CULTURE OF SWEET SORGHUM FOR SIRUP PRODUCTION

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PREFACE

This handbook summarizes information on sweet sorghum production in the United States and is based on extensive research findings and grower experience. It is intended to give essential information for growers, producers, processors, extension personnel, and others interested in the production of this crop.

This handbook supersedes U.S. Department of Agriculture Farmers' Bulletin No. 2100, "Culture of Sorgo for Sirup Production."

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CULTURE OF SWEET SORGHUM FOR SIRUP PRODUCTION

By K. C. Freeman and D. M. Broadhead, *research agronomists*, and Natale Zummo, *pathologist*, *Southern Region, Agricultural Research Service, Meridian, Miss.*

INTRODUCTION

Good sweet sorghum sirup is light colored and mild and has a characteristic flavor. It is a wholesome food and is a favorite as a table sirup in sweet sorghum areas.

Sweet sorghum is grown most extensively for sirup in the Southeastern States. Eight States (Alabama, Arkansas, Georgia, Iowa, Kentucky, Mississippi, North Carolina, and Tennessee) in the sweet sorghum sirup area produce about 90 percent of the total sweet sorghum sirup in the United States.

Sweet sorghum is adapted to diverse climatic and soil conditions like those found in Alabama and Minnesota. Consequently, some sweet sorghum is grown for sirup in 19 of the 50 States. The peak annual income from sweet sorghum sirup was $21,670,000 in 1946 for 10,171,000 gallons. During the 1960's, the annual income from sweet sorghum sirup averaged about $5 million for 2.5 million gallons. During this time, the price per gallon and yield of sirup per acre have increased slightly (*22*).[1]

Some sweet sorghum sirup producers grow sweet sorghum in large fields but the average producer grows less than an acre for sirup. The manufacturing of sirup also is usually on a small scale. Community projects, however, are becoming more common. In these projects, the sirup for an entire community is manufactured at one plant, which is owned by an individual or a corporation. Even though the average acreage is low, sweet sorghum sirup constitutes a meaningful cash crop for most of its producers.

The name "sweet sorghum" is used to identify varieties of sorghum, *Sorghum bicolor* (L.) Moench, that are sweet and juicy. These sweetstalk varieties are also called "sugar sorghums." Sweet sorghum is grown for sirup or forage, whereas some other sorghums, such as kafirs and milos, are grown for grain. Other types of sorghum include broomcorn, *Sorghum dochna* var. Technicum (Koern.) Snowden, the head of which is used in making brooms and brushes; and johnsongrass, *Sorghum halepense* (L.) Pers., and sudangrass, *Sorghum sudanense* (Piper) Stapf, which are cultivated for forage.

Cultural practices for sweet sorghum used for sirup or for forage are similar, but the harvesting and processing methods are different.

The primary objective in growing sweet sorghum for sirup is to obtain the largest possible yield of good-quality sirup at the lowest cost. Yield and quality of sirup are influenced by varieties, diseases, insects, weeds, soil type, climatic conditions, cultural and harvesting practices, and manufacturing methods.

[1] Italic numbers in parentheses refer to Literature Cited, p. 29.

DESCRIPTION OF THE PLANT

Sweet sorghum, a member of the grass family, is closely related to kafir, milo, broomcorn, johnsongrass, and sudangrass. Sugarcane, *Saccharum officinarum* L., another member of the grass family used to produce sirup, is more distantly related. Sweet sorghum is a perennial in the Tropics but it winterkills in areas where frosts occur. Young sweet sorghum plants are small, and their growth is slow. In the germinating process, the radical (first root) bursts through the seedcoat. Shortly thereafter, the plumules (first leaves) appear and later develop into the shoot that grows upward. The first node or joint is found just beneath the soil surface where it develops permanent roots. When the seed is planted deeply, the subcrown internode may grow 2 inches or longer before the first node is apparent. The crown roots develop at this point, and the tiller buds are formed.

After the seedling stage, the early growth above the surface consists mainly of leaves. The stalk, however, is developing during this period, mainly by the formation of nodes very close together. A leaf is produced at each node; the base or sheath of the leaf closely surrounds the stalk. The internodes from this time grow more rapidly and become much longer. The number of internodes varies with the varieties and individual stalks. Stalks of most varieties taper from the base toward the top; the diameter of the last internode or the peduncle is the smallest. The exterior of the mature internodes of most varieties is covered with a thin film of waxy bloom. This outer region (rind) of the internode is hard and consists of numerous fibers that strengthen the stalk. The interior of the stalk is composed mainly of soft pith that contains the sweet juice.

The feeding roots originate from the lower nodes or joints of the stalks at a point slightly beneath or at the surface of the soil. The feeding roots radiate in all directions and are always most abundant in the upper first few inches of soil. The plant obtains most of its moisture and mineral nutrients from the upper 1 foot of soil although some of the roots extend 3 to 4 or more feet downward when soil conditions are satisfactory. If the soil is moist for long periods of time, tough brace roots may develop considerably above the surface of the soil. Those from the lower nodes may help to anchor the plants to the soil. When the plants are 3 to 6 inches tall, some of the buds at nodes below the soil surface develop into shoots that later become secondary stalks or tillers. In early stages, these tillers can be distinguished from the initial stalks by the fact that they grow out obliquely from the base. Later they grow upright and develop into independent stems. At the stage when these tillers are stems, they cannot easily be distinguished from the initial stalks. They may mature a few days later or, in some special cases, even a few days earlier, but their juice quality is normally equal to that of the main stalk, and they also should be used for sirup production.

Initial stalks and tillers may put out short side branches from their upper nodes when the seed heads (panicle) fail to develop normally or when harvesting is delayed after the seed are ripe. These side branches may grow 12 to 15 inches long and produce small seed heads. Side branches should not be used for sirup production, but their presence on the plant does not decrease the yield or quality of sirup.

CHARACTERISTICS OF SWEET SORGHUM VARIETIES

The desirable characteristics of sweet sorghum varieties for sirup production are: (1) Ability to produce a high yield of medium to large stalks per acre; (2) strong, erect habit of growth, not readily lodging during storms; (3) a high percentage of extractable juice; (4) juice having a high total soluble solids (Brix) content, mostly sugars; (5) resistance to diseases; (6) ability to produce a high-quality sirup; (7) comparatively short growth period; (8) tolerance to drought; (9) tolerance to excessive water; and (10) resistance to damage from insecticides. Varieties differ greatly in these qualities and in their adaptation to soil and climatic conditions. The grower should carefully consider all these qualities in his choice of a variety.

Varieties used for sirup production vary in stalk characteristics and potential ability to produce a high yield of stalks per acre. A good variety should yield stalks that are large in diameter and vigorous enough to reach a good but not excessive height and to develop two to four tillers. Varieties that do not tiller freely usually produce low yields of stalks. Tillering is also influenced by the condition of the soil and by cultural practices such as row spacing and planting time. It is, therefore, subject to some control by the grower.

Lodging of stalks increases the cost of harvesting, which is a major expense in producing sweet sorghum sirup. A good variety should resist lodging. Lodging may be due to: (1) Inherited weakness of the stalks that causes them to bend to a horizontal position before harvesting; (2) severe disease infection that weakens the stalks by destroying their internal tissue; or (3) caving over of the entire plant, which may be influenced by varietal weakness of the root system, poor cultural practices, insect damage, or high wind during rainstorms.

The percentage of juice extracted depends primarily upon the juiciness of the stalks and the milling equipment. Most of the available commercial varieties have adequate juiciness. In general, the small mills used to crush sweet sorghum stalks consist of three rollers propelled by motor power. Results from these mills are satisfactory when the rollers are properly adjusted. Simple extraction tests to determine the set of the rollers can be made by weighing 100 pounds of stalks, passing the stalks through the mill, and weighing the juice extracted. The weight of the juice is the percent extraction. A good sirup variety and a good mill will yield approximately 55-percent extraction in such a test.

Sirup yield per ton of stalks is determined by the extraction and the total soluble solids content (Brix) of the juice. A good variety should have a high content of total soluble solids in the juice. Varieties differ widely in their potential ability to produce such juice. The total soluble solids content may be influenced adversely by diseases and by cultural practices and climatic conditions that hinder the normal development of the plants.

All commercial varieties are susceptible to one or more of the sweet sorghum diseases. A satisfactory variety should be resistant to the major diseases. Losses from diseases may range from a slight reduction in yield and quality of sirup to a total loss of the crop. In addition to type of variety grown, cultural practices and time of harvest may influence the overall effects of a disease epidemic.

A good variety should produce high-quality sirup that has the following characteristics: (1) Light-amber color that is almost free of opaqueness; (2) mild, sweet flavor, nearly free of a tang; (3) little colloidal sedimentation or sediment confined to a trace of small particles near the top or bottom of the container; (4) high viscosity, which causes sirup to move slowly when poured from a container but to be free of a jellylike consistency usually associated with a high starch content; and (5) no crystallization or crystallization limited to a few small crystals. Sound cultural and manufacturing practices are also important in producing high-quality sirup.

A good sirup variety should mature and be ready for harvest well in advance of the first date of killing frost. Sweet sorghum varieties are quite divergent in their date of ripening. The grower should select a variety that is adapted to the growing season in his area.

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Sweet sorghum varieties are quite different in their tolerance to drought or excessive water during growing season. A variety to be grown in the hill area where drought stress is common should be well adapted to growing under low available moisture conditions. Varieties, however, that are to be grown on bottom land where flooding is common should be able to withstand extended periods of excessive water.

Resistance to damage from insecticides, particularly those used on cotton, is important for sweet sorghum varieties that are grown in areas where cotton is the important crop and aerial dusting or spraying is common. Care should be used to choose varieties in these areas that are tolerant or resistant to these insecticides.

VARIETIES

The selection of the variety that is grown is one of the most important decisions in the production of sweet sorghum sirup.

Explorations have brought to the United States valuable breeding material for use in extensive variety-improvement programs. Typical is the breeding and improvement work conducted at the United States Sugar Crops Field Station near Meridian, Miss. Here, the sorghums of the world are being assembled, crossed, and improved so that better sirup varieties adapted to the specific requirements of each locality can be developed and made available to farmers.

The results of selecting for red rot resistance in an established sweet sorghum variety are shown in figure 1.

Below are brief descriptions of some commercial varieties known to produce good-quality sirup under some conditions and to be suited to a wide range of soil and climatic conditions in the principal States where sweet sorghum is grown for sirup production. Comparative yield and other data for these varieties are included in tables 1 and 2.

Before the grower buys seed, he should ask the nearest agricultural experiment station agronomist or county extension agent about the suitability of these varieties in his locality. He should choose the variety carefully and should buy the best pure seed available.

FIGURE 1.—*On the left,* sweet sorghum selection susceptible to red rot; *on the right,* selection resistant to red rot under normal conditions.

Wiley

Wiley is a late-maturing variety that originated from two crosses made by the U.S. Department of Agriculture. The first cross, made in 1947, involved Collier and MN 822. A second cross was made in 1948 between the first generation of the first cross and MN 2046. A superior selection from the second cross was tested; this was released in 1956 under the name of Wiley (*9*).

Seed heads of Wiley (fig. 2) are of medium length and semicompact to irregularly compact. The small, mostly globuse, reddish-brown seed extend about one-half to three-fourths beyond the length of the straw-color glumes. The brown subcoat is absent. Under optimum conditions, the stalks grow 12 to 16 feet tall. The stalks tend to lodge more than Sart, are quite juicy, and are easily crushed in a small mill. Wiley is immune to red rot and leaf anthracnose, moderately resistant to zonate leaf spot and rust, and highly resistant to injury by the common cotton insecticides.

The quality of the sirup is excellent. Wiley is about 1 foot taller than Sart but matures at about the same time. It usually yields about 18 gallons of sirup per ton of stalks. Acre yields of sirup average about 34 percent higher than those of Sart because Sart fails to make commercial sirup some years. Wiley is recommended for the area of Tennessee southward. It usually requires 130 to 140 days to mature.

Sart

Sart is also a late-maturing variety of sweet sorghum for sirup production. It is an original variety introduced by the U.S. Department of Agriculture into the United States in 1945 from the Kordofan Province of Sudan, Central Africa (*20*).

Sart (fig. 3) has relatively large white seed when grown in the greenhouse but the seed are characterized by irregular purplish spots in the field; the brown nucellar layer is always present. The seed protrude well beyond the blackish glumes. Seed heads are erect, compact, and cylindrical. The plants grow 8 to 14 feet tall, depending on the fertility of the land, the available moisture supply, and the length of the growing season. Sart has large-barreled stalks that tiller well when the plants are properly spaced in the field. The hard rind of the stalk enables Sart to resist lodging under ordinary field conditions. It may develop characteristic multiple buds at the nodes late

TABLE 1.—*Relative yields and days to maturity of sweet sorghum at Meridian, Miss., Holly Springs, Miss., and Crossville, Ala.*

Location and variety	Stripped stalks per acre	Sirup per ton of stalks	Sirup per acre	Days to maturity
	Percent	*Percent*	*Percent*	*Number*
Meridian, Miss.:[1]				
Brandes	106	100	106	143
Dale	75	98	74	120
Honey	81	82	68	120
Sart	104	72	74	133
Tracy	80	68	57	115
Wiley (standard)	100	100	100	142
Holly Springs, Miss.:[2]				
Brandes	82	91	75	140
Dale	76	106	81	128
Honey	105	90	94	121
Sart	104	83	84	137
Tracy	81	87	72	113
Wiley (standard)	100	100	100	140
Crossville, Ala.:[3]				
Brandes	114	107	122	138
Dale	98	109	108	127
Honey	106	102	107	118
Sart	89	82	71	134
Tracy	83	87	74	110
Wiley (standard)	100	100	100	138

[1] All yields are expressed in percentage of the yield of Wiley, which was—
Stripped stalks per acre ---- 22.2 tons.
Sirup per ton of stalks ---- 17.1 gallons.
Sirup per acre ---- 374.0 gallons.

[2] All yields are expressed in percentage of the yield of Wiley, which was—
Stripped stalks per acre ---- 17.9 tons.
Sirup per ton of stalks ---- 16.0 gallons.
Sirup per acre ---- 284.0 gallons.

[3] All yields are expressed in percentage of the yield of Wiley, which was—
Stripped stalks per acre ---- 15.2 tons.
Sirup per ton of stalks ---- 16.2 gallons.
Sirup per acre ---- 240.0 gallons.

TABLE 2.—*Relative yields, days to maturity, and lodging of sweet sorghum at Blairsville, Ga., and Quicksand, Ky.*

Location and variety	Stripped stalks per acre	Sirup per ton of stalks	Sirup per acre	Days to maturity	Lodging
	Percent	*Percent*	*Percent*	*Number*	*Percent*
Blairsville, Ga.: [1]					
Brandes	104	86	90	135	0
Dale	89	94	84	142	0
Honey	108	90	98	125	8
Sart	76	82	63	114	6
Tracy	84	56	50	116	1
Williams	96	107	103	116	38
Wiley (standard)	100	100	100	135	9
Quicksand, Ky.: [2]					
Brandes	80	90	73	128	0
Dale	85	100	85	132	1
Sart	93	42	37	136	7
Sugar Drip	83	56	47	129	12
Tracy	89	39	34	129	4
Williams	76	68	49	132	76
Wiley (standard)	100	100	100	128	38

[1] All yields are expressed in percentage of the yield of Wiley, which was—
Stripped stalks per acre 20.7 tons.
Sirup per ton of stalks 15.5 gallons.
Sirup per acre 319.0 gallons.

[2] All yields are expressed in percentage of the yield of Wiley, which was—
Stripped stalks per acre 17.7 tons.
Sirup per ton of stalks 16.1 gallons.
Sirup per acre 264.0 gallons.

in season. It is very resistant to leaf anthracnose and stalk red rot, moderately resistant to damage by cotton insecticides, but susceptible to zonate leaf spot and rust and should not be grown where the latter two diseases tend to be prevalent.

When free of disease, Sart has juice of high sugar content and under ideal conditions makes an excellent, mild sirup. Under some conditions the juice of this variety cannot be boiled down to commercial density because of the presence of too much starch. It yields about 17 gallons of sirup per ton of stalks when the juice can be boiled down to commercial density. This variety usually requires about 134 days to mature. It is recommended for use in Alabama, southern Georgia, and Mississippi. Sart is sensitive to day length and temperature and may act as an early variety (mature in 100 days) if planted in April in the South. Sart may also act as an early variety if planted later than April at high elevations.

Tracy

Tracy, a midseason variety, originated from a cross between White African and Sumac made in 1923 by the U.S. Department of Agriculture. The final selection was released in 1953 under the name of Tracy (*21*).

Tracy has small, brown seed with no brown nucellar layer. The seed extend well beyond the small, dark, reddish-brown glumes. Seed heads of this variety are small, erect, compact, and almost cylindroid. Under optimum conditions the stalks grow 9 to 12 feet tall. Amount of tillering is intermediate and somewhat less than that of Sart. The erect, juicy stalks are easily crushed in a small mill. Tracy is susceptible to leaf anthracnose, red rot, zonate leaf spot, and rust, but moderately resistant to damage by cotton insecticides.

The quality of the sirup is inferior to that of Wiley but is excellent under ideal conditions. Under other conditions the juice of this variety cannot be boiled down to commercial sirup density because of the presence of too much starch. Tracy usually yields about 19 gallons of sirup per ton of stalks. It is an exceptionally heavy-tonnage variety for the midseason group. On an average, the per acre yield of sirup is about 55 percent of that of Wiley. Tracy matures in about 116 days. It is well adapted to the area from Kentucky southward where rainfall is adequate.

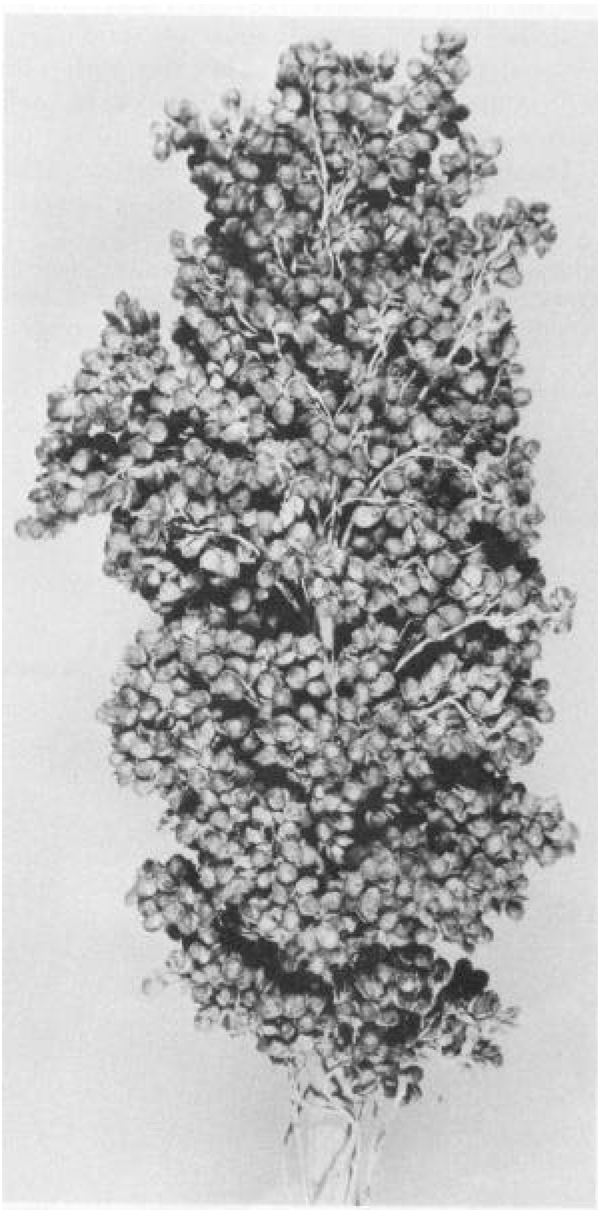

FIGURE 2.—Typical head of Wiley sweet sorghum.

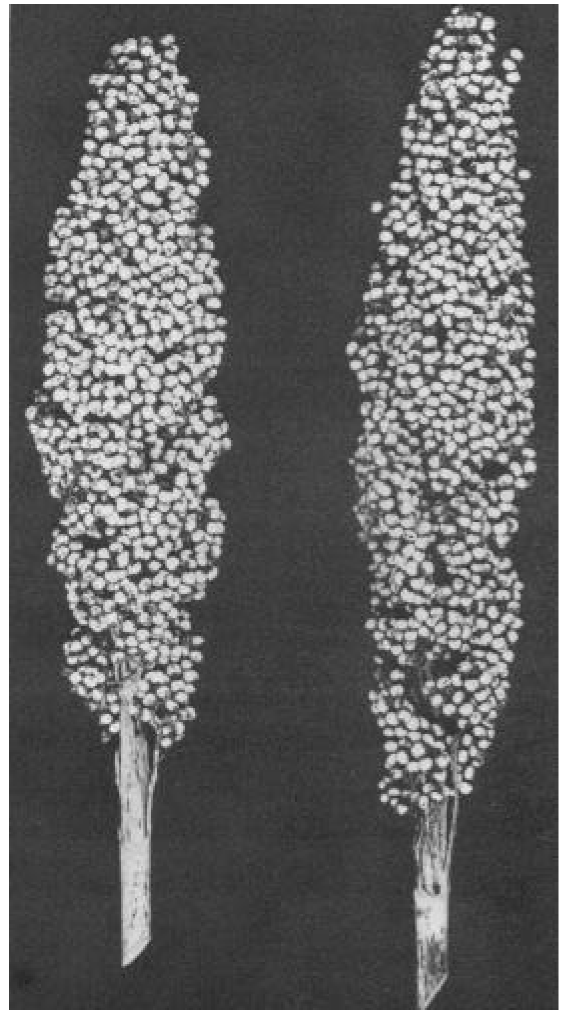

FIGURE 3.—Typical head of Sart sweet sorghum.

Brandes

Brandes, a late-maturing variety, originated from a cross between Collier 706–C and MN 1500 (*6*).

The name "Brandes" was selected in honor of the late Dr. E. W. Brandes, Head Pathologist in charge of Sugar Crops Investigations, U.S. Department of Agriculture.

Brandes (fig. 4) seed are small, with a white chalky color seed but lack the brown nucellar layer. The endosperm is mostly corneous. The medium-length panicle is semicompact to irregularly compact. Brandes usually produces seed that have a high germination, which is retained well during storage. It has an excellent root system coupled with stiff, pliable stalks that usually remain erect after severe storms.

Brandes is resistant to leaf anthracnose, red rot, and many other important diseases. It is, however, very susceptible to cotton insecticides and is not recommended for areas where these insecticides are applied by plane.

The yield and quality of sirup of Brandes compare favorably with those of Wiley under average conditions. Brandes is less drought resistant than Wiley and should be planted on soils with good moisture-holding capacity. Lodging resistance is the major advantage of Brandes.

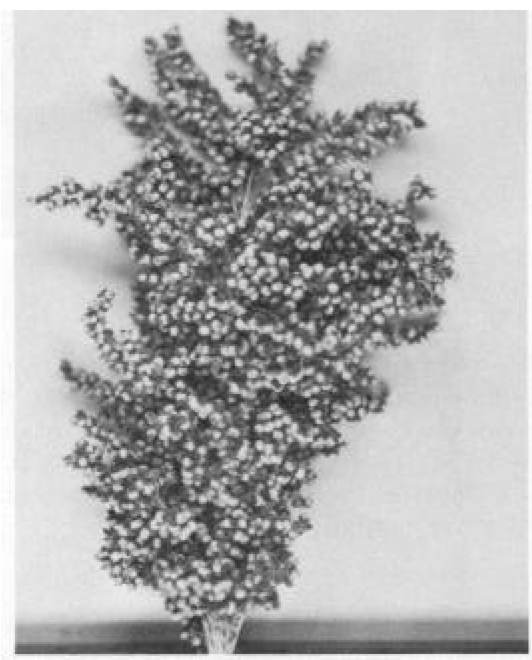

FIGURE 4.—Brandes, a sweet sorghum with excellent lodging resistance.

Dale

Dale, a midseason variety with superior disease resistance, was developed at the U.S. Sugar Crops Field Station, Meridian, Miss. It is a selection from the progeny of the fourth back-cross between Tracy and MN 960 (P.I. 152857),[2] with Tracy as the recurrent parent (*3*).

Dale is similar in appearance to Tracy and matures at about the same time as Tracy and about 3 weeks earlier than Brandes and Wiley. Dale (fig. 5) has a medium-length, somewhat erect, compact panicle, which approaches a cylindroid in shape. The glumes cover about one-third of the seed and are reddish brown to blackish, with tufts of hyaline pubescence at the base, apex, and margins.

The seed are small and thresh free, and they

[2] P.I. refers to the accession number assigned to foreign introductions by the Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture.

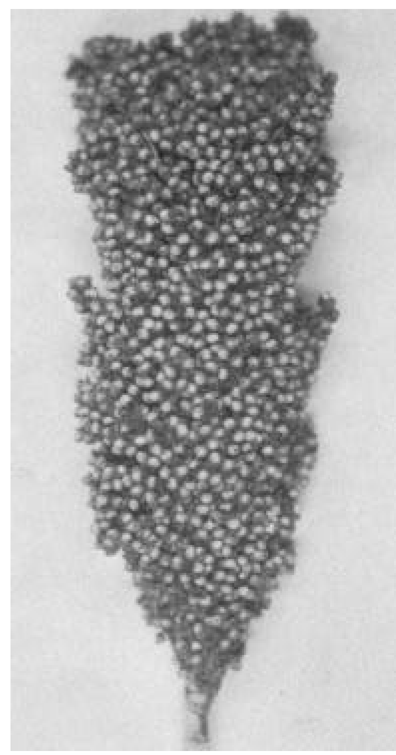

FIGURE 5.—Dale, an anthracnose-resistant mid-season sweet sorghum for sirup.

vary from obovoid to globose. Seed color varies from light to dark reddish brown and is often somewhat lighter where the seed are exposed. The endosperm is starchy, with a medium to thick corneous layer surrounding a chalky-white center. It does not have the brown nucellar layer. Dale seed usually have high-percent germination and retain this high germination when stored properly.

Dale is resistant to leaf anthracnose and stalk red rot, whereas Tracy is susceptible. Dale is tolerant to cotton insecticides.

The medium-sized stalks of Dale grow upright and straight and are covered with a waxy bloom. The stalks are juicy and sweet, producing a high yield of sirup per ton of stalks. Dale normally has adequate starch in its juice to give desirable sirup body, but not enough to interfere with sirup manufacturing.

The sirup made from Dale has a mild sorghum flavor and good color and is of excellent quality.

Sugar Drip

The origin of this midseason variety is not known. Sugar Drip (fig. 6) has medium-size, brown seed. The seed have a brown subcoat and extend well beyond the dark reddish-brown glumes. The seed heads are erect, medium size, relatively compact, and nearly cylindroid. The stalks are somewhat shorter and smaller barreled than those of Tracy. Under good growing conditions, Sugar Drip may lodge enough to handicap harvesting operations. Sugar Drip is very susceptible to most sorghum diseases in the sweet sorghum sirup area.

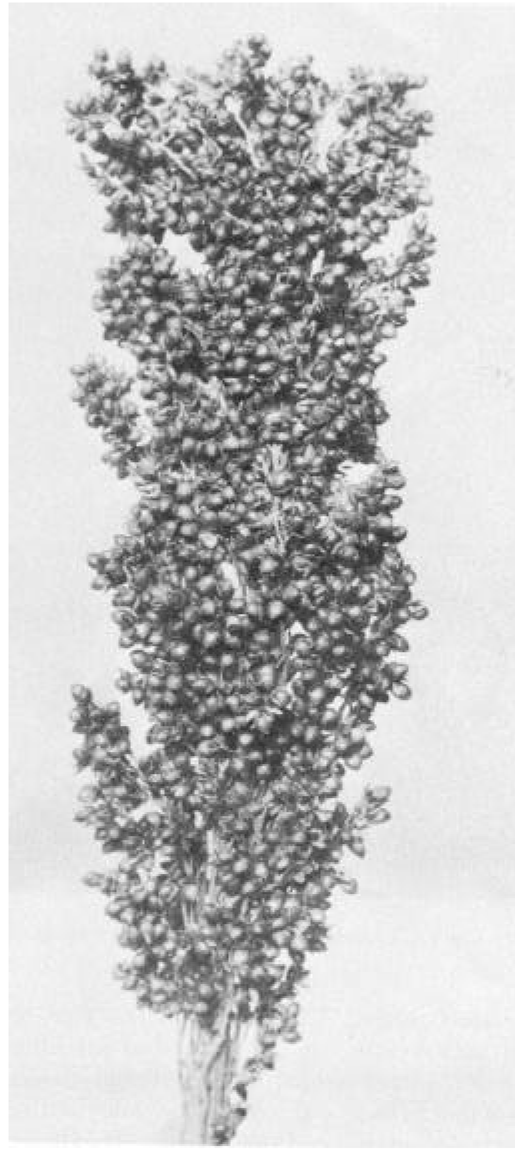

FIGURE 6.—Typical head of Sugar Drip sweet sorghum.

Honey

This variety was grown as early as 1880 by the U.S. Department of Agriculture and was formerly known as Honey Cane. One of its common names is Texas Seeded Ribbon.

Honey (fig. 7) has medium-size, brown seed that have a brown nucellar layer and are usually shorter than the brownish-red glumes. The large, erect seed heads are open and are variable in shape. Under optimum conditions, the large-barreled stalks grow 7 to 10 feet tall. This variety has a very weak stalk in relation to its height and tends to lodge badly under ideal growing conditions. It is very susceptible to all the major sorghum diseases in the sweet sorghum sirup-producing areas and is particularly susceptible to damage by cotton insecticides.

Under ideal conditions, it produces a good yield of juicy stalks and an excellent quality of sirup. Honey usually matures about midway between the maturity dates of Tracy and Sart.

Georgia Blue Ribbon and Williams

Two varieties, Georgia Blue Ribbon and Williams, have an uncertain ancestry and appear to

FIGURE 7.—Typical head of Honey sweet sorghum.

be closely related. They have medium-size, brown seed with brown subcoat. The seed are about as long as the dark reddish-brown glumes. Seedheads are semicompact and erect. The juicy stalks are somewhat shorter and smaller barreled than those of Tracy. These two varieties lodge badly and are very susceptible to the major sweet sorghum diseases in the sirup area. They mature at about the same time as Tracy but yield somewhat less tonnage of stalks per acre. They produce an excellent sirup.

DISEASES

Sweet sorghum, like all other agricultural crops, is subject to a number of diseases. Damage to a crop may vary from year to year, depending on locality, environmental conditions, and resistance of varieties, from little or no loss to complete destruction of the crop. Sorghum diseases are easier to prevent than to control, therefore, the resistance of different sweet sorghum varieties to the prevailing diseases in an area should be considered when selecting a variety. Appropriate cultural practices such as crop rotation, clean cultivation, and seed treatment will also aid in the control of some diseases and minimize losses from others. In this report, the specific diseases are discussed in order of economic importance.

Downy Mildew

Downy mildew incited by the fungus *Sclerospora sorghi* (Kulk) Weston and Uppal is one of the newer diseases of sweet sorghum in the United States. This disease was first reported from Texas in 1964 (*17*). Since then, it has spread to Georgia, Kansas, and Mississippi (*12*, *13*, *18*). The disease is presently limited in distribution but its potential for further spread is considerable.

The most conspicuous symptom of downy mildew (the systemic phase) is the appearance of vivid green and white stripes on the leaves in the late spring (fig. 8). These striped leaves later split or shred along the white stripes. Plants systematically infected frequently fail to head. Close examination of the underside of the leaves during humid weather will show the presence of a white downy material. This down or fuzz is made up of the asexual fruiting bodies (conidia and conidiophores) of the fungus. The conidia (asexual spores) are spread by the wind and infect other plants in the field. The infection produced from conidia (foliar infection) somewhat resembles mosaic symptoms in that the leaves are mottled and yellow. Downy mildew, in many instances, however, can be distinguished from mosaic by the presence of the white downy material (conidiophores) during humid weather. Foliar infection may repeat itself several times during a growing season so that a high percentage of plants may become infected. If foliar infection occurs early in the growing season, infected plants may develop systemic symptoms later in the season. These plants may not produce seed heads.

As the systemically infected leaves shred, oospores (sexual spores) are released from the white striped areas of the leaf into the soil. These oospores may remain viable in the soil for several years. When sorghum is planted in an infested

FIGURE 8.—Sweet sorghum plants systematically infected with downy mildew.

field, these oospores can infect the young seedlings before they emerge from the soil. Those infected seedlings that emerge will show a chlorotic mottle. Those that do not die at a young age generally develop the systemic symptoms and the disease cycle is repeated.

Corn and johnsongrass are also attacked by the downy mildew fungus. Some varieties of sudangrass and broomcorn are very susceptible to injury by the fungus.

CONTROL.—Brandes (*25*) is resistant to downy mildew and should be grown in areas where the disease is present.

Anthracnose and Red Rot

The fungus *Colletotrichum graminicolum* (Ces.) G. W. Wils incites two phases, anthracnose and red rot, of one of the most destructive diseases of sweet sorghum in the Southeast (*14*).

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The anthracnose phase usually appears on the leaves of susceptible varieties in midsummer as small, circular to elliptical spots ranging from one-sixteenth to one-quarter inch in diameter. The spots are well defined and vary in color from tan-orange-red to blackish-purple, depending on the variety affected. Under conditions of high humidity the spots increase in number and enlarge to cover a large part of the leaf area. Midrib infection commonly occurs as elliptical to elongate discolored lesions. These lesions frequently coalesce so that the entire length of the midrib is covered. Leaf anthracnose may occur at any stage of plant development but normally shows up in midsummer when plants are from 3 to 5 feet tall. Anthracnose may defoliate the plants markedly, thus reducing the sugar content of the juice. In severe cases, plants of susceptible varieties such as Hodo, Honey, C. P. Special, and Williams may be killed before they reach maturity (fig. 9). Fortunately, varieties such as Brandes, Dale, Sart, and Wiley are resistant to the disease.

The red rot phase primarily affects the stalks of the mature plant. Spores of the fungus from the anthracnose phase produced on the leaves are washed down behind the leaf sheath by rains. These spores germinate and the fungus enters the stalks at any time after the jointing stage and causes rotting of the interior of the stalk (fig. 10). Infected areas become discolored and the en-

FIGURE 9.—Anthracnose on C.P. Special, resulting in total destruction of plants.

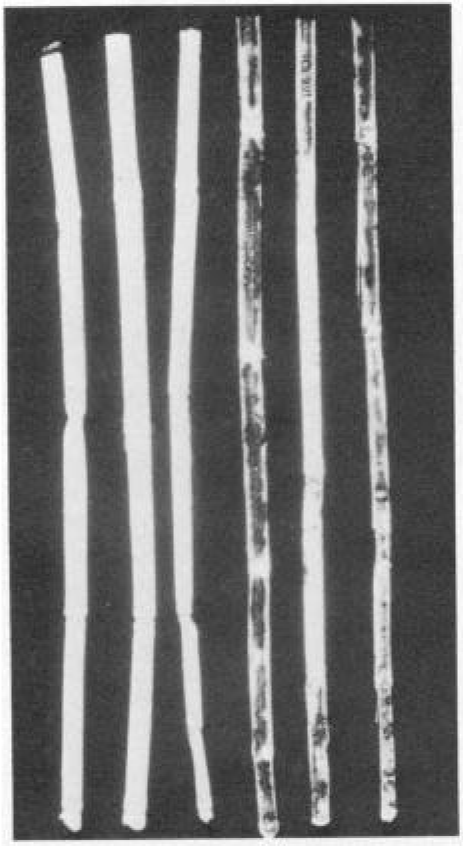

FIGURE 10.—Stalks of sweet sorghum *on right* infected with red rot.

tire stalk may become rotted in advance stages. When diseased stalks are split lengthwise, discolored areas interspersed with white can be seen throughout the affected parts of the stalk. Badly rotted stalks yield less juice than healthy stalks and produce poor-quality sirup with a reddish color.

CONTROL.—To control anthracnose and red rot, grow resistant varieties such as Brandes, Dale, Sart, and Wiley. However, if a suspectible variety is grown, crop rotation and clean cultivation will help reduce the threat from this disease because the fungus overwinters on the crop residues of sweet sorghum. The fungus also attacks broomcorn, johnsongrass, and sudangrass.

Mosaic

Mosaic on sorghum is caused by the sugarcane mosaic virus (*1*) or one very closely related to it (*24*). The disease normally appears on the upper two to three leaves as an irregular mottling of green and light-green areas often interspersed with longitudinal white or light-yellow streaks (*11*) (fig. 11). On some varieties, however, the disease will appear as a brilliant-red, mottled streaking of the upper leaves or as mottled necrotic lesions on the upper leaves, depending on the variety affected (fig. 12). The virus is transmitted from diseased plants to healthy plants in the field by several species of aphids (*23*).

Mosaic has been known on sorghum for many years with little cause for concern. In the past, mosaic has been confined to areas in the vicinity of diseased sugarcane plants that have carried the disease over from year to year. However, since 1965, a mosaic disease has been found on sorghum in widely scattered areas of the Southeast where sugarcane has never been grown. This form of the

FIGURE 11.—Mosaic on sweet sorghum showing typical mosaic pattern.

FIGURE 12.—Mosaic on sweet sorghum showing the red or necrotic reaction.

virus also infects johnsongrass, corn (*Zea mays* L.), perennial fescue (*Festuca* spp.), foxtail (*Setaria* spp.), and many other grasses. These grasses may also harbor some vectors of the virus (corn leaf aphid, rusty plum aphid) and if they become infected, spread of the disease into nearby sweet sorghum fields is likely.

Some varieties, such as Williams and Sugar Drip, when infected at an early stage of growth, may be severely stunted (*26*). On the other hand, varieties such as Dale, Sart, and Wiley may not be severely affected by the disease. Brandes is moderately resistant to mosaic infection in the field.

Grey Leaf Spot or Angular Leaf Spot

Grey leaf spot or angular leaf spot of sorghum incited by the fungus *Cercospora sorghi* Ell. and Ev. is a conspicuous disease of rather minor importance. The spots are rather long and narrow and limited somewhat by the leaf veins, giving them an angular appearance (fig. 13). As the spots enlarge, they become covered with copious greyish mycelium of the fungus. This disease is also found on johnsongrass and sudangrass.

Although all available sweet sorghum varieties are susceptible to grey leaf spot, the disease generally occurs late in the growing season after the crop is matured so that little loss results.

Bacterial Stripe

Bacterial-stripe disease of sweet sorghum, incited by *Pseudomonus andropogoni* (E.F. Sm) Stapp, is found throughout the sorghum sirup area. The disease is characterized by tan-brick-red to dark purplish-red stripes on the lower leaves. These stripes are generally restricted to the interveinal areas of the apical parts of the leaves (fig. 14).

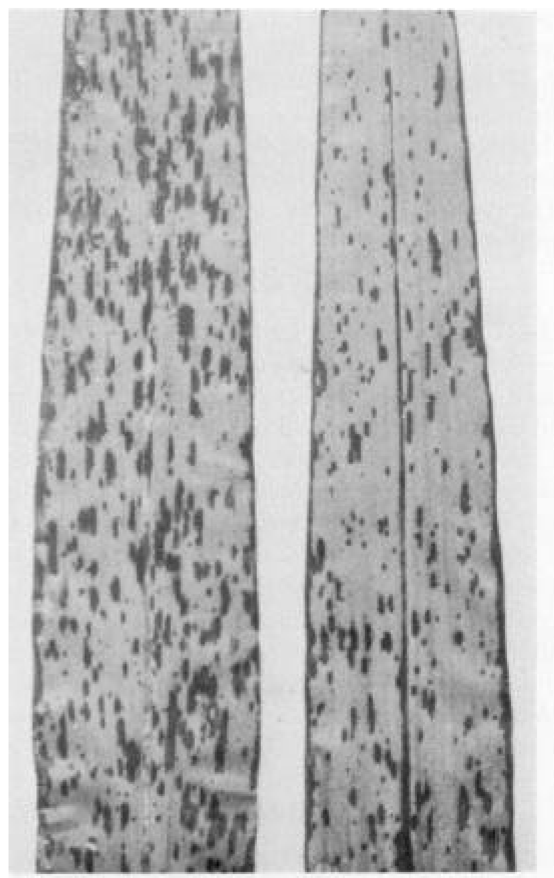

FIGURE 13.—Grey or angular leaf spot on Rio sweet sorghum.

FIGURE 14.—Bacterial stripe on leaves of 3 sweet sorghum varieties.
(The difference in color is due to varietal reaction to the disease.)

They range in length from less than 1 inch to the length of the leaf blades. Sometimes the stripes fuse so that large areas of the leaf are affected. A slime or bacterial exudate may be found on the affected part of the leaves and along the leaf margins.

Bacterial stripe, although conspicuous in appearance and widely distributed throughout the sweet sorghum belt, does not generally reduce yields significantly.

Leaf Blight

Leaf blight incited by the fungus *Helminthosporium turcicum* Passerini and southern leaf blight incited by the fungus *H. maydis* Nisikado and Miyake have been known on sweet sorghum in the more humid areas of the South for many years. Varieties that were injured by leaf blight have not been grown extensively so that although no direct effort has been made to obtain resistance to leaf blight, sweet sorghum varieties now produced have some resistance. During the leaf blight epiphytotic (*H. maydis*) of 1970, all sweet sorghum varieties showed some slight degree of infection; however, there was little or no damage to infected plants.

Insecticide Injury

Some sweet sorghum varieties are susceptible to injury from certain cotton insecticides such as *o,o*-dimethyl *o*-(*p*-nitrophenyl) phosphorothioate (methyl parathion), toxaphene, and some of the other organic phosphates (fig. 15). Widespread injury from airplane dusting of cotton may occur when sweet sorghum is planted close to cottonfields. This injury appears as irregular, circular or elliptical, watersoaked spots on any part of the leaves within 24 hours of the time the chemical is applied. These spots dry out and turn reddish to blackish on the margin within 72 hours. When a large quantity of insecticide is applied to a susceptible variety, large parts of the leaves may be destroyed. Repeated applications of insecticides may severely stunt or kill plants of susceptible varieties.

CONTROL.—If sweet sorghum is to be grown near cottonfields, plant varieties such as Dale, Sart, or Wiley, which are only slightly affected by insecticides (7). If susceptible varieties such as Honey or Brandes are to be grown, plant them as far from cottonfields as possible.

Rust

Sorghum rust incited by the fungus *Puccinia purpurea* Cke. occurs generally in the more humid regions of the sirup area every year. It is not as prevalent in the less humid regions. Rust appears on both surfaces of the leaves as small, raised, brownish pustules, filled with powdery brown spore masses (fig. 16). By rubbing the fingers gently over these raised pustules one may easily differentiate between rust and other leaf spots. In severe infections, these pustules may be so nu-

FIGURE 15.—Insecticide injury on Honey sweet sorghum 72 hours after application of the chemical.

FIGURE 16.—Rust on Sart sweet sorghum.

merous that the entire leaf is destroyed. If severe infection occurs when the plants are almost mature, as often happens in some areas, heavy losses may be avoided by harvesting the crop in the late milk or early dough stage. Growing resistant or tolerant varieties is the only practical method of rust control. All of the available sirup varieties of sorghum, except Brandes, are somewhat susceptible to rust. However, all varieties can be grown in most of the sirup areas with little or no damage from rust. Brandes is completely rust resistant.

Rough Spot

Rough spot incited by the fungus *Ascochyta sorghina* Socc. is prevalent throughout the sirup area of the Southeast. This conspicuous leaf disease is easy to identify by the sandpaperlike roughness caused by the hard, black, raised fruiting bodies of the fungus in the late stages. The disease begins as small, circular to oblong, light-color spots near the ends of the leaves. Small, hard, black specks, the fruiting bodies of the fungus, develop in the injured areas. As the spots enlarge, they grow together so that the size of the diseased areas may cover a large part of the leaf. Generally the damage from rough spot is not severe.

Smut

Three smuts of sorghum occur in the United States: covered kernel smut incited by the fungus *Sphacelotheca sorghi* (LK) Clint; loose kernel smut incited by the fungus *Sphacelotheca cruenta* (Kuehn) Potter; and head smut incited by the fungus *Sphacelotheca reiliana* (Kuehn) Clint. These diseases are rarely destructive on sweet sorghum in the sirup area.

Covered kernel smut is readily controlled by treating the seed before planting with any of the good seed treatment fungicides on the market.

Loose kernel smut arising from seedborne fungus spores is also controlled by chemical seed treatment. However, most of the loose kernel smut found in sweet sorghum in Mississippi is not the result of seedborne inoculum but is the result of secondary infection resulting from inoculum originating on smutted johnsongrass growing in or around the field (*10*). Chemical seed treatment is of no value in controlling loose smut from this source. Only certain varieties are susceptible to this mode of infection: Sart is; Wiley and Tracy are not.

Head smut cannot be controlled by chemical seed treatment; however, the disease is not important in the sirup-producing areas.

Pokkah Boeng

Pokkah boeng or twisted top incited by the fungus *Gibberella moniliformis* (Sheldon) Wineland occurs during periods of high rainfall. This disease is characterized by deformed or discolored leaves near the top of the plant (fig. 17). In severe cases, the leaves become so wrinkled and drawn that they are unable to unfold properly. In very severe cases, infection may pass from the leaves and sheath into the stalks, causing death of the tops. Although the disease may be very conspicuous on some varieties, losses are usually minor.

Zonate Leaf Spot

Zonate leaf spot incited by the fungus *Gloeocercospora sorghi* Bain and Edgerton is common in

FIGURE 17.—Pokkah boeng or twisted top of sweet sorghum.

FIGURE 18.—Zonate leaf spot of sweet sorghum.

the humid areas of the Southeast. The disease is very conspicuous on sorghum leaves as circular reddish-purple bands alternating with straw- or tan-colored areas, forming a concentric or zonate pattern (fig. 18). These spots vary in size from a fraction of an inch in diameter in the early stages to several inches in later stages. In these later stages the entire width of the leaf may be covered so that in effect the leaf may be considered cut off from the stalk at this point. When a high incidence of the disease occurs on plants in the seedling stage, severe defoliation and death of infected plants may follow. Abundant spotting on the leaves of older plants may cause premature destruction of the foliage, reduction of sugar content of the juice, and some reduction in yield of stalks. The fungus also attacks corn, johnsongrass, sudangrass, sugarcane, and other grasses.

CONTROL.—Fully developed measures for the control of this disease are not presently known. Crop rotation and clean cultivation to destroy residues of susceptible host crops should reduce the likelihood of severe losses in sweet sorghum. Highly resistant varieties are not presently available.

Root Rot and Seedling Blight

Several soilborne and seedborne fungi reduce stands by rotting the seed after they are planted or by killing young plants soons after the seed germinate. These fungi may be particularly damaging if a period of cool weather occurs soon after planting. Seed treatment with the same chemicals used to control the smut diseases may help to reduce this type of damage.

Summary of Disease-Control Measures

Three primary control measures should always be considered in growing sweet sorghum: (1) Planting resistant varieties when they are available; (2) crop rotation and clean cultivation; and (3) chemical seed treatment.

INSECTS INJURIOUS TO SWEET SORGHUM [3]

Sweet sorghums are infested by several species of insects. Usually insect damage is slight but occasionally it is severe.

[3] Reviewed by C. A. Henderson, research entomolgist, Southern Grain Insects Investigation, Southern Region, Agricultural Research Service, U.S. Department of Agriculture, State College, Miss. For information on insecticide control of insects attacking sweet sorghum, consult your State agricultural experiment station.

Lesser Cornstalk Borer

The lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), may severely damage young sweet sorghum plants during dry periods. These insects bore into the plant near but below the soil surface and reduce the stand.

This larva is slender and greenish and has dark-brown, longitudinal bands. It is about 1 inch long when full grown. It makes a rapid jerking motion when disturbed.

The lesser cornstalk borer can be controlled by the proper use of insecticides.

Sorghum Midge

The sorghum midge, *Contarinia sorghicola* (Coquillet), occurs over most of the Gulf Coast and South Atlantic States. It is a small orange-colored fly that deposits white eggs in the glumes at blossoming time. The larvae feed on the developing glumes and destroy the sorghum seed. As they grow, the larvae darken from pink to orange. A generation is produced in about 15 days.

The sorghum midge feeds on the heads of sweet sorghum, grain sorghum, broomcorn, johnsongrass, and sudangrass, but does not have a detrimental effect on sweet sorghum used for sirup. It winters as a cocooned larva in the spikelets of the host plant. The flies appear early in the spring at about the time johnsongrass begins to bloom; they lay their first eggs in the heads of this grass.

It is difficult to control the midge with insecticides. Losses can be reduced by locating sweet sorghum fields where johnsongrass is not common or by cutting or destroying nearby johnsongrass before it blooms. Plant all the sweet sorghum at the same time and properly space and cultivate it to produce uniform heading. Destroy heads that bloom much before the main crop. Before the flies emerge in the spring, plow under or destroy all material in which the midge may hibernate.

Satisfactory crops of sweet sorghum for seed can be obtained if paper bags are tied over the heads of selected plants during the blooming season to protect them from midge infestation. Remove the bags shortly after the blooming period because they provide conditions favorable for the corn earworm and corn leaf aphid that attack the seed heads.

Sugarcane Borer

The Sugarcane borer, *Diatraea saccharalis* (Fabricius), occurs in southern parts of Florida, Louisiana, and Texas, but rarely in Mississippi. It attacks sugarcane, corn, rice, broomcorn, sorghum, sweet sorghum, and several wild grasses. The adult is a moth that deposits eggs in clusters on the leaves of the host plant. The eggs hatch into small white larvae that bore into the stalk and make tunnels in it. These tunnels reduce the growth of the injured plants, weaken them so that they break over, and furnish entrance places for various organisms that may lower the sugar content. A generation of the sugarcane borer is produced in about 40 days. The pest overwinters as a larva in the stalks or stubbles left in the field.

Borer injury to sweet sorghum usually is not heavy until the latter half of August or September. Consequently, early-maturing varieties or early plantings are valuable in decreasing injury. In infested areas, plant sweet sorghum as far as possible from fields of sugarcane, corn, and rice. Before moth emergence in March or April, plow under or destroy stubble and pieces of sweet sorghum in which the larvae hibernate.

Corn Leaf Aphid

The corn leaf aphid, *Rhopalosiphum maidis* (Fitch), is sometimes very common on sweet sorghum throughout the sirup-producing area. It is usually found in the central whorl of the plant or on the panicle after it has emerged. This aphid has been seen in such heavy numbers that it prevented the formation of grain. It transmits the sugarcane mosaic disease, which attacks sweet sorghum. Plant sweet sorghum as far as possible from mosaic-infected sugarcane or wild grasses.

Fall Armyworm

The fall armyworm *Spodoptera frugiperda* (J. E. Smith), is found in the United States wherever sweet sorghum is grown for sirup. The larva is grayish and has three whitish longitudinal bands and a blackish head. It is about 1⅝ inches long when full grown. It eats the leaves of corn, sugarcane, sweet sorghum, and a number of wild grasses, and may strip the plant of leaves.

Corn Earworm

The corn earworm, *Heliothis zea* (Boddie), is found throughout the United States. It attacks many food plants. The moth varies from a light olive green to a dark reddish brown. Eggs are laid singly on sweet sorghum leaves and hatch in about 4 days. The caterpillars, feeding mostly in the leaf whorl, become full grown in about 3 weeks and are then about 1½ inches long. They are pink, green, cream, or yellow, and often striped. The pupae pass the winter in the soil. In the Gulf Coast States, there are four full generations each year.

Wireworms

Wireworms are the larvae of click beetles, *Elateridae*. They are yellow or brown and about ½ to 1 inch long. They are hard, shiny, and slender.

Wireworms injure sweet sorghum by boring into the plant seed, drilling into the young shoots, and feeding on the roots. Sometimes replanting is necessary. Wireworms can be controlled by insecticides.

Other Insects

The whorls of the sorghum plant often are infested by a sharp-nose grain leafhopper, *Draeculacephala portola* Ball. Stink bugs, Pentatomidae, have been observed in considerable numbers sucking the glumes. Flea beetles, Chrysomelidae, sometimes feed on the under surface of the leaves. The white-fringed beetle, *Graphognathus* spp., damages stand under some conditions.

INSECTS INJURIOUS TO STORED SWEET SORGHUM SEED

Sweet sorghum seed is attacked by many kinds of insects that commonly infest stored grains. The more important ones are the Angoumois grain moth, *Sitotroga cerealella* (Olivier), and the rice weevil, *Sitophilus oryzae* (L.). These insects begin their attack on the seed in the field before harvest and continue their infestation and damage during storage. Other species attack the seed only during storage. Malathion, pyrethrins plus piperonyl butoxide, or diatomaceous earth applied to stored seed will control these pests. Follow the directions on the label for application as grain protectants. Additional general information on bulk grain protectants and application methods can be found in U.S. Department of Agriculture Marketing Bulletin No. 20.

CULTURAL PRACTICES

Yield and quality of sweet sorghum sirup and the economy of handling the crops are affected by the soil type, crop rotation, fertilization practices, growth and diameter of the stalks, erectness of the stalks, uniformity of plant maturity, and ability of plants to withstand deterioration after reaching approximate maturity. Cultural practices that influence some of these factors are discussed in the following pages.

Soil Requirements

Many different types of soil are used for the production of sweet sorghum, but a soil of good physical character and high fertility produces the best yield. Poor soils usually produce slow-growing plants with small stalks. In general, loam and sandy loam soils are best for the growth of sweet sorghum for sirup production.

Soils high in organic matter are thought to have a detrimental effect on the quality of sirup. However, if other cultural practices are satisfactory, good-quality sirup is frequently made from sweet sorghum grown on soils that are high in organic matter supplied by green manure crops.

The field should have good natural drainage, especially in localities that may have periods of heavy rainfall. Ample moisture during the growing period is also important for good yields of stalks and sirup. Organic matter improves the waterholding capacity of the soil.

If the planting is to be done early in the season, a soil that becomes warm early should be used.

Heavy clay soils that warm slowly in the spring often remain cloddy after the seedbed has been prepared and have a tendency to form crusts through which the sweet sorghum seedlings cannot push to the surface. These soils usually produce poor stands, poor yields, and poor sirup.

Crop Rotation

Sweet sorghum usually fits into most common crop rotation systems. Cotton and corn are the principal crops in most of the sweet sorghum sirup area. They can be used with sweet sorghum in a rotation system. Because cotton is a clean-cultivated crop, it usually leaves the land in good condition for sweet sorghum the next year; few weeds will be present in the soil to interfere with the young sweet sorghum plants. The cotton stalks should be thoroughly chopped into the soil several weeks before sweet sorghum is planted so that the deterioration of the stalks will not interfere with the germination of the seed.

A winter cover crop may be grown in the cotton rows. However, during many seasons a cover crop cannot be planted early enough in the fall to produce a satisfactory growth before cold weather. Because the cover crop must be turned under early in the spring to avoid damage to sweet sorghum seed, the cover crop usually does not have time to produce a satisfactory yield of green manure.

Sweet sorghum may be grown successfully following a corn crop. The cornstalks should be thoroughly chopped into the soil several weeks before sweet sorghum is planted. However, an abundance of weed seed is usually present in the soil following the corn crop; therefore, weed control in sweet sorghum following corn may be difficult.

Planting soybeans in May or June on land to be used for sweet sorghum the following year is usually a very good practice. The plants may be disked down and permitted to remain on top of the soil during the winter months. In the spring they are turned under and allowed to deteriorate in the soil. Sometimes the beans are harvested and the stalk refuse spread on the land. After any of these treatments, the land usually has enough organic matter to place it in good condition for the sweet sorghum seed the following year.

Other types of leguminous plants, particularly blue lupine (*Lupinus angustifolius* L.) or field peas (*Pisum sativum* subsp. *arvense* (L) Poir) (where these crops grow well), have been used in rotation with sweet sorghum with equal success.

Fertilization Practices

Fertilizer requirements for land used for growing sweet sorghum depend largely on soil types, rainfall, crop history, and previous additions of manure and fertilizer.

The heavy types of soil may produce a good sweet sorghum crop with a moderate amount of fertilizer. Sandy soils are generally less fertile than heavy soils and usually require more fertilizer for a good growth of sweet sorghum. Some upland soils of intermediate types such as silt loams produce a poor sweet sorghum crop without fertilizers. Lime should be applied to acid soils to correct soil acidity, supply calcium, improve availability of other plant nutrients, and increase efficiency of added fertilizer and manures.

When legume cover crops are used for green manure, the need for fertilizer, especially nitrogen, is reduced. This need for fertilizer is also reduced on land that has been well manured in the past or on land just plowed out of improved pasture.

Many growers add fertilizer or manure before planting sweet sorghum. This treatment furnishes the young plants with an abundant supply of plant food to give them a quick start. It also helps them to overcome such hazards as weeds, soil crusts, insects, and diseases.

In a fairly fertile soil a small application of fertilizer to help this early growth may be all that is necessary for the entire season. On many soils, however, the quantity of fertilizer applied at planting time should be greater than that needed for a starting effect only. Moreover, fertilizer may be added later.

Each grower should study his soils and fertilization practices and get current fertilizer and liming recommendations from the nearest experiment station or the county extension agent.

Most of the fertilizer used for sweet sorghum is a mixture of nitrogen, phosphorus, and potassium. The ratio varies in different localities, depending on local requirements or customs. Nitrogen particularly is needed in most soils and is usually given first consideration.

It is not possible to recommend a single fertilizer practice to fit all farm conditions. In the absence of specific information about the needs on a particular farm, the grower should use the standard fertilizer formula for his area such as 4–12–12 (N, P_2O_5, K_2O), 6–8–8, 12–8–8, or 13–13–13. These mixtures should be applied in amounts that will supply approximately 40 pounds of nitrogen (N) and phosphate (P_2O_5) [18 pounds of phosphorus (P)] and 30 to 40 pounds of potash

(K_2O) [25 to 33 pounds of potassium (K)] per acre. On sandy soils, it may be advisable to apply part of the nitrogen at planting time and the remainder as side dressing before the crop is 30 inches tall. Typical yield data from fertilizer tests in Mississippi with the Wiley variety of sweet sorghum (table 3) indicate that 40 pounds of nitrogen per acre produced maximum economically profitable yields (*4*).

It was formerly believed that nitrogen added in an organic fertilizer such as cottonseed meal or tankage produced a superior sirup. Present (1972) information indicates that a sirup of good quality can be produced also by the use of inorganic nitrogen in ammonium sulfate, sodium nitrate, ammonium nitrate, and anhydrous ammonia (*15*). Nitrogen should be applied during early growth in amounts not exceeding the requirements of the crop.

A late application of manure or high-nitrogen fertilizer ordinarily should be avoided. When a side dressing is used, the fertilizer should be applied before the crop is 30 inches tall. If fresh manure is used, it should be applied to the previous crop instead of directly to the sweet sorghum crop. If heavy additions of manure are made directly before the sweet sorghum is planted, a poor-quality sirup may be produced.

TABLE 3.—*Effects of fertilizer on the yield of Wiley sweet sorghum at State College, Miss.*

Fertilizer per acre			Stripped stalks per acre	Sirup per ton of stalks	Sirup per acre
N	P_2O_5	K_2O			
Pounds			*Tons*	*Gallons*	*Gallons*
0	0	20	17.0	18.7	312
0	40	20	17.2	19.0	324
0	80	20	17.3	18.7	324
40	0	20	21.1	20.1	418
40	40	20	20.5	19.4	390
40	80	20	20.1	19.3	380
80	0	20	21.1	19.4	401
80	40	20	21.6	19.5	412
80	80	20	22.2	19.2	416
Mean			19.8	19.2	375
L.S.D. at 5-percent level			1.3	NS	40
L.S.D. at 1-percent level			1.7		54

When the fertilizer is applied in the row, either beside or below the seed, smaller applications are required than when it is broadcast. Both methods appear to be satisfactory. The need should never be allowed to come in contact with the fertilizer. This contact may kill some emerging seedlings and result in a poor stand.

Seedbed Preparation

Thorough preparation of the seedbed by breaking to a depth of 4 to 6 inches is important in the production of sweet sorghum. The land should be plowed early so that there will be ample time for all plant material to decay before the average planting date for sweet sorghum.

Disking the land thoroughly after plowing destroys clods and facilitates decomposition of the organic matter. Usually the organic matter is left on top of the soil through the winter months, where it protects the soil against erosion and remains in the best form until spring. This material is later disked into the soil during seedbed preparation. After the land is disked, the rows are set up in ridges with a middle buster.

Rows should be set up in time for settling by rainfall before planting. Firm beds preserve essential moisture until optimum planting time. A firm, moist seedbed is essential for obtaining a stand of sweet sorghum.

At planting, the tops of beds are scraped off down to the moist soil with a planter with running wings (fig. 19). The planter destroys early weeds and leaves the land in ridges about 4 inches high. This operation makes possible a uniform depth of planting, fertilizer application, and preemergence application of chemicals for weed control in a firm moist seedbed.

Planting Time

The optimum time to plant sweet sorghum can best be determined from actual practices in the community. Planting when the soil is thoroughly warm produces good germination, early growth, and uniform stands. An adequate supply of moisture is also essential for satisfactory germination

FIGURE 19.—Firm, moist seedbed developed by scraping off tops of ridges and placing seed, fertilizer, and weed-control chemical with planter with runner wings.

and early growth. Therefore, delay in planting until rainfall is scant and the warming of the soil has resulted in much loss of moisture is not advisable.

Typical yield data from date-of-planting tests in Meridian, Miss., with sweet sorghum (fig. 20) show that under normal conditions the best planting time may extend over a period of several days. In the early plantings the early growth was slow; as a result, weed control was difficult. In the late plantings, total production was low. The best planting period is usually from the middle of April to the middle of May.

Results from tests made at Meridian, Miss., to show the influence of planting date on time required to reach the dough stage of maturity were as follows:

Date of planting:	*Time to maturity (Days)*
April 1	126
May 1	117
June 1	106

Late plantings grow more rapidly than early plantings. However, sweet sorghum must be planted early enough to mature before the first killing frost.

The late-maturing varieties usually produce the highest yields of sirup per acre. However, even under the best planting conditions the late-maturing varieties take longer to develop than early varieties. The late-maturing varieties can be grown only in localities where the plants reach maturity by harvesttime.

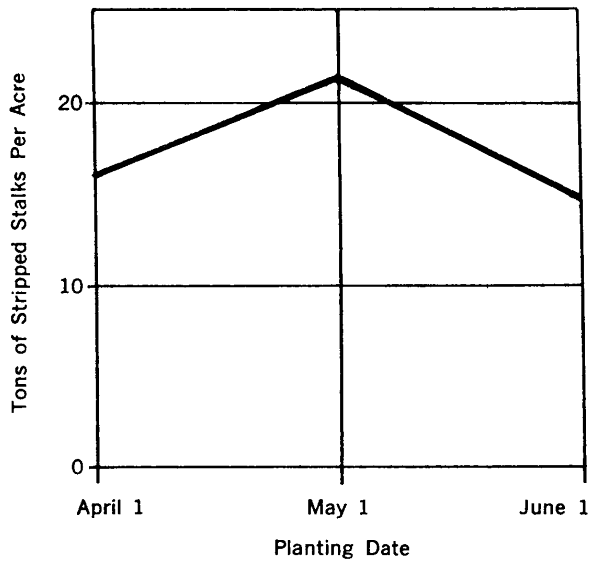

FIGURE 20.—Yields from date-of-planting tests of sweet sorghum at Meridian, Miss., 1968–70.

In the major sirup-producing areas the planting period may extend from the middle of April to about the middle of May. The planting period may be limited in the northern part of the sweet sorghum belt to a 10- to 15-day period near the middle of May. Otherwise, the plants may not mature before the first killing frost.

Planting Methods

Planting is one of the most important cultural operations in sweet sorghum production. A uniform, adequate stand influences the yield obtained and the amount of work required to control weeds. The seed should be covered with about 1½ inches of sandy soils and about 1 inch of the heavier soils. The soil should be firmly packed around the seed. Many dependable planters are available that drop the seed regularly either in hills or in drills. These planters are also equipped with a split, concave wheel for covering and packing the soil around the seed. Hill plantings of two stalks every 16 inches and four stalks every 24 inches have produced yields equal to those of drill plantings where one stalk is left every 6 to 8 inches in the row. Tables 4 and 5 show results from hill plantings in Mississippi. Hill plantings require less seed for planting and less labor for thinning, cultivating, and harvesting than drill plantings require. Seed planted in hills emerge better in crusted or compacted soils (fig. 21) than seed planted in drills. Sweet sorghum seed germinate within 3 to 5 days under optimum moisture and temperature conditions.

TABLE 4.—*Effects of spacing on the yield of Tracy sweet sorghum at Meridian, Miss.*

Method of planting	Spacing	Stripped stalks per acre	Lodging
Plants/hill	*Inches*	*Tons*	*Percent*
Drill:			
1	8	12.4	3.4
Hill:			
2	16	11.9	2.4
3	24	11.2	1.9
4	24	11.9	1.8
L.S.D. at 5-percent level		.4	
L.S.D. at 1-percent level		.5	

Row Spacing

Most sweet sorghum is planted in rows that are spaced about 42 inches apart on low ridges or on

FIGURE 21.—Hill-planted sweet sorghum plants emerging in crusted soil.

TABLE 5.—*Effects of spacing on the yield of Wiley sweet sorghum at Meridian, State College, and Holly Springs, Miss.*

Method of planting	Spacing	Stripped stalks per acre	Stalk weight	Lodging	Sirup per ton of stalks	Sirup per acre
Plants/hill	*Inches*	*Tons*	*Pounds*	*Percent*	*Gallons*	*Gallons*
Drill:						
1	1	16. 3	0. 5	11	17. 9	300
1	3	16. 6	1. 0	9	18. 4	310
1	6	15. 8	1. 4	4	18. 9	301
1	9	15. 0	1. 7	4	18. 6	282
1	12	14. 6	1. 9	3	18. 4	271
Hill:						
3	24	15. 4	1. 8	2	19. 1	295
L.S.D. at 5-percent level.	--------	1. 0	---------------		NS	25
L.S.D. at 1-percent level.	--------	1. 3	-----------------------			NS

practically level land. Planting sweet sorghum in rows 4 to 6 feet apart results in decreased yields.

The data in table 6 show typical yields from different row spacings (*19*). Most of the equipment on farms in the sweet sorghum sirup area is not designed for cultivating rows spaced 2 feet apart. The relatively small advantage of using such narrow rows usually does not justify the extra total expenditure that is involved in redesigning the equipment. Rows spaced about 42 inches apart are satisfactory for sweet sorghum production in the sirup area.

Cultivation

Cultivation should start when the plants are 3 to 4 inches high. Early cultivation can be performed successfully with horse-drawn or tractor cultivators equipped with spring teeth, small plows, or small disks. These critical, early, shallow cultivations control the young weed growth and furnish a mulch around the plants. Depth of cultivation depends largely on the root spread; it should destroy weeds but not prune the root system excessively. Early cultivations may be somewhat deeper than later ones because root development in the early stages is not extensive. The early cultivations may be deeper in the middles than next to the plants; moderately deep cultivation may often be continued there without causing injury until the crop is ready to lay by.

The cultivation may be level or the rows may be ridged (fig. 22). Ridges reduce soil erosion, facilitate drainage, and anchor the stalks against lodging.

Time of planting, variety of sweet sorghum, type of weed infestation, and climatic conditions influence the number of cultivations. Because late plantings grow rapidly, fewer cultivations are needed for them than for early plantings. Early-

TABLE 6.—*Results from a typical row-spacing test at Meridian, Miss.*

Row spacing (feet)[1]	Weight of stalks		Sirup per ton of stalks	Sirup per acre
	Per acre	Per stalk		
	Tons	*Pounds*	*Gallons*	*Gallons*
2	19. 6	1. 2	18. 3	359
3	18. 2	1. 5	19. 0	436
4	12. 2	1. 4	19. 5	238
5	11. 9	1. 4	19. 1	227

[1] The plants were spaced 8 inches apart in the drill.

FIGURE 22.—Ridged sweet sorghum during lay-by cultivation.

maturing varieties grow faster early in the season than late-maturing ones, shade the soil sooner, and usually require fewer cultivations. Perennial weeds such as johnsongrass and bermudagrass, *Cynodon dactylon* (L.) Pers., and fast-growing, vigorous annual weeds may necessitate more cultivations.

Hoeing and Thinning

Planting six to eight good seed in hills 24 inches apart and early cultivation will usually eliminate the need for hoeing and thinning (spacing). However, if hoeing is required to remove weeds and space plants properly in drills, the ground may be hoed when the plants are about 3 inches tall. Whether the ground is hoed immediately before or immediately after the first cultivation depends largely on the weed infestation. When the weed infestation is heavy, hoeing is usually easier and cheaper after the first cultivation. Plants should always be thinned before tillers are put forth; the earlier the plants are thinned, the better.

The plants in single drills should be spaced 6 to 8 inches apart at the time of first hoeing (*5*). Four plants can be left in hills spaced 24 inches apart when the plants are about 3 inches tall (fig. 23).

Close spacing of the plants results in small, weak stalks that lodge readily, have small heads and irregular maturity, or fail to mature under adverse growing conditions (figs. 24 and 25). The amount of leafy material on close-spaced plants (1 inch) is much greater than on plants spaced 6 to 8 inches apart.

Varieties differ in their ability to compensate for wide spacing or gaps in a drill. With most varieties the yield of sirup per acre decreases when single plants are spaced more than 9 inches apart. This reduction in yield is due to a decrease in the population of stalks per acre even though the size of individual stalks is usually larger.

Chemical Weed Control

A preemergence treatment with 2-chloro-4,6-bis(isopropylamino)-*s*-triazine (propazine) at the broadcast rate of 2.0 to 3.2 pounds per acre (active ingredient) will control many species of small-seed annual weeds in sweet sorghum without injury to the crop in most situations. On light soils, rates of 2 to 2.5 pounds per acre control these weeds adequately, whereas higher rates would be likely to injure the crop severely. Residues from such treatments with propazine may injure susceptible crops unless their planting is delayed for at least 18 months after applying the propazine (*16*). The county agent or nearest agricultural experiment station can usually provide current information on weed control.

Harvesting

Changes in the composition of the juice and soundness of the stalks as the crop matures influence the quantity and quality of the sirup. It is

FIGURE 23.—Stand of sweet sorghum in which 4 plants were left in hills 24 inches apart.

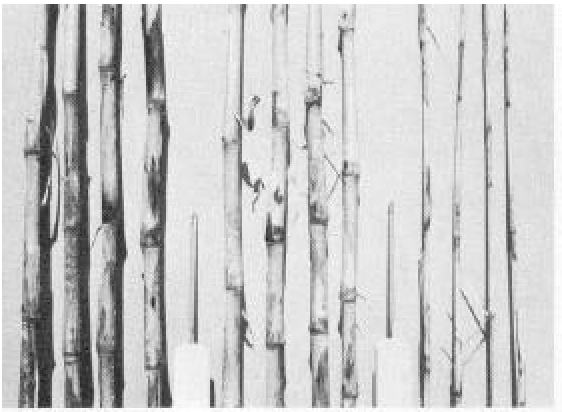

FIGURE 24.—Stripped stalks of sweet sorghum spaced: *Left to right*, 3 plants in hills 24 inches apart; plants 6 inches apart in drills; plants 1 inch apart in drills.

essential that the grower be skilled in judging the right time for harvesting.

After the stalks reach their full size, maturity of the entire plant advances at about the same rate as maturity of the seed head. The plants are generally considered mature when the seed are hard (ripe). However, this is only an approximate method of determining maturity of the plant. Difference in maturity of the stalks as shown by the seed heads depend on varieties and on climatic conditions from one year to another.

Descriptions of the stages of maturity of the seed are as follows:

Early-flowering	Flowers open 2 inches down from the top of the seed head (panicle).
Flowering	Flowers open three-fourths of the distance down from the top of the seed head.
Late-flowering	All flowers on the seed head open.
Early-milk	Contents of the seed a thin, milky liquid.
Late-milk	Contents of the seed a thick, milky semisolid. This stage is often described as late-milk to early-dough.
Dough	Contents of the seed of the consistency of soft dough.
Hard-dough	Contents of the seed firm, pliable, and easily cut with thumbnail.
Ripe	Seed firm and hard and cannot be cut with thumbnail.

When suitable facilities are available, the most accurate way to determine the time for harvesting is to run adequate mill and laboratory tests to evaluate the yield and quality of sirup. The best product is usually obtained if the sweet sorghum is harvested sometime before the ripe stage.

The effect of time of harvesting sweet sorghum at different stages of maturity on yield of sirup is shown in table 7. The data indicate a progressive increase in the sugar content of the juice and the yield of sirup per ton of stalks from the early-flowering through the ripe stage. Harvesting should therefore be delayed until the seed reach the dough stage, provided other factors permit the manufacturing of a good-quality sirup. Delaying the harvesting operations after the seed have reached the dough stage is not usually profitable in the southern part of the sweet sorghum area.

Some varieties such as Sart and Tracy that produce a good-quality sirup when harvested in the dough stage often produce a poor-quality sirup when harvested at a later stage. Varieties that are particularly susceptible to diseases may produce a good-quality sirup, though in a smaller quantity, in the late-milk stage; if harvesting were delayed, the stalks might be almost worthless.

Harvesting methods vary considerably throughout the sweet sorghum sirup area, depending largely on the acreage involved and on local customs. If leaves are customarily stripped from the stalks, they should be stripped while the stalks are standing. Leaves can be stripped with a paddle, a

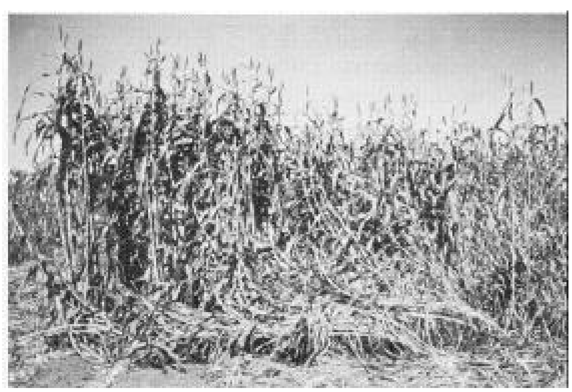

FIGURE 25.—Effect of spacing of sweet sorghum plants on lodging. Plants at right spaced 1 inch apart in drills; plants at left placed 3 plants in hills 24 inches apart.

TABLE 7.—*Results from 4 time-of-harvesting tests of sweet sorghum at Meridian, Miss.*[1]

Stages of maturity	Weight per stalk	Juice analyses				Sirup per ton of stalks
		Extraction	Brix	Sucrose	Purity	
	Pounds	*Percent*	*Degrees*	*Percent*	*Percent*	*Gallons*
Early-flowering	1. 45	57. 3	11. 23	4. 70	41. 9	12. 7
Flowering	1. 43	57. 8	12. 07	5. 64	46. 7	13. 8
Late-flowering	1. 39	58. 0	13. 14	6. 92	52. 7	15. 0
Early-milk	1. 45	58. 5	14. 73	8. 86	60. 1	17. 0
Late-milk	1. 40	57. 5	15. 20	9. 57	63. 0	17. 3
Dough	1. 39	57. 9	15. 76	10. 28	65. 2	17. 8
Hard-dough	1. 30	56. 8	16. 34	10. 94	67. 0	18. 3
Ripe	1. 41	56. 2	16. 54	11. 29	68. 3	18. 4
Post-ripe 1 week	1. 34	55. 7	15. 79	10. 64	67. 4	17. 4
Post-ripe 2 weeks	1. 26	56. 1	15. 18	10. 11	66. 6	16. 8
Post-ripe 3 weeks	1. 24	54. 4	14. 65	9. 32	63. 6	15. 8

[1] Each figure is the average of 100 observations.

cane stripper, or the knife used to cut the stalks, or they may be pulled off by hand. Leaf sheaths usually are left on the stalks. All side branches should be removed from the stalks. The top internode, or peduncle, contains less sugar than the rest of the stalk and should be removed with the seed head.

Sweet sorghum for sirup production can be harvested by hand or machinery (fig. 26). A cane knife, corn knife, or hoe can be used for hand cutting. Corn binders are adequate for harvesting even though hand labor is needed to load the bundles of stalks onto trailers or trucks. The stalks can be topped by hand or machine before milling. Some growers have modified silage harvesters to cut stalks into 4- to 8-inch-long sections (*2*). Stalk sections and leaves are separated by air while the cut sections are being conveyed to a trailer body. Leaf removal or stripping is very effective by this harvesting method (fig. 27).

Because most sweet sorghum sirup is manufactured on small-scale equipment, stalks must sometimes remain in the field or at the mill for several days before they are milled. This practice does not cause a loss of sirup if the stalks are in good condition at the time of harvest, if they are stored not longer than 7 to 10 days, and if they are not subjected to freezing temperatures.

Some farmers shock the sweet sorghum stalks in the field or at the mill during the storage period, either with or without the leaves. If the leaves are not removed before milling, the quality of sirup may be decreased during rainy periods (*8*).

Many farmers save seed for planting the next crop or for sale to other farmers. This is a good practice if (1) the seed have reached the hard-dough stage of maturity at the time of harvest, (2) the field is sufficiently isolated to prevent mix-

FIGURE 26.—Machine harvesting (cutting) sweet sorghum.

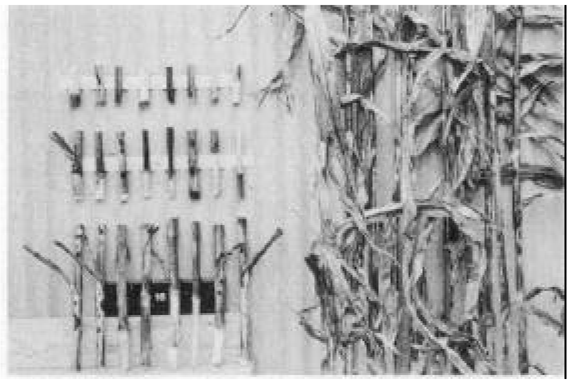

FIGURE 27.—*Left, top to bottom,* Effect of stalk chopping on stripping 4-, 8-, and 16-inch sections; *right,* whole stalks of sweet sorghum.

ing with other varieties, (3) the seed have not been damaged by insects or freezing temperatures, and (4) suitable facilities are available for drying the seed.

The seed may be dried by (1) spreading the seed heads thinly on a floor where there is good aeration or on an almost flat roof during dry weather, (2) tying the seed heads in bunches or placing them loosely in burlap sacks and hanging them in a sunny or airy place, or (3) subjecting the seed heads to artificial heat in a drier. The last method is usually the surest and quickest way of adequately drying the seed. A good procedure dries not only the seed but also the peduncles and branches of the seed heads in a relatively short time.

When the seed heads are dry, the seed should be threshed immediately either by hand or with a suitable thresher. After threshing, the seed should be thoroughly cleaned and cured by proper aeration or in a drier. They should be placed in tight containers and treated chemically to prevent insect damage during the winter months. (See "Insects Injurious to Stored Seed," p. 18.)

MANUFACTURE OF SWEET SORGHUM SIRUP

The yield and quality of sorghum sirup are influenced by the equipment and process used in manufacture and by the skill of the sirup maker. Examples of methods successfully used by many farmers for small-scale manufacture of sorghum sirup are briefly described here. Large commercial sirup manufacturers, however, usually employ other types of continuous-processing operations, including enzymatic treatments, to assure high-quality products.

Several types of mills have been used in the past, but since 1950 the small upright three-roller mill propelled by animal power usually has been replaced by the larger mill consisting of three horizontal rollers propelled by motor power (fig. 28). The extraction of juice should be between 50 and 60 percent; that is, 100 pounds of stalks should furnish 50 to 60 pounds of juice. Extracting less juice results in less sirup. More juice may be extracted in a good mill if such a procedure does not lower the quality of the sirup.

Most farmers make sirup on continuous-type, galvanized-iron, or copper evaporators (fig. 29). These evaporators are shallow and have crosswise baffles. One big advantage of the continuous-type evaporators is that a steady stream of cold or preheated juice enters the cooler end of the pan and then flows slowly to the opposite end, where it is drawn off as finished sirup.

The Stubbs pan is another continuous type of evaporator. It is not used so widely as evaporators with baffles, but it requires somewhat less skill for efficient operation. The model shown in figure 30 is 12 feet long, 3 feet 6 inches wide, and 10 inches deep. The juice side is 1 foot 3 inches wide; the other side is 2 feet 3 inches wide. Juice enters the cool end and travels lengthwise along the high, longitudinal partition, around the end of this par-

FIGURE 28.—Grinding sweet sorghum at sirup mill at Booneville, Miss.

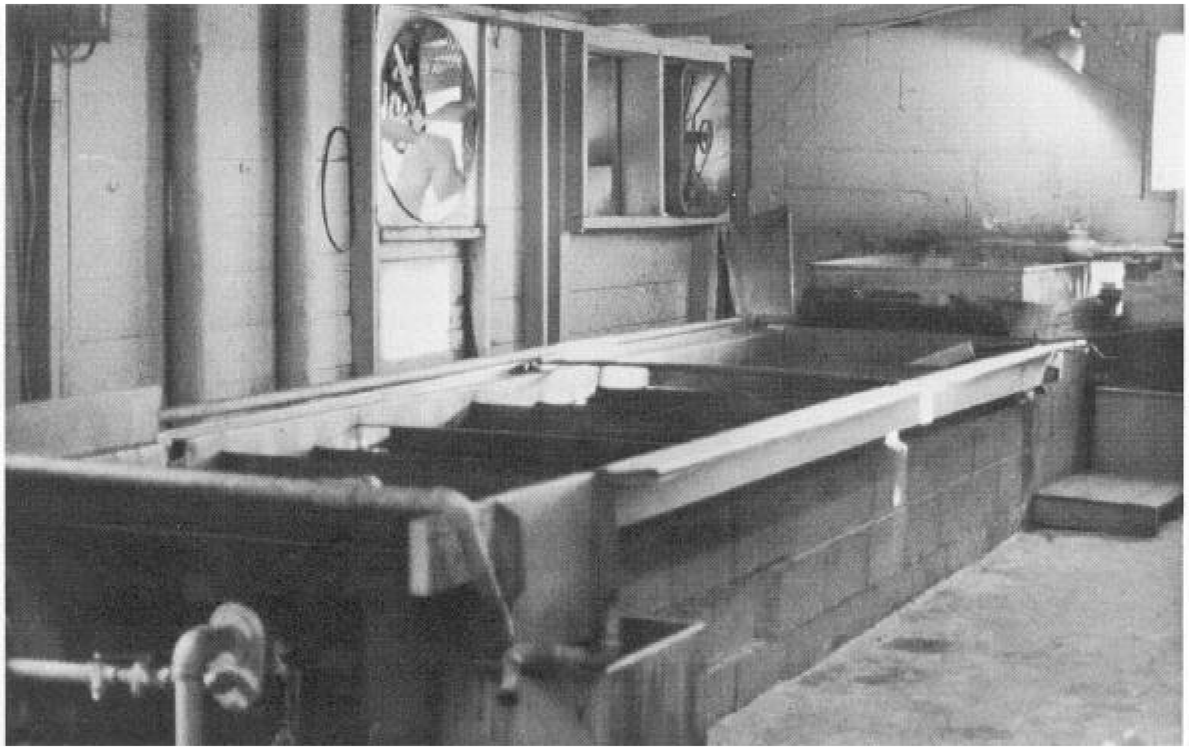

FIGURE 29.—Continuous-flow type evaporator at Boaz, Ala.

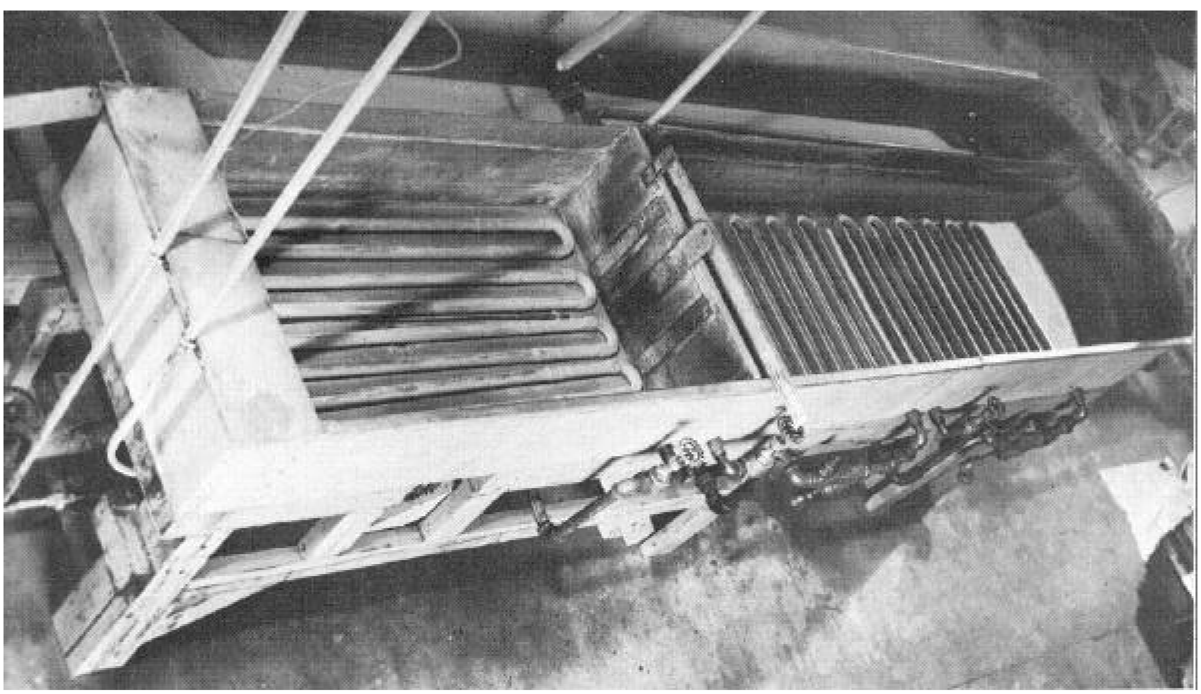

FIGURE 30.—Stubb-type evaporator.

tition, and back up to the finishing-off compartment.

Fuels used for heating the evaporators include wood, oil (kerosene or fuel oil), liquid petroleum gas, and coal. In small-scale operations, the fire heats the bottom of the evaporator. In some large-scale operations, steam coils placed in the evaporator heat the juice.

The juice is heat clarified in the evaporator. When the cold juice is heated, certain proteins and nonsugar substances are coagulated. This coagulated material, called skimmings, rises to the surface and is removed.

After clarification, the juice is evaporated to sirup density as rapidly as possible. The desired sirup density can be determined by a sirup hydrometer or a thermometer. A suitable thermometer is preferred because it provides an accurate and continuous indication of the sirup density. When sirup is tested near the boiling temperature, the reading for sirup of good density should be 35° to 36° Baumé with the sirup hydrometer. The boiling temperature should be 226° to 230° F. or 108° to 110° C. with a good thermometer.

The finished sirup should be filtered as efficiently as possible, cooled to the proper temperature, and stored in containers. The temperature of the sirup should be 190° F. for filling one-half-gallon and smaller containers, 180° F. for 1-gallon containers, and 120° F. for barrels.

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