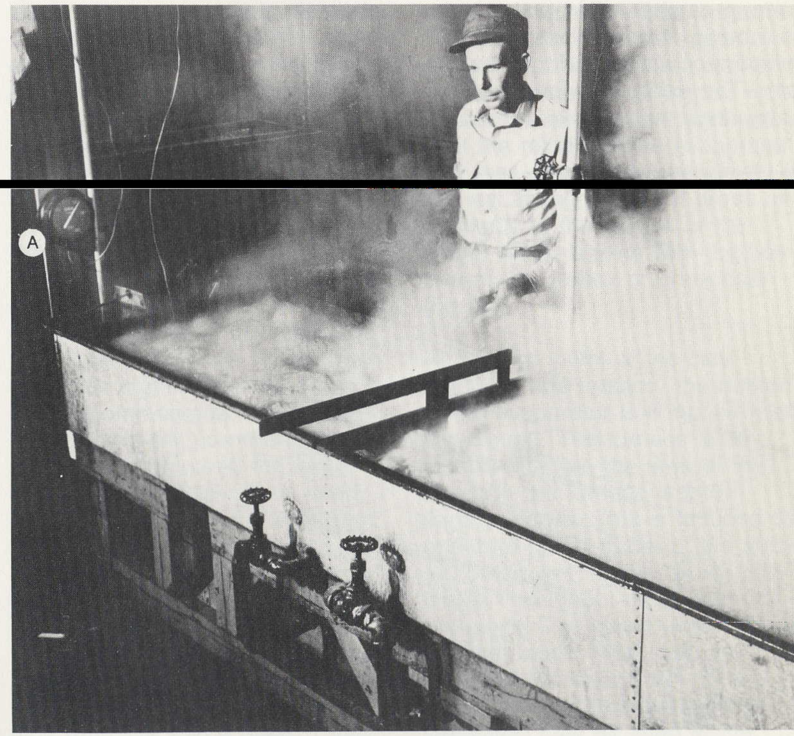

Figure 25
Stubbs-type evaporator in operation. Thermometer (*A*) used to determine syrup density.

Skimming troughs attached to the entire length of the gunnels on both sides of the evaporator (fig. 26) greatly reduce the labor for skimming the juice. Heat should be regulated to produce high boiling with a constant depth of juice (0.75 to 1 inch at shallow end) in the evaporator so that there is a continuous flow of skimmings to the skimming troughs. Excessive dabbling with a skimmer can cause skimmings to become mixed into the syrup and can result in a green syrup with a grassy flavor. Where possible, the skimmings should be allowed to form in patches or a blanket before being removed from the evaporator with a perforated skimmer. The exception would be the skimmings that cling to corners and edges of the evaporator near the syrup end and drawoff opening. These skimmings should be removed with a solid paddle or scoop. After clarification, the juice is evaporated to syrup density as rapidly as possible.

A drain valve at the lower end of the evaporator (preferably the juice end) is desirable for draining the semisyrup that remains in the evaporator at the end of the day's processing. The drain valve should be located with sufficient clearance from the furnace wall so that the semisyrup may be strained into a container for overnight storage. This semisyrup is mixed with raw juice at the beginning of the next day's processing.

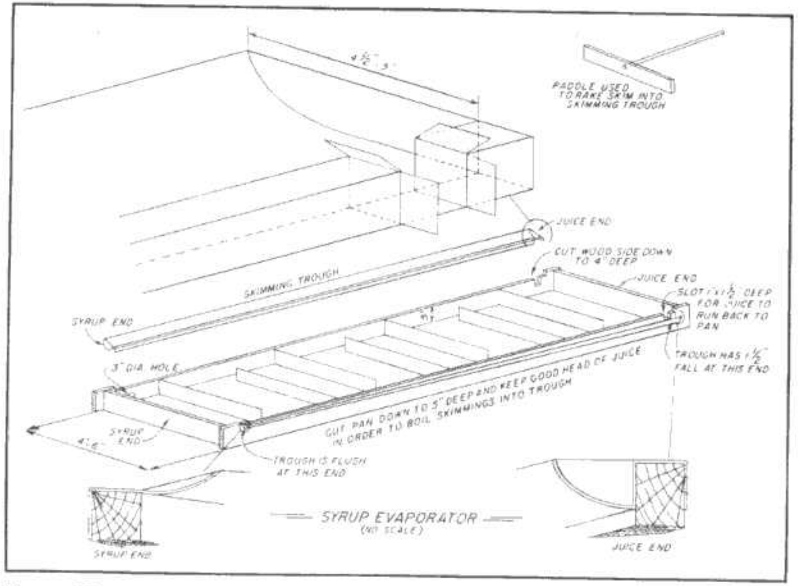

Figure 26
Syrup evaporator.

At the end of each workday, the evaporator should be washed with warm water and prepared for overnight acid cleaning. This acid cleaning requires covering the bottom with warm water, adding 1 cup of muriatic acid, and soaking overnight. By morning, the solution will have softened the deposited sediment so that it can be removed from the sides and bottom of the pan with steel wool. Rubber gloves and other protective clothing should be worn during cleaning with the acid solution. The used solution should be disposed of safely away from trees, streams, and grass areas to prevent injury and to minimize pollution. The evaporator should be thoroughly flushed out with clean water before the cooking operation is resumed.

Evaporator Furnace

The furnace should be located with the fire or front end toward the prevailing wind. For maximum durability, it should be constructed with double-thick brick walls. The inner wall of firebrick should be one brick higher than the outer wall of common clay brick. Cement blocks will crumble from the intense heat required for syrup making and should not be used. The furnace should be level from side to side and slope 1 inch downward from the syrup end to the fire end.

The evaporator is set on and completely covers the firebrick wall on both sides. It should reach 0.25 inch from the space plate, 1 foot from the stack, and to within 4 inches of the front wall (fig. 23). A seal should be made of heat-resistant fiber or clay between the bottom of the evaporator and the top of the firebrick wall.

The firebox should have a metal door. The ashpit is left open when solid fuel, such as wood or coal, is used. The firebox front wall for furnaces that use jet burners (gas or liquid fuel) should have an opening for mounting the burner and additional space for manual control vents.

The furnace should be constructed to distribute the heat properly over the bottom of the evaporator. A mound of fire-resistant clay is erected between the furnace walls so that it rises about 18 inches past the middle of the evaporator and then slopes down gradually to the last section where it drops off suddenly to the bottom of the stack, which is level with the bottom of the firebox or grate bars (fig. 23).

At the high point of the clay mound in the furnace, the bottom of the evaporator is 8 inches from the mound. The furnace is 30 inches wide, so the area of the throat in the furnace is 240 square inches. This is reduced by one-third in the throat of the stack to 160 square inches, which continues throughout the height of the stack. The stack height should be from one to two times the length of the evaporator. A 3- by 4-inch damper (manual control ventilator) may be used in the stack to regulate the draft. This is placed 18 inches above the bottom of the stack.

So that the stack will not need frequent rebuilding because of burnout, it should be made with an interior wall of the firebrick and an outer wall of clay brick to a height of about 6 feet. The upper part of the stack may be constructed of clay brick or sheet-steel pipe. The inside dimension of the stack should be 160 square inches throughout its entire height. The metal part of the stack needs a metal base secured to the brick base, and it should be frequently painted with heat-resistant aluminum paint to prevent rust. Guy wires with metal ground anchors should be used to secure the stack and to protect from lightning.

Making and Canning Syrup

Evaporating Syrup to Uniform Density

The finished syrup as it comes from the evaporator should have a near amber color, uniform density, well-developed flavor characteristic of sugarcane syrup, and an attractive appearance. The syrup should be removed from the evaporator when it reaches 226° to 230°F. Some experienced operators are able to judge the density of syrup fairly accurately while it is boiling. But not all sugarcane varieties produce syrup that can be judged accurately for density by observing the boiling syrup. An accurate thermometer placed in the evaporator allows the syrup maker to continuously monitor the syrup density (fig. 25). The bulb should be placed near the syrup drawoff opening so that it does not touch either the bottom or side of the evaporator and remains covered with boiling syrup at all times. The bulb of the thermometer should be cleaned daily when the evaporator is cleaned.

Most consumers of pure sugarcane syrup prefer a syrup with fairly heavy density. To meet this demand, it is necessary to coordinate the geographical elevation and boiling point of finished syrup. At elevations from sea level to 500 feet above, the temperature of the syrup at the drawoff valve should be from 228° to 230°F. For each 500-foot rise in elevation, it can be reduced 1°.

Canning Syrup

Finished syrup is thoroughly sterilized by boiling. If packed in clean containers while hot and sealed immediately, it will not spoil or ferment. The cans or glass containers must be airtight to prevent fermentation or surface mold growth. Large containers, such as kegs, wood barrels, and metal drums, should be thoroughly washed several times with boiling water, or steamed if possible, then dried before syrup is put into them.

Syrup flowing from the evaporator to the canning area should be protected from insects, strained through cheesecloth or fine-mesh nylon, and cooled to a specific temperature for canning. For filling half-gallon and smaller containers, the syrup should be very near 190°F and for gallon containers near 180°. For barreling, the syrup should be cooled to at least 120° (Stokes et al. 1961).

Caution: Excessive agitation and aeration through pumping and stirring the syrup increases cloudiness and tendency for sugaring. The hot containers should be allowed to cool before they are packed in boxes. If hot containers are immediately packed in cartons or stacked too close together, the syrup may boil in the containers, producing scorched flavor, broken seals, and messy boilover.

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