SWEETPOTATO CULTURE AND DISEASES

Agriculture Handbook No. 388

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

Some of the information given in this handbook is similar to that formerly contained in U.S. Department of Agriculture Farmers' Bulletin 2020, "Commercial Growing and Harvesting of Sweetpotatoes," and in Farmers' Bulletin 1059, "Sweetpotato Diseases." Both of these reports are now out of print.

PRECAUTION

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary landfill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Department of Agriculture, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

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SWEETPOTATO CULTURE AND DISEASES

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Part I: CULTURE

INTRODUCTION

The sweetpotato (*Ipomoea batatas* (L.) Lam.) has been used as human food for many centuries. However, early peoples of Africa, Asia, Australia, and Europe apparently did not use, or know of, the sweetpotato, and there is no available evidence that this plant was known to the ancient Arabs, Chinese, Egyptians, Greeks, Hebrews, Indians, or Romans. Primitive peoples in tropical areas of Central and South America, as well as in numerous tropical islands in the Pacific, were using this plant long before first written historical records came into existence. In spite of the more or less restricted areas of the world in which the sweetpotato was known in early times, the subsequent spread of the plant throughout other areas of the world has been very extensive. This crop plant has been referred to under numerous names. Some of these synonyms are listed in the Appendix of this handbook.

It is not possible to accurately determine in just what part of the world the sweetpotato originated. Some authorities believe it evolved in tropical America; others believe it evolved somewhere in the tropical South Pacific Islands. The evidence appears to favor American origin, however, because a considerable number of other closely related wild plant species belonging to the same botanical genus (*Ipomoea*) as the sweetpotato are native to the American tropics and subtropics. Among these other species are believed to be the progenitors of the sweetpotato.

Wherever it originated, the spread of this crop plant to other climatically suitable areas of the world has been very extensive. Today sweetpotatoes are grown in tropical, subtropical, and warmer temperate areas throughout the world. The Food and Agriculture Organization of the United Nations, in Production Yearbooks in 1963 and 1965 estimated the world production and yields of sweetpotatoes and yams from 1960 through 1965 (*4,5*).[1] Sweetpotatoes are of prime importance in the food supplies and economies of many countries. (See Appendix.) Production is especially large in the African, Far Eastern, and Latin American regions; is moderate in the North American region; and is notably smaller in the European, Near Eastern, and Oceanic regions (table 1).

The sweetpotato was used in tropical regions of Central and South America long before the Spanish explorations. Columbus found the natives in the West Indies using it, and he is reported to have presented a sweetpotato to Queen Isabella upon his return to Spain. Other Spanish explorers later found the plant in Mexico and in South America. It probably was not cultivated in what are now the 48 contiguous States of the United States before the time of Columbus. It may have been introduced into this country later through trading among Central and North American Indian tribes. Early American settlers probably obtained sweetpotatoes during trading with the West Indians. The crop was introduced into Virginia sometime before 1560.

Early records give only sketchy, incomplete descriptions of the sweetpotato. Very likely the forms referred to in those early records were notably different from the sweetpotatoes grown commercially in the United States today. Selection and propagation of naturally occurring sports or mutations over the years have resulted in numerous productive forms (varieties) possessing desirable horticultural characteristics. Some early varieties probably arose through selection of naturally occurring hybrids among flowering types. Since 1937, with controlled breeding and selection programs, rapid progress

[1] Italic numbers in parentheses refer to Literature Cited p. 71.

TABLE 1.—*Estimated average annual production and yields of sweetpotatoes and yams in various regions, from 1960 through 1965* [1]

Region	Production area	Yield per acre	Production
	1,000 acres	*Cwt.*	*1,000 cwt.*
Africa	[2] 6,323	[2] 61	[2] 392,040
Far East	4,150	89	367,048
Latin America	1,131	65	74,096
North America	200	81	16,214
Oceania	[3] 49	[4] 67	[4] 3,300
Europe	35	108	3,740
Near East	11	175	1,892

[1] Calculated to acres and hundredweights from metric units shown in Production Yearbook 1963 *(4, table 26)* and Production Yearbook 1965 *(5, table 27)*.
[2] Data for period from 1948 through 1953.
[3] Data for period from 1958 through 1962.
[4] Data for period from 1960 through 1962.

has been made in the United States in developing improved, disease-resistant varieties.

Importance

For many generations the sweetpotato has been an important crop in the United States. Until about the time of World War II, it ranked second only to the Irish potato in importance among vegetable crops. Maximum acreage and production was in 1932 when 47.6 million hundredweight was produced on 1,059,000 acres. Since that time, acreage planted, total production, per capita consumption, and relative importance of sweetpotatoes among vegetable crops have decreased. These changes have occurred in spite of rapid increases in population and substantial increases in yields of sweetpotatoes produced per acre (table 2).

A number of factors have contributed to changes in status of the crop. Increased urbanization of our population and mechanization of our industry and agriculture have reduced the overall average physical labor requirements and the needs for high-calorie foods. As a result of this and of changed dietary concepts, the per capita consumption of all starchy foods, including sweetpotatoes, has declined. The per capita consumption of sweetpotatoes in the United States was approximately 31 pounds in 1920; it had dropped to about 21 pounds by 1940; and it was only 5 to 6 pounds by 1968.

Greatly increased efficiency through progress in mechanization of large farm units has sharply reduced not only the numbers of small farm units but also the size of rural populations, which formerly consumed sizable proportions of the sweetpotatoes produced. In 1940 consumption of sweetpotatoes in homes on farms where the sweetpotatoes were grown was approximately 12 million hundredweight; in 1962 it had declined to less than 2 million hundredweight. Much of this decline has been associ-

TABLE 2.—*Sweetpotato acreage, production, yield, value, and price in the United States in selected years, from 1910 through 1969*

Year	Planted	Production	Yield per harvested acre	Value of crop	Average price per cwt.
	1,000 acres	*1,000 cwt.*	*Cwt.*	*1,000 dollars*	*Dollars*
1910	641	32,966	51	40,216	1.22
1915	731	41,601	57	46,980	1.13
1920	992	57,159	58	117,834	2.04
1925	778	34,372	44	85,554	2.49
1930	670	30,017	45	57,751	2.02
1932	1,059	47,627	45	40,650	.86
1935	944	44,687	47	54,545	1.25
1940	652	28,434	44	44,160	1.59
1945	652	33,692	52	124,306	3.64
1950	499	27,269	56	85,589	2.99
1955	352	21,608	63	72,392	3.27
1960	207	14,858	79	61,358	4.09
1961	201	14,415	79	61,924	4.30
1962	229	17,120	85	61,488	3.54
1963	204	14,356	84	57,835	4.03
1964	187	12,969	86	65,980	5.09
1965	172	15,524	92	65,628	4.21
1966	161	13,697	87	62,399	4.98
1967	149	13,658	93	61,204	4.49
1968	151	13,763	92	66,526	4.90
1969	154	13,958	95	62,342	4.44

ated with the decrease in number of farm family units. According to the U.S. Census, in 1939 about 1,200,000 farms were reported as producing sweetpotatoes. By 1959 the number of such units had decreased to 310,000, and the downward trend still continues.

Relatively less mechanization has occurred with sweetpotatoes than with many other farm crops. The high requirement for hand labor during production and harvesting has put sweetpotatoes in a poor position for the reduced, but increasingly more expensive, available labor supply. Costs of production and harvesting, therefore, remain relatively high and contribute to the comparatively high prices of sweetpotatoes at the retail level. In the highly competitive food market, high prices tend to reduce sales.

Fresh sweetpotatoes have a relatively high perishability rate. They are easily bruised and often injured by storage at low temperatures. Both conditions lead to excessive losses from rots and shrinkage. Distribution personnel sometimes lack the proper appreciation of the necessity of careful handling and temperature control for maintenance of quality. This lack has often resulted in unappealing displays on retail counters and in poor edible qualities of the product. As a consequence, customer purchases of sweetpotatoes have declined. Recent trends toward the preparation and sale of sweetpotatoes in processed forms (canned, frozen, flaked) better adapted to the needs of the modern housewife and toward the attractive prepackaging in consumer-size containers and the retailing of a better graded and sized fresh product have helped to curtail the rate of decline in consumer purchases of sweetpotatoes.

Along with the changes in overall production, consumption, and yields of sweetpotatoes, some significant shifts in production between regions and among States within the several regions have occurred. On the whole, acreage and actual production have increased in the Western States (mostly in California) but have decreased considerably in the three main production regions in the Central States and in South Atlantic and Central Atlantic Coast States. Table 3 shows that during the period from 1934 through 1966 the proportions of the total production for the country increased in the Central Atlantic Coast and Western States but decreased in the Central States and South Atlantic Coast States.

TABLE 3.—*Shifts in proportions of national sweetpotato output originating in leading production areas, from 1934 through 1968*

Production region	Average proportions of national production		
	1934-37	1965-68	Shift
	Percent	*Percent*	*Percent*
Central States[1]	54	52	−2
South Atlantic Coast States[2]	32	23	−9
Central Atlantic Coast States.[3]	12	19	+7
Western States[4]	2	6	+4

[1] Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, Texas.
[2] Florida, Georgia, North Carolina, South Carolina.
[3] Delaware, Maryland, New Jersey, Virginia.
[4] Arizona, California, New Mexico.

Uses

Sweetpotatoes are used primarily for human food, but they may also be used for animal feed, for starch production, and for various other industrial purposes. Of the sweetpotatoes produced each year in the United States, approximately 60 to 70 percent are used as human food. Approximately 5 percent of the crop must be retained for "seed" (plant-producing) purposes. The other 25 to 35 percent of the potatoes are lost through disease or shrinkage either at the farm or during preparation and marketing of the fresh or processed products or are used in small amounts for animal feeding or for industrial purposes.

For Human Food

A large part of the crop is prepared by the housewife from fresh roots, but increasingly larger proportions of the sweetpotatoes consumed in the United States are prepared commercially in various canned, frozen, or dehydrated forms (table 4). In 1965 over 11 million cases (each case equivalent to about 1 bushel of sweetpotatoes) were canned, over 9 million pounds were frozen, and additional large quantities were preserved as various dehydrated products, including the recently developed sweetpotato flakes. Some of the factors in the progressively increasing popularity of processed products with both housewives and institutional users are assurance of products with acceptable levels of quality, convenience in storage, ease of preparation of the processed products, and avoidance of the high rates of spoilage frequently encountered with fresh market sweetpotatoes.

The nutritive value of sweetpotatoes is high. They are good sources of energy-supplying sugars and other carbohydrates; of calcium, iron, and other minerals; and of vitamins, particularly of Vitamin A in the popular high-carotene, orange-flesh varieties and of Vitamin C (tables 5 and 6).

TABLE 4.—*Forms in which sweetpotatoes are processed for food*

Manner of preservation and type of product	Characterization
Canning:	
Sirup packs	Small whole roots, chunks, or mixed types packed and processed in sugar sirups of varying concentrations.
Vacuum packs	Roots, as above, processed under vacuum without addition of sirups.
Solid packs	Mashed stock packed solidly in cans and heat processed.
Purees	Comminuted, strained, precooked stocks, usually unflavored, heat processed.
Baby foods	Specially prepared and blended, heat-processed purees for infant and child feeding. Usually without additives.
Freezing:	
Strips, slices, dices, chunks.	Variously prepared from peeled or unpeeled potatoes, frozen with or without sirups, and with or without cooking or baking.
Mashed, souffle	Stock prepared as for solid-pack canning, but preserved by freezing.
Purees	Pureed product preserved by freezing.
Dehydration:	
Strips, dices	Prepared pieces blanched, dehydrated with heat and vacuum with or without antidarkening treatments.
Flakes	Peeled, preheated stock, sliced, cooked, pureed, double-drum dried, flaked, packaged in low-oxygen atmospheres.
Flours	Stock washed and dehydrated fresh or after cooking, ground and sifted.
"Alayam" and similar specialty products.	Prepared prebaked roots pulped, pureed, other additives incorporated, extruded onto trays, baked in ovens. Used directly as cookies, snacks, or confections; or ground to give "Alamalt" flour for use in ice creams or other products.
Cooking in oil:	
Chips	Prepared raw slices of suitable thickness and shapes immersed in hot cooking oils, drained, salted as desired, packaged in low-oxygen atmospheres.

For Animal Feed

Limited quantities of sweetpotatoes are used as high-carbohydrate feeds for cattle, hogs, poultry, and other domestic animals. Most of these sweetpotatoes are fed raw on farms where they are grown and most are cull or offgrade and offsize roots not suitable for fresh market use. Considerable portions of the cull roots formerly used for animal feed because of their unmarketability as first-grade stock are now being used in preparation of various processed sweetpotato food products. Vines and foliage, as well as storage roots, are usable for animal feed but are not widely used for this purpose. A satisfactory, nutritious silage can be prepared from vines, leaves, and roots. Present methods of silage preparation, however, are not economical.

TABLE 5.—*Proximate composition of edible portion of raw sweetpotatoes* [1]

Component	Percentage
Solids	31.5
Total carbohydrate	27.9
Protein	1.8
Mineral matter (ash)	1.1
Fat	0.7

[1] Calories per pound of peeled tuber—565.

The extent to which sweetpotatoes can be fed raw is restricted by the handling and storage problems resulting from the high water content, bulkiness, and perishability of the sweetpotato. These limitations on use for animal feed can be largely overcome by partly drying or dehydrating the materials before storage. Satisfactory methods have been worked out for sun-drying or artifically dehydrating chopped, shredded, chipped, or macerated sweetpotatoes for feed. However, because of the relatively high costs of growing, harvesting, and handling sweetpotatoes, as compared with costs for corn and other high-carbohydrate feed crops, the production and dehydration primarily for animal feed probably will remain economically unfeasible in most of the United States. Dehydration for animal feed will be feasible only in locations in the South favored with long growing seasons and abundant sources of cheap fuel, and for growers who are able to produce raw stock at lowest possible costs and who are located reasonably close to available dehydrating facilities. Maximum mechanization of all production and handling operations will be necessary to keep costs of raw stock for feed dehydration at economically workable levels. One limited source of dehydrated feed is the byproduct obtained by dehydrating culls and trimmings from canning, freezing, or other processing operations.

For Starch Production or Other Industrial Purposes

Starch can be manufactured from white- or very light-flesh sweetpotato varieties but at present (1970) there is no commercial production of sweetpotato starch in the United States.

TABLE 6.—*Nutritive value of sweetpotatoes prepared in various ways*

Nutrient	Nature and size of prepared sweetpotato			
	Baked, peeled after baking 1 medium about 6 ounces (5 by 2 inches) 110 grams	Baked, peeled after boiling 1 medium about 6 ounces (5 by 2 inches) 147 grams	Candied, 1 (3½ by 2¼ inches) 175 grams	Canned, vacuum or solid pack 1 cup 218 grams
Food energy ______cal.______	155.0	170.0	295.0	235.0
Protein ___________g.______	2	2	2	4
Fat _____________g.______	1	1	6	Trace
Carbohydrates ____g.______	36	39	60	54
Calcium __________mg.______	44	47	65	54
Iron _____________mg.______	1	1	1.6	1.7
Vitamins:				
A ______________I.U.______	8,970	11,610	11,030	17,110
Thiamin ________mg.______	.10	.13	.10	.12
Riboflavin ______mg.______	.07	.09	.08	.09
Niacin _________mg.______	.7	.9	.8	1.1
C ______________mg.______	24	25	17	30

SOURCE: Nutritive Value of Foods *(19)*.

In the late 1930's and early 1940's interest was aroused in the South in the possibilities of developing a commercial sweetpotato starch industry. Federal and State agencies successfully solved the technical aspects of starch manufacture from this crop, and plant breeders developed productive varieties with high starch contents. In small-scale commercial trials sweetpotato starch proved quite suitable for use in certain adhesives, in bakery products, in textile sizings, in cosmetic manufacture, and in laundry products. However, the costs of producing raw stock remained so high that farmers could not grow and handle the crop at prices the extraction plants could afford to pay, and starch production on a commercial basis failed to materialize. Other crops, such as waxy corn and waxy sorghum, contain starches similar to those of the sweetpotato, and they can be grown for starch production and handled by mechanized methods far more cheaply than sweetpotatoes. Also, seeds of grain crops are more easily handled and stored for prolonged periods than are sweetpotatoes.

In some countries, Japan, for example, sweetpotatoes are the basic stock used in the fermentation industry to produce industrial alcohol and associated byproducts. Such use has not been promoted in the United States where such products can be obtained more economically from other sources.

Botany

The sweetpotato (*Ipomoea batatas* (L.) Lam.) is placed by taxonomists in the botanical family Convolvulaceae, which includes various morning-glories, bindweeds, dodders, and several hundred other species found widely distributed throughout the world. It is a perennial in its growth habit but in crop practice it is treated as an annual.

The sweetpotato is an herbaceous plant with stems that vary greatly in thickness, length, spacing of nodes, and general growth habit. Forms that have more or less twining and trailing, long stems of slender to moderate thickness and moderately to widely spaced leaves are most prevalent. It is not uncommon, however, to find sweetpotato types with relatively short, thick stems and short internodes, semierect to erect growth habits, and little or no tendency to twine. Stem fasciation is sometimes observed and this condition is characteristically more prevalent in certain varieties and selections than in others.

Leaves in the sweetpotato are alternately and spirally spaced along the stems in a pattern known as 2/5 phyllotaxy; that is, for two leaves to be located in the same vertical (longitudinal) plane on the stem, five leaves will be so spaced that the stem will be spirally encircled twice in order for the fifth leaf to lie directly above or below the first. The spiralling direction may be either clockwise or counterclockwise. There are no stipules at the junction of leaf petioles with stems. Leaf shapes and sizes in *I. batatas* vary widely. In outline, leaves may be shouldered, toothed, entire, deeply cleft (parted), variously lobed or fingered, or sagittate (fig. 1). Petioles also vary in length, thickness, and degrees of erectness.

Colors and pigmentation patterns in leaves, stems, and petioles of sweetpotatoes range widely and these are useful characteristics for identifying particular varieties and selections.

Flowers of this plant have a form and appearance very similar to that of the ornamental morning-glories (fig. 2). They are axillary and borne either singly or in cymes on short peduncles. The corolla is funnel shaped, about 1½ to 2 inches long and 1 to 1½ inches wide at the mouth, made up of five fused petals, and colored various shades of lavender to light purple. The stamens, typically five in number, are attached to the base of the corolla. The calyx is persistent, and made up of five greenish imbricated sepals about one-half inch long. The ovary is superior, bicarpellate, two to four celled and four ovuled. One to four slightly flattened or somewhat angular brown to black seeds are borne in the capsulate fruit. Seedcoats become very hard when seed is fully matured and dried,

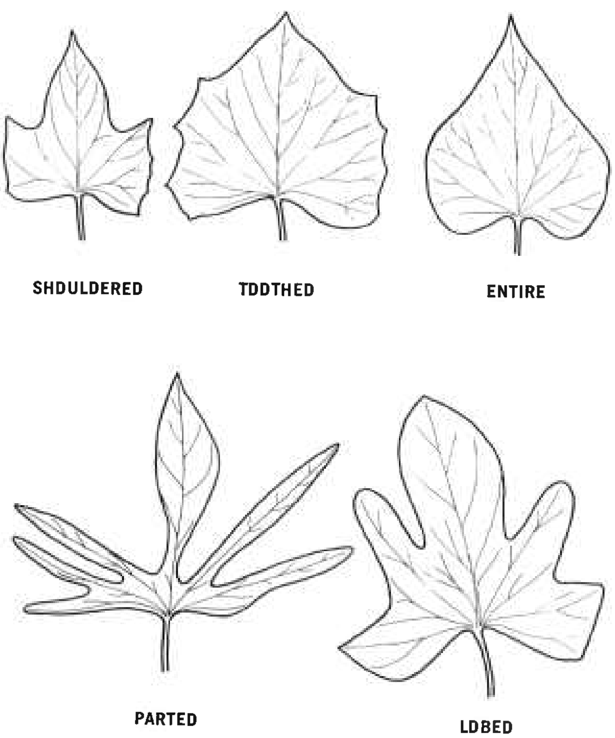

FIGURE 1.—Some leaf shapes found in sweetpotatoes.

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FIGURE 2.—Flowering sweetpotato plant growing in a greenhouse.

necessitating some form of scarification to insure prompt seed germination. Both colors and sizes of flowers and flower parts and seeds vary somewhat among sweetpotato varieties and selections.

The feeding root system of the sweetpotato is more or less fibrous and is relatively extensive both in depth and in lateral spread. The edible sweetpotato is variously referred to as a "root," a "root-tuber," or a "tuber." Although a few earlier investigators considered this organ to be a true tuber, that is, a thickened, modified underground stem, more recent careful anatomical studies of the developing young sweetpotato have proved conclusively that this is a fleshy thickened root. The fleshy thickening occurs principally through the activity of a primary cambium located in a more or less continuous peripheral vascular ring, and through that of secondary and tertiary cambiums located in numerous vascular strands embedded within the extensive central core of thin-walled storage parenchyma tissue.

In the very young sweetpotato storage root the outermost protective layer is a single-cell-deep epidermis. This is soon replaced by a periderm layer composed of relatively large, thin-walled cells. The outer cells in this layer become partly lignified and are progressively sloughed off as the root grows and expands. A phellogen (cork cambium) forms news cells to replace those lost in the sloughing process. This outer periderm layer with its regenerative cambium is very important to the handling and storage physiology of sweetpotatoes. Postharvest regulation of factors that favor proper development of this layer and adjacent tissues developed at sites of surface wounds is essential to the successful handling, storage, and marketing of sweetpotatoes.

In the more mature sweetpotato storage root, the protective periderm layer is underlain by a cortical layer composed of large starch-filled parenchyma cells among which are dispersed phloem conductive elements—sieve tubes and their so-called companion cells. Adjacent to some of the sieve tubes are latex vessels that contain the white, viscid latex fluid. Below this cortical layer and external to the more or less continuous peripheral secondary xylem ring, lies the main cambium from which both the adjacent cortex and xylem ring arise. Beneath the xylem ring lies the large central, parenchymatous-celled storage area, with its embedded vascular strands, which constitutes the main bulk of the fleshy sweetpotato.

Both skin and flesh colors vary widely in the fleshy sweetpotato root. Skin colors may range from almost pure white through cream colored, yellow, orange, pink, red, to very dark purple. Flesh colors may be white or various shades of cream, yellow, salmon, or orange, depending largely on the amounts and proportions of various carotenoid pigments present. The flesh may also contain red or purple anthocyanin or other pigments, which can impart an undesirable greyish appearance to the cooked sweetpotato. In the United States, types having roots with any appreciable amounts of purple pigmentation in the flesh are looked on with disfavor. In some countries, however, types with such purple pigmented flesh are actually preferred.

VARIETIES

Many varieties of sweetpotatoes have been grown in the United States but only a few have been important commercially. Productiveness, appearance, and acceptable edible qualities were usually the main bases for selection of most of the older varieties. With the advances in mechanization, specialization in production, processing, handling, and marketing operations and with the increased competition between this crop and others, numerous other characteristics have become essential for acceptability in good commercial varieties. These additional characteristics include such attributes as uniformity of root size, shape, and flesh color, nutritional properties, processing characteristics, storage and reproductive capacities, and resistance to serious diseases.

Of some 40 distinct varieties of sweetpotatoes grown commercially in the United States in about 1920 only two or three, or selected strains of those two or three, furnish an appreciable part of the current sweetpotato supply. A number of improved varieties developed in recent years in breeding and improvement programs now make up the major portion of the commercial crop (table 7).

Varietal Types

Sweetpotato varieties can be classified into two types, according to their principal uses—(1) **food types** and (2) **feed or industrial types.**

In practice many varieties are used for both fresh market and processing. The forms in which they are used are often determined largely by the economics of supply and demand and by the comparative prices being offered for the fresh stock.

Food type varieties, particularly those for fresh market use, are often designated as "dry-flesh" or "moist-flesh" according to the feel sensation experienced in the mouth during mastication of the cooked or baked sweetpotatoes. The terms dry-flesh and moist-flesh do *NOT* refer to the percentages or proportions of water in the roots of the two types. Studies have shown that the moisture content of freshly harvested roots of a dry-flesh variety such as Big Stem Jersey is often higher than that of roots of a moist-flesh variety such as Porto Rico produced under the same conditions. It is the difference in the character of the solids in the cooked roots of the two types rather than the difference in actual moisture contents that causes the dissimilarity in the feel sensation in the mouth. Varieties that tend to convert most of their starch to sugars and dextrines during cooking become quite sweet and soft and are referred to in the trade as moist-flesh or "yam" types; those that tend to convert the starch less completely are usually not as sweet as these moist-flesh types, are firmer, and are referred to as dry-flesh. Many varieties are intermediate with respect to these classes.

TABLE 7.—*Acreage and production of principal food-type sweetpotato varieties grown commercially in the United States, 1965*

Variety	Acreage		Production	
	Acres	Percentage of U.S. total	1,000 cwt.	Percentage of U.S. total
Allgold	2,125	1.1	187	1.0
Carogold	300	0.1–	22	0.1–
Centennial	96,615	48.9	9,148	49.4
Coastal Sweet	300	0.1–	30	0.1
Earlysweet	2,000	1.0	200	1.1
Gem	460	0.2	75	0.4
Georgia Red	10,600	5.4	1,463	7.9
Goldrush	26,090	13.2	1,813	9.8
"Jerseys"[1]	8,470	4.3	643	3.5
Julian	800	0.4	95	0.5
Kandee	3,050	1.5	250	1.4
Lakan	920	0.5	86	0.5
Nancy Hall	100	0.1–	10	0.1–
Nemagold	16,950	8.6	2,103	11.4
Nugget	3,280	1.7	401	2.2
Oklamar	1,340	0.7	129	0.7
Porto Ricos[2]	10,475	5.3	665	3.6
Redgold	800	0.4	54	0.3
Sunnyside	1,180	0.6	127	0.7
Tanhoma	1,000	0.1–	87	0.5
Velvet	4,710	2.4	447	2.4
Virginian	300	0.1–	30	0.1
Total—varieties listed.	191,865	96.7	18,065	97.7
U.S. total—all varieties.	197,700	100	18,502	100

[1] "Jerseys" includes Jersey Orange, Orange Little Stem, Orlis, Maryland Golden, Big Stem Jersey, Little Stem (Yellow) Jersey, and Red Jersey.

[2] Porto Ricos includes both vining and bunch types.

The term "yam" is commonly used by the trade for sweetpotatoes of the moist-flesh type but strictly speaking this terminology is incorrect since a true edible yam is an entirely different plant from the sweetpotato. The true yam is grown in the Continental United States on only a limited scale in Florida.

In the United States attractiveness of skin and flesh colors, uniformity of root shapes, pleasing flavor and texture of flesh, high vitamin and nutritional values, and productiveness, all are important attributes in food type sweetpotatoes. High yielding capacities, high percent solids and carbohydrates, including high starch content and recovery, and superior propagative and storage properties are important attributes in varieties intended primarily for feed or industrial uses.

Certain very light-colored, relatively starchy varieties such as Triumph and Hayman (Southern Queen) are sometimes used as early market food types. In some countries, particularly where maximum production of solids and carbohydrates is essential in the food economy, the light-flesh varieties are actually preferred for food over the orange- or deep-yellow-flesh varieties, high in vitamin content and generally preferred in the United States. On the other hand, the deep-yellow-flesh varieties can be used for production of high-quality feeds or for industrial use where economic factors permit. As an example, highly nutritious, high vitamin content, dehydrated sweetpotato meal for feed is sometimes produced as a byproduct from culls and trimmings in the canning and processing operations.

Varietal Improvement

New varieties of sweetpotatoes may originate either by chance genetic mutation or by breeding. Vegetative propagation of desirable genetic mutants has been practiced for many years. In recent years seedlings originating by pollinating flowering types in breeding programs have provided greater varietal improvement than is possible through selecting mutant forms.

Mutations of various kinds occur frequently in the sweetpotato. Changes may be desirable or undesirable and may involve various characteristics such as skin or flesh colors, general growth habits, shape of roots, or even productivity factors. Just why these sudden and sometimes relatively large deviations or changes in type occur in certain individuals of a plant population is not adequately understood. Whatever the cause(s), the changes involve heritable alterations in the nuclear makeup of the plant cells.

Either through chance observation or by conscious search over the years, many naturally occurring, desirable, mutant forms have been collected, propagated, tested, and grown as new varieties. The opportunities for subsequent improvement of forms originating through mutations are limited. Propagation of such forms by vegetative means involves thousands of somatic or vegetative divisions of plant cells, each normally identical in its genetic constitution with the cell from which it arose and therefore ultimately identical with the first mutated or changed cell that started the new mutant form. Thus, each vegetatively propagated plant of a clone or variety is made up of many thousands of cells all having identical heritable genes. The only opportunity for further improvement depends on the rare, fortuitous occurrence and detection of possible subsequent *favorable* alterations in the genic makeup of propagatable plant cells.

Greater opportunities for varietal improvement than are provided through mutations are offered through the sexual method in which new combinations of desirable characteristics are obtained by hybridization or crossing of parent stocks that possess known heritable characteristics and properties. Flowering of parent stocks, either naturally or by induced conditions, is essential to use of this method. Sweetpotatoes may flower rather readily under field conditions in tropical and subtropical habitats but flowering is usually sparse and virtually absent in many varieties and selections in the temperate areas of the United States. Several techniques have been found effective for inducing flowering. These include grafting on rootstocks of other related species, girdling of stems, treating with certain chemicals, adjusting the photoperiod, and regulating temperatures and nutritional conditions. Through the use of one or more of these techniques, nearly all sweetpotato clones used in breeding programs have flowered and set seed.

An active sweetpotato breeding program was initiated at the Louisiana Agricultural Experiment Station in 1937. Subsequently, additional breeding programs were undertaken by State experiment stations in California, Georgia, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, and Virginia, and by the United States Department of Agriculture at Beltsville, Md., and at Meridian, Miss. Many thousands of seedlings have been produced and evaluated through the cooperative efforts of these and other experiment stations. After thorough testing and evaluation, the best of the selections are named and released to the trade as new varieties. Among the many characters observed are plant type and growth characteristics such as yields, earliness, root set, placement, shape, uniformity, skin and flesh colors, and sprout-producing properties; edibility and nutritive values (including vitamin contents); solids and carbohydrate composition; reaction to important diseases, nematodes, and insect pests; shipping, handling, and storing properties; and suitability for various processing or other uses. In the period from 1935 through 1966, more than 40 new varietal releases were made to the trade (table 8). Some of the commercially important properties and characteristics of a number of these varieties currently in production are indicated in table 9. More detailed descriptions of the most important of these varieties have been published by Steinbauer (*16*). Roots of some varieties are illustrated in plates I and II.

Properties and Characteristics of Important Varieties

Varieties Used Primarily for Food

BIG STEM JERSEY.—Mainly fresh market but sometimes processed. Dry-flesh type. Roots mostly fusiform and fairly regular in shape; set close to hill; surface generally smooth but sometimes veined; small to large. Skin russet-yellow, flesh amber- to straw-yellow. Quality very good, sweet and mealy when baked. Vines long, trailing, moderately thick, green. Leaves medium size, entire to shouldered, green. Moderate foliage density. Yields moderate to heavy. Propagates well, producing an abundance of draws or sprouts in the plant bed. Roots have relatively short storage life. Excessive shrinkage and development of pithiness by midwinter necessitates early marketing. Susceptible to stem rot (fusarium wilt), scurf, black rot, soil rot, and russet crack diseases; somewhat resistant to internal cork and root-knot nematodes. Maryland Golden, an orange-flesh mutant selection from Big Stem Jersey, was in extensive commercial production for several years but because of disease susceptibility, inadequate sprouting properties, and excessive tendency for root cracking, this variety is now (1970) unimportant.

TABLE 8.—*Origin and principal uses of new sweetpotato varieties developed in the United States, from 1935 through 1966*

Variety	Principal uses[1]	Origin	Originating agency[2]	Year released as variety
Acadian	Fresh market	Breeding-selection	Louisiana	1957
Allgold	Fresh market, processing.	do	Oklahoma	1952
Apache	Fresh market	do	U.S. Dept. of Agriculture.	1959
Australian Canner	Canning	Selection, open-pollinated seedling.	U.S. Dept. of Agriculture, Mississippi.	1948
Canbake	Fresh market, processing.	Breeding-selection	Georgia	1958
Carogold	Fresh market	do	South Carolina	1958
Centennial	Fresh market, processing.	do	Louisiana	1960
Georgia Bunch Porto Rico (Cliett Bunch).	do	Hill selection from Vining Porto Rico.	Private grower, Georgia	1949
Coastal Sweet	Fresh market	Breeding-selection	Georgia Coastal Plain	1965
Earlyport	do	do	Louisiana	1953
Earlysweet	Early fresh market	do	Georgia Coastal Plain	1956
Gem	Fresh market, processing.	do	North Carolina	1964
Georgia Red	Fresh market	do	Georgia Coastal Plain	1956
Goldrush	Fresh market, processing.	do	Louisiana	1951
Heartogold	Fresh market	do	do	1947
Hopi	do	do	U.S. Dept. of Agriculture, New Mexico.	1965
Jersey Orange	Fresh market, processing.	Mutation from Little Stem Jersey.	Kansas	1947
Julian	do	Breeding-selection	Louisiana	1964
Kandee	Fresh market	do	Kansas, Louisiana	1958
Lakan	do	do	Louisiana	1958
Murff Bush Porto Rico	do	Mutation from Vining Porto Rico.	Private grower, Texas	—
N.C. Porto Rico 198	Fresh market, processing.	Flesh color mutation from Porto Rico.	North Carolina	1965
Nancy Gold	Fresh market	Mutation from Nancy Hall.	Kansas	1950
Nemagold	Fresh market, processing.	Breeding-selection	Oklahoma	1958
Nugget	do	do	North Carolina	1961
Oklamar	Fresh market	do	Oklahoma	1957
Orange Little Stem	Fresh market, processing.	Mutation from Little Stem Jersey.	Kansas	1950
Orlis	Fresh market	do	do	1950
Pelican Processor	Feed, industrial	Breeding-selection	Louisiana	1944
Unit I Porto Rico	Fresh market, processing.	Hill selection	do	1935
Queen Mary	Fresh market	Breeding-selection	do	1944
Ranger	Fresh market, processing.	do	do	1944
Redcliff	do	do	South Carolina	1966
Redgold	Fresh market	do	Oklahoma	1953
Red Nancy	do	Mutation from Nancy Hall.	Kansas	1950
Rols	do	Mutation from Orange Little Stem.	do	1950
Shoreland	do	Breeding-selection	Maryland	(3)
Sunnyside	Fresh market, processing.	do	U.S. Dept. of Agriculture.	1953
Tango	Fresh market	do	U.S. Dept. of Agriculture, Missouri.	1957
Tanhoma	do	do	Oklahoma	1960
Virginian	do	do	Virginia Truck ExperimentStation.	1949
Whitestar	Feed, industrial	do	U.S. Dept. of Agriculture.	1948

[1] Processing = canning, freezing, or flaking.
[2] Unless otherwise indicated, these varieties were developed at Agricultural Experiment Stations.
[3] Named but not officially released.

TABLE 9.—*Some commercially important properties and characteristics of sweetpotato varieties in production, 1967* [1]

Variety	Relative yield	Skin color[2]	Flesh color[2]	Flesh type	Canning quality	Storage life[3]	Plant production[4]
Most important commercially:							
Centennial	****	Orange	Orange	Moist	Fair	Good	Fair.
Georgia Red	**	Red	Light orange.	do	Poor	do	Good.
Goldrush	***	Copper-orange.	Orange	do	Good	do	Do.
"Jerseys" [5]	***	Tan to orange-tan, red.	Yellow, orange.	Dry to semi-dry.	Fairly good.	Short	Do.
Nemagold	***	Orange-tan	Orange	Semi-moist	do	do	Do.
Nugget	***	Light copper to tan.	do	Semi-dry	Good	Good[6]	Fair.
Porto Rico (strains).[7]	**	Copper	Salmon-orange.	Moist	do	do	Excellent.
Other varieties:							
Allgold	**	Orange	Salmon-orange.	Moist	Fairly good.	Good	Fairly good.
Carogold	***	do	Orange	do	do	do	Poor.
Coastal Sweet	***	Copper-red	do	do	do	do	Fairly good.
Earlyport	***	Copper	do	do	do	do	Good.
Earlysweet	***	Cream	do	do		Fair	Do.
Gem	****	Light copper.	do	do	Good	Good	Do.
Heartogold	***	Tan	do	do	do	do	Do.
Julian	***	Salmon	Deep orange.	do	do	do	Poor.
Kandee	***	Orange	Salmon-orange.	Moist	Good	Good	Good.
Lakan	***	Reddish-tan.	Deep orange.	do	Fair	do	Do.
Oklamar	**	Purple	Salmon	do	Good	Fairly good.	Do.
Redgold	***	Reddish-purple.	Salmon-orange.	do		do	Fair.
Sunnyside	**	Tan	do	do	Good	Good	Fairly good.
Tanhoma	***	Copper	Salmon	do	Fair	do	Good.
Virginian	**	Copper-red	Orange	do	Poor	do	Fair.

1 For reaction to diseases, see table 21, page 50 and descriptions of individual varieties beginning on page 9.
2 Colors vary somewhat, depending on soil type, culture, and handling practices used.
3 Rated with respect to development of "spongy" or "pithy" condition.
4 Relative abundance and vigor of plants.
5 Includes the older, yellow-flesh varieties Big Stem Jersey and Little Stem Jersey and the orange-flesh varieties Orange Little Stem, Orlis, Jersey Orange, and Red Jersey.
6 Roots remain sound but often develop "blister" spots in storage.
7 Include both vining and short vining types. Root characteristics similar in most strains but Velvet (Red Velvet) has reddish-purple skin and sometimes some purple in flesh.

LITTLE STEM JERSEY (YELLOW JERSEY).—Similar in most respects to Big Stem Jersey but has somewhat more slender vines, smaller leaves, and roots that are sometimes shorter and not quite so large.

ORANGE LITTLE STEM, ORLIS, JERSEY ORANGE.—Color-mutant selections from Little Stem Jersey. Flesh less "firm" or "dry" than Little Stem Jersey. Roots have orange-tan skin and orange flesh. Other root and plant characteristics very similar to those of Yellow Jersey. All susceptible to stem rot, black rot, scurf, russet crack, and soil rot diseases.

CENTENNIAL.—Fresh market and processing. Moist-flesh type. Roots variably tapered to cylindrical, medium to large, orange skin and deep-orange flesh. Good quality. Vines vigorous, thick, long, trailing, reddish-purple except green at terminal ends. Leaves large, entire to lightly toothed, light-green. Very prolific, heavy yielder. Stores well. Only fair sprout producer. Moderately susceptible to stem rot and internal cork; susceptible to black rot, scurf, soil rot, and root-knot nematodes.

GEORGIA RED.—Fresh market. Moist-flesh type. Roots slightly variable tapered-spindle, purplish-red to copper-red skin and light-orange flesh. Excellent quality when baked. Vines long, moderately vigorous, trailing. Heavy foliage density. Leaves large, toothed to shouldered with heart-shaped base, green with light-bronze tips. Moderately heavy yielder. Stores and propagates well. Susceptible to stem rot, black rot, scurf, internal cork, and root-knot nematodes. Susceptible to (but somewhat tolerant of) soil rot disease.

GOLDRUSH.—Excellent quality for fresh market and processing. Moist-flesh type. Roots tapered-spindle, uniform, attractive copper-orange skin and orange flesh. (Strains with more copper-colored skin have largely replaced the original lighter orange-skinned form.) Skin smooth. Vines short to medium length, moderately vigorous, smooth, semibunch growth habit, vines and petioles deep reddish-purple. Moderately heavy foliage density. Leaf blades sagittate with heart-shaped base. Yields about same as Porto Rico. Stores and propagates well. Very resistant to stem rot under usual field conditions. Susceptible to black rot, scurf, soil rot, internal cork, russet crack, and root-knot nematodes.

JULIAN.—Fresh market and processing. Moist-flesh type. Roots smooth, tapered to spindle-shaped, with salmon skin, deep-orange flesh, and high carotene content. Good appearance. Makes very heavy set of roots with a large proportion in the small to medium canning sizes. Good canning and culinary quality. Vines vigorous, coarse, moderate length, trailing, green. Leaves entire or lightly toothed in outline. Moderately heavy foliage density. Stores satisfactorily. Overall yields moderate to heavy. Poor plant producer. Resistant to stem rot in the field; appears to be resistant to internal cork. Susceptible to black rot and root-knot nematodes.

NEMAGOLD.—Fresh market and processing. Semimoist flesh type. Roots medium-size, short to long spindle, with orange-tan skin and orange flesh. Skin usually smooth, but sometimes veined. Good quality. Vine type similar to that of Little Stem Jersey. Leaves distinctly shouldered, small but slightly larger than those of Little Stem Jersey. Possesses certain other characteristics of Jersey-type varieties such as heavy root set, relatively uniform root size and shape, and relatively short storage life. Propagates well. Susceptible to stem rot and scurf. Resistant to root-knot nematodes. Somewhat tolerant to soil rot and internal cork. Best adapted in Jersey-type variety production areas, especially the Eastern Shore of Delaware–Maryland–Virginia.

NUGGET.—Fresh market and processing. Semidry-flesh type. Roots medium size, smooth, slightly blocky tapered to cylindrical. Skin light-copper to tan and flesh orange. Excellent quality. Vines long, medium thickness, trailing, green. Somewhat light foliage density. Leaves rather small, entire, green. Yields well. Stores well. Produces sprouts late and in only fair numbers. Moderately resistant to stem rot, black rot, and soil rot. Symptomless carrier of internal cork virus.

PORTO RICO.—Fresh market and processing. Moist-flesh type. Roots variable spindle to globular and irregular. Skin smooth, light-copper to copper; flesh orange-yellow to salmon, often lighter colored at root end; excellent edible quality. Vines medium to long, trailing, coarse, vigorous, reddish-purple. Moderately heavy foliage density. Leaves medium to large, shouldered to sagittate, green except purple at base of blade and on veins. Moderate to heavy yielding. Very susceptible to stem rot, black rot, scurf, soil rot, internal cork diseases, and root-knot nematodes. Extensively grown, but less well adapted in northern areas than in southern.

A number of strains of Porto Rico, selected for better and more uniform skin and flesh color, root shape, and yielding capacity, have been developed and released as separate varieties. One of these, designated UNIT I PORTO RICO, developed through hill selection, has been one of the most extensively grown of the Porto Rico varieties.

The GEORGIA BUNCH PORTO RICO (CLIETT BUNCH) variety has shorter vines than vining Porto Rico and is usually earlier and has more uniform roots than most other strains. Good plant producer. Otherwise like vining Porto Rico.

The VELVET and RED VELVET varieties are selections of Porto Rico with reddish-purple to dark reddish-purple skin and sometimes with considerable purple pigment beneath the skin. In some strains some purple streaking in flesh. Otherwise like vining Porto Rico. Production mainly in California and in the Southwest.

The N. C. PORTO RICO 198 variety is a flesh-color mutation selection from a high-yielding Porto Rico clonal line. Flesh color deeper and more uniform than that of regular Porto Rico. Other characteristics similar to those of vining Porto Rico.

Varieties Used Primarily for Feed, Starch, or Other Industrial Purposes

PELICAN PROCESSOR.—Feed and industrial type with high yield and high starch content. Roots medium to large, fusiform-cylindrical, with cream skin and light-cream flesh. Good keeper but only fair plant producer. Vines vigorous, intermediate length, trailing, green. Heavy foliage density. Leaves entire to sagittate with heart-shaped base, dark-green. Resistant to internal cork. Moderately tolerant to stem rot. Susceptible to black rot, scurf, soil rot, and root-knot nematodes. Best adapted in Gulf Coast States area.

WHITESTAR.—Feed and industrial type with roots spindle-cylindric to chunky, medium to large, with russet-white skin and cream-colored flesh. Heavy yielding, moderate solids and starch contents. Good keeper and satisfactory propagator. Vines green, medium length and vigor, trailing. Leaves dark-green, lobed to doubly sagittate with heart-shaped base. Resistant to internal cork. Slightly susceptible to stem rot. Susceptible to black rot, scurf, and soil rot.

GROWTH REQUIREMENTS OF SWEETPOTATOES

Climatic Adaptation

The sweetpotato is native to the Tropics, and accordingly, as a crop plant, it thrives best under tropical or subtropical climatic conditions. The warmer parts of the United States are best suited to its culture but commercial crops are produced over wide areas. Most extensive production occurs from New Jersey south in States bordering the Atlantic Coast and the Gulf of Mexico and westward to California (table 10). There is sizable, but less extensive, production of sweetpotatoes in "Middle States" extending north of the Gulf Coast area and west as far as Kansas and Oklahoma. Limited production occurs even farther north and west in certain favorable locations in Idaho, Illinois, Indiana, Iowa, Michigan, and Washington.

Because the sweetpotato is a tropical plant, both warm days and warm nights are essential for its best development. For good commercial production mean summer temperatures should average above 72° F., and there should be ample sunshine, warm nights, a minimum of cool, cloudy weather, at least 1 inch of either rainfall or moisture supplied through irrigation per week, and a minimum frost-free growing season of 4 to 5 months.

TABLE 10.—*Average yields, acreages harvested, and production of sweetpotatoes in principal producing States, from 1965 through 1969*

State	Average yield per acre	Acreage harvested	Production
	Cwt.	*1,000 acres*	*1,000 cwt.*
Maryland	137	3.7	429
Virginia	120	13.6	1,617
North Carolina	112	20.8	2,448
California	98	8.3	814
Tennessee	98	3.5	341
New Jersey	97	6.2	599
New Mexico	93	0.6	49
Kansas	89	1.1	95
Mississippi	85	12.5	1,037
Georgia	84	8.5	714
Louisiana	82	51.8	4,253
Alabama	81	5.7	464
Arkansas	78	2.0	153
South Carolina	75	3.2	237
Texas	71	12.0	856
Oklahoma	66	0.8	54

Average yields of sweetpotatoes produced per acre are usually considerably higher for States in the Atlantic Coast area extending from New Jersey south through North Carolina than for States in other areas (table 10). However, sweetpotatoes of the same varieties grown on mineral soils in more southern parts of the production areas usually have higher total solids and starch contents than do those of the same varieties grown in the northern parts, even when the length of the growing period is the same in each part.

Varieties differ considerably in their adaptation to climatic, soil, and other conditions existing in different producing areas within the United States. Jersey-type varieties and others such as Nemagold, with more or less similar characteristics, grow and produce best in the more northern producing States (Iowa, Kansas, Maryland, New Jersey, Oklahoma, and parts of Virginia) but produce poorly in most areas in the Deep South. On the other hand, some varieties such as Goldrush and Porto Rico, which are well adapted to production in most southern areas, often fail to produce well in northern areas. Very few, if any, varieties are sufficiently wide in their adaptation to produce equally well in all producing areas.

Soils for Sweetpotato Culture

Types

Sweetpotatoes may be grown on a wide variety of soils but production of high-quality roots with desirable sizes, shapes, appearance, and yields is best on certain fertile, well-drained, moderately deep, friable, fine sandy loams, sandy loams, and loamy fine sands underlain by firm, friable, heavier subsoils such as clay loams or sandy clay loams. The principal sweetpotato soils are the sandy loams of the Norfolk, Ruston, Marlboro, and Sassafras series and other series with similar characteristics.

Surface layers of best sweetpotato soils should range from about 8 inches to 24 inches deep. Where the surface layers are too light and deep, roots tend to become too long and to penetrate too deeply. Then harvesting is difficult and injuries to roots are often excessive. Where subsoils are too heavy and tight, they interfere with proper soil drainage. Sweetpotatoes produced on heavy soils with silty or clay surface layers tend to be rough and poorly colored, and are usually difficult to free of adhering soil. All fine-texture surface soils such as clay loams, silt loams, silty clays, clay soils, and deep sands are poorly adapted for sweetpotato culture.

Reaction

Sweetpotatoes are fairly tolerant of variations in soil reaction (within the ranges usually encountered in crop production). The sweetpotato grows reasonably well at soil reactions ranging from about pH 4.5 to pH 7.5 and yields and plant growth are usually best where the soil reaction ranges from about pH 5.6 to 6.5. Under some conditions where the more acid soils are deficient in available calcium or magnesium, or both, liming may make those elements more soluble and available to improve the growth and quality of sweetpotatoes. Land should be limed the year before the sweetpotato crop is planted. Avoid overliming and do not raise the soil reaction too near to neutrality (pH 7.0). Infections by certain sweetpotato disease organisms, such as those causing the soil rot (pox) and scurf diseases, are more severe as the soil reaction approaches neutrality. Such disease infections are controlled to a practical degree when the soil reaction ranges from about pH 4.5 to 5.5. Where land is used primarily for production of sweetpotatoes, applications of sulfur to increase soil acidity to within this range may become necessary to attain practical levels of disease control.

Crop Rotation

Sweetpotatoes are grown over a wide range of territory on farms of many different kinds and with different cropping practices. Even though soils on these farms may be well adapted to sweetpotato culture, market prospects, availability of labor, and other economic considerations determine which crops are to be grown on the land in any particular year.

Studies in Louisiana and Maryland have demonstrated that where serious disease and pest infestations are absent, continuous production of sweetpotatoes on the same land is *possible* without undue soil impoverishment, provided sufficiently large quantities of fertilizers are applied and suitable green manures and cover crops are properly incorporated into the soil. Even so, continuous cropping with sweetpotatoes is to be considered as an exceptional practice to be applied only under special conditions and only where disease and pest infestations are absent or of minor consequence. Sweetpotatoes cannot be grown continuously, year after year, even on land of suitable type, without serious danger of building up in the soil various disease-causing organisms or pests that sooner or later reduce both yield and quality of the sweetpotato crop. Some pathogenic organisms, for example, *Fusarium oxysporum f. batatas* that causes the stem rot or wilt disease and *Ceratocystis fimbriata* that causes blackrot, persist in soils for at least 2 years. Therefore, sweetpotatoes should be grown in rotation with other suitable crop plants or soil-building cover crops. Except under special conditions, sweetpotatoes should not be planted on the same land more often than once in 3 or 4 years. Sweetpotatoes should not be included in rotations that include other crop plants that are susceptible to, or are carriers of, the same disease or diseases as sweetpotatoes. Growing stem rot (wilt) susceptible varieties of sweetpotatoes in rotations that include any wilt susceptible type of tobacco, for example, should be avoided because both crops are susceptible to some of the same pathogenic races of the *Fusarium* fungus that causes the sweetpotato wilt disease.

Sweetpotatoes can successfully follow a wide variety of farm and truck crops, especially on land where soil pests or diseases have not become serious problems and where the preceding crop does not leave the land high in nitrogen content. Excessive nitrogen encourages excessive vine growth in sweetpotatoes, which often results in poor storage root growth and poor root shape. For these reasons, legume crops, as a rule, should follow but not immediately precede sweetpotatoes in the cropping sequence.

Suitable cover crops and green manures must be included in the cropping program both as a conservation measure by preventing erosion of the generally relatively light-texture soils on which this crop is usually grown and as a means of maintaining soil organic matter at moderate levels. Various legumes such as soybeans, cowpeas, crimson clover, and vetch, as well as winter cereal grains such as rye, wheat, or oats, are used for such soil improvement. To avoid excessive nematode buildup in soils and serious nematode damage to sweetpotatoes, plant only more or less root-knot resistant varieties of such soil-improving crops, especially in the South. Rye is much better than other cereals for preventing nematode buildup. The time of digging the sweetpotato crop will determine to some extent what type cover crop is planted. Crimson clover or winter vetch, for instance, can be planted after an early harvest but winter rye or wheat will be better suited to planting conditions after late harvest.

Land Preparation

Plow land at least 6 to 7 inches deep when the soil is sufficiently dry to pulverize well. Plow early enough to allow for decomposition of cover crop or other plant residues before planting time. Follow this plowing with prompt and thorough disking and harrowing. Since sweetpotato planting and cultural operations are now usually mechanized, to avoid any interference of bulky residue materials in subsequent fitting, planting, and cultural operations, any plant residues from preceding crops must be chopped up and adequately incorporated into the soil before or during plowing and disking.

Land preparation may involve incorporation of chemicals for control of nematodes, insects, and weeds. Use of herbicides is discussed on page 33. The nematicides and the insecticide registered for use on sweetpoptatoes are listed in table 11. Apply the chemicals after the land has been plowed and prepared, before ridges are constructed, and sufficiently in advance of planting time to insure that the chemicals do not remain to injure the sweetpotato plants after they are set in the field. Because the usefulness of these pesticides and the amounts of undesirable residues left in the soil and on the crop are influenced by numerous factors such as soil characteristics, moisture, rainfall, and concentration of chemicals used, recommendations of State or local specialists based on label requirements and local experience should be followed.

TABLE 11.—*Nematicides and insecticide used for pest control in sweetpotatoes* [1]

Nematicide	Insecticide
About 50% 1,3-dichloropropene and about 50% 1,2-dichloropropane mixture (DD).	*0,0*-Diethyl *O*-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorodithioate (diazinon).
100% 1,3-Dichloropropene and related C_3 hydrocarbons (1,3–D).	[Apply 4.0 lb. actual/acre as a preplanting broadcast soil application. Tolerance 0.1 p.p.m.]
83% Ethylene dibromide (EDB).	
79% 1,3-Dichloropropenes and 19% ethylene dibromide mixture (1,3-D–EDB).	
Sodium methyldithiocarbamate (SMDC).	
80% DD and 20% methyl isothiocyanate (DD–MENCS).	

[1] Toxic residue tolerances have been established by the Food and Drug Administration for most of these pesticides, subject to revisions whenever such are found necessary. Application and use of the materials should conform to the tolerance limitations and label directions.

Make the first application of fertilizer 10 days to 2 weeks before planting time. For most producing areas, the fertilizer is applied before the planting ridges are constructed. Methods of applying and placing fertilizers and of constructing the ridges vary somewhat in different producing areas and with the type and power of equipment used. To a large extent, single- or multiple-row, tractor-mounted equipment of various designs applies the fertilizer at desired rates and placements, mixes it with the soil, and constructs ridges uniformly and to the desired heights, often in a single operation. Various designs of disk-hillers, listers, or middlebuster-type equipment are used in constructing the ridges. Sometimes the fertilizer is applied broadcast as a separate operation and ridges constructed afterward with the horse- or tractor-powered equipment. The ridges are allowed to settle or firm-up until shortly before planting; then the ridge tops are flattened off slightly with a pole or plank or with a roller drawn by a horse or tractor, either as a separate operation or as a part of the mechanical planter operation. Some mechanical planters have a built-in "plow" or levelling blade to flatten the ridge tops to the desired height ahead of the plant-setting equipment. (See fig. 9, p. 28.)

Ridge Height

In most areas sweetpotatoes are grown on ridges. Soil texture and the amount and intensity of rainfall are important factors determining the best ridge height to use. On heavy sweetpotato soils in areas where rainfall may be heavy and drainage slow, ridges 12 to 15 inches high are often needed. On light sandy loams, somewhat lower ridges, averaging about 10 inches high, may be adequate. On light sandy soils, ridge heights are usually 8 inches or less. In a few areas, such as the Eastern Shore area of Maryland and Virginia where the soils are very light and sometimes in other areas where rainfall is erratic, sweetpotatoes are planted "on the flat," without ridges. Even though some soil is pulled toward the rows during cultivation in these areas, thus forming essentially low ridges by digging time, for most other growing areas this method of planting on the flat is usually unsatisfactory. Roots in low ridges will sometimes set so deeply that they are cut and damaged severely during digging.

Row spacings must be wider where ridges are high than where they are low. Spacings of 42 to 48 inches between rows are often used with high ridges; spacing of only 30 inches may be adequate on light soils and with low ridges.

FERTILIZERS

Composition and Rates of Application

High yields of high-quality sweetpotatoes can be obtained only on suitable soils with a moderately high supply of available nutrients. For the most part soils best suited to production of this crop are more or less sandy and have only low to moderate levels of natural fertility. Addition of fertilizers is, therefore, essential for best production of high-quality roots. Good soil management practices, proper handling of manures and cover crops, and attention to soil nutrients supplied to other crops grown in rotation with sweetpotatoes can aid materially in providing part of the needs of the crop. The heavy feeding requirements of this crop, however, usually make additional liberal applications of commercial fertilizers necessary for optimum profitable production. At the Maryland Agricultral Experiment Station studies showed that about 100 pounds per acre of nitrogen, 40 pounds of phosphorus (as P_2O_5), and 210 pounds of potassium (as K_2O) were taken up by a crop of the Maryland Golden variety during the growing season (*15*) (table 12). Approximately half each of the nitrogen and potassium was used for vine growth; the other half was removed in the root crop harvested. Two-thirds of the phosphorous was removed in the root crop. In addition to the fertilizer elements actually used by the crop, additional amounts must be provided to compensate for losses due to leaching and to "fixing" in the soil in forms not available to the plants.

The composition and amounts of commercial fertilizers, the timing of applications, and the methods of placement recommended for best production of sweetpotatoes will vary from place to place because of the variations in climatic conditions, in amounts and frequency of rainfall or irrigation, in physical and chemical characteristics of the surface soils and subsoils used, in cropping practices, and even in the varieties grown. Because of these many variables, no really satisfactory, generally applicable, recommendations are possible. More reliable and specific advice for fertilization should be obtained from the local county agent or State agricultural experiment station or college representatives who are familiar with particular combinations of soil and climatic conditions and cropping practices in a given locality or area. Many different fertilizer formulas and methods and rates of application have been published by the various experiment stations (table 13). Generally they have included only moderate amounts of nitrogen and relatively high proportions of phosphorus and potassium. Most profitable yields generally have been obtained from the use of 1,000 to 1,500 pounds per acre of mixtures containing 3 to 5 percent nitrogen, 6 to 8 percent phosphoric acid, and 8 to 12 percent potassium.

Sweetpotatoes require moderate amounts of nitrogen for good crop production. On soils where previous cropping and soil management practices have provided good residual quantities of nutrients, sometimes only 20 to 30 pounds of nitrogen per acre need be added in the fertilizer mixture used with the sweetpotato crop. Under conditions of high rainfall or with irrigation, particularly on soils favoring high leaching rates, higher rates of nitrogen application may be required for best crop production.

Potassium is used in relatively large amounts by the sweetpotato and is often easily leached from soils suitable for this crop, consequently the amounts supplied in fertilizers also must be relatively large. Studies at the Maryland Agricultural Experiment Station showed that sweetpotato yields can be increased significantly by heavy applications of potassium but that the higher yields are accompanied by a lowering in the solids content of the roots so produced.

TABLE 12.—*Mineral uptake by a 400-bushel-per-acre crop of Maryland Golden sweetpotatoes*

Minerals	Uptake		
	Vines	Roots	Total
	Pounds per acre	*Pounds per acre*	*Pounds per acre*
Nitrogen	49.7	53.4	103.1
Phosphorus (P_2O_5)	13.7	26.8	40.5
Potassium (K_2O)	107.6	102.2	209.8
Calcium	24.6	5.9	30.5
Magnesium	5.2	4.7	9.9

SOURCE: The Mineral Uptake by the Sweet Potato (*15*).

TABLE 13.—*Sweetpotato fertilizers and rates of application recommended in publications of agricultural experiment stations in 8 States*

State and formula [1]	Rate
	Pounds per acre
California:	
8-10-12	750
Georgia:	
3-9-9	800-1,000
4-8-8	800-1,000
Louisiana:	
4-12-8	500-800
5-10-10	500-800
6-12-6	500-800
Maryland:	
3-9-12	1,000-2,000
Mississippi:	
6-6-6	800
6-8-8	500-1,000
8-8-8	600
New Jersey:	
2-8-10	1,200
3-9-9	1,000-1,800
3-12-15	800
Texas:	
4-8-8	800-1,000
4-12-8	400-1,000
6-10-7	400-1,000
Virginia:	
2-8-10	1,500
3-3-15	1,000
3-9-9	1,000
3-9-15	1,200

[1] Percentages of nitrogen, phosphorus, and potassium, in order shown.

Phosphorus is used by sweetpotatoes in much smaller quantities than are nitrogen and potassium. On many of the sandy soils used for this crop, most of the phosphorus remains readily available to the plants and the rates of application could probably be lower than are often recommended and still be adequate. However, on some heavier types of sweetpotato soils, significant proportions of the phosphorus become tied up in the soil in forms unavailable or only slowly available to plants. On such soils it is necessary to supply phosphorus at moderately heavy rates.

In addition to nitrogen, phosphorous, and potassium, smaller amounts of a number of other nutrient elements, such as calcium, magnesium, and boron, are required for normal growth and development of sweetpotatoes. An inadequate supply of these elements from the soil will result in abnormal growth and development of characteristic deficiency symptoms in the plant.

Some calcium is supplied as calcium phosphate and limestone "fillers" in low-analysis fertilizers. When high-analysis fertilizers are used or the soils become calcium deficient for other reasons, additional calcium may be supplied in the form of gypsum or limestone.

Sweetpotatoes require small amounts of boron for satisfactory growth and root development. However, even a small excess of this element in the soil can injure this crop. Caution, therefore, must be used in supplying this element. As little as 5 pounds of borax per acre, applied well mixed in the regular fertilizer, may adequately satisfy the boron requirements of sweetpotatoes in soils where insufficient amounts of this element are available.

Nutrient Deficiency Symptoms

The following are some of the symptoms by which serious deficiencies in the supply of the main nutrient elements needed by sweetpotato plants may be recognized:

Boron—Restriction and stunting of terminal growth and shortening of internodes; leaf petioles become curled; storage roots become slender and elongate and show necrotic brown internal spotting.

Calcium — Reduction in plant growth; new leaves are light green, reddish, turning to brown in some basal leaves; small yellow leaves develop on thin lateral branches.

Magnesium—Interveinal areas of leaves gradually turning yellow from margins inward; veins very dark green; new stems become light bluish green.

Nitrogen—Reduced vine growth; basal leaves develop red margins, turn yellow or yellowish green; necrotic areas appear; leaves abscise; tip leaves turn light green.

Phosphorus—Defoliation; young leaves are dark green; old leaves develop large yellow areas, turn purple, then brown.

Potassium — Reduced growth; defoliation; few stems develop; marginal areas of old leaves turn brown; leaf blades become yellow and puckered.

Fertilizer Placement

Many tests have been conducted on the time and methods of application and the placement of fertilizers for sweetpotatoes. Although there were exceptions, results were usually best when about one-half of the fertilizer was applied before planting, either directly under the ridge or a few inches to the sides of the center line of the ridge and on a level with or a little below the depth at which the plants were set. The rest of the fertilizer was applied as side or top dressings 2 or 3 weeks after planting.

Side dressings are often applied with special fertilizer attachments during the second or third cultivation. In some places where sweetpotatoes were grown "on the flat" instead of on ridges, side dressing all or a part of the fertilizer 4 to 5 inches from the row and 3 to 5 inches deep resulted in better yields than in places where the fertilizers were broadcast before plowing. When herbicides are used for weed control and cultivation is greatly reduced, fertilizer may be applied as surface side dressings along one or both sides of the row. This procedure is most effective when the fertilizer application is followed by irrigation or rainfall.

The principal advantage of side placement of fertilizers is the reduced amounts of plant injury. Whatever the placement pattern used, it is not wise to apply fertilizers close to the root area of the plants. At the heavier rates of application the fertilizer must be placed farther from the plant root zone to avoid injury. Nitrogen and potassium salts, especially, cause injuries when the fertilizer is placed too close. Phosphorus salts are less soluble and are less likely to cause injury under the same conditions. In studies in Texas, plant stands were significantly better where fertilizers were applied entirely as side dressings 3 weeks after plants were set than where fertilizers were applied entirely under the ridge 5 weeks before plants were set.

TYPES AND SOURCES OF PLANTING MATERIALS

Two types of planting materials are commonly used in the commercial propagation of sweetpotatoes: transplants and vine cuttings. The largest part of the crop is from plants grown from roots that have been placed in warm soil or sand. Such plants are often called draws, slips, or transplants. When they have 6 to 10 well-developed leaves (fig. 3), the plants are pulled from the propagating beds and set in the field.

Use of transplants permits early field plantings but makes necessary the storage and bedding of considerable quantities of "seed" roots. A *minimum* of 10 to 12 bushels of medium-size roots of a good sprouting variety such as Porto Rico must be bedded to insure sufficient strong plants at a single pulling to set an acre with average row and plant spacings. More roots must be bedded for varieties that produce sprouts less abundantly. Both the earliness and numbers of plants produced can be improved by presprouting roots before bedding.

The quantities of seed roots bedded can be reduced if well-developed sprouts from second and third pullings are also set in the field. However, although equally strong sprouts from late pullings have productive capacities equal to those from the first pulling, the delay needed to develop these plants in the beds means a corresponding delay in making the field planting. A delay in planting usually results in a reduction in yield; the shorter the growing season, the more serious the yield reductions occasioned by the delay.

Another disadvantage of propagation by transplants is the danger of transmitting certain diseases that may be on or in the seed roots. Black rot, soil rot (pox), scurf, certain virus diseases, and even nematodes may be spread from diseased roots to the new plants as they grow in the bed. The infestations are then carried into the field with the plants.

To reduce the amounts of seed stock needed and the costs of building and operating large plant beds and to avoid the disease hazard of plants from "mother" roots, many growers in the South plant a part of their acreage with vine cuttings (sometimes also referred to as "slips") made from the early vine growth of early field plantings set with transplants. The cuttings are set in the field the same as bed-produced plants. There is less danger of carrying disease organisms into the field on or in cuttings taken from *healthy* vines of early-transplanted plants than on plants pulled from the average plant bed containing average seed stock. This is a very important advantage of vine cuttings over transplants. Use of vine cuttings causes a considerable delay in planting, however, because the mother plants must be grown first.

"Bed cuttings," a special type of plants made by cutting off 10- to 12-inch-long shoots just above the soil surface in regular plant beds, are also sometimes used in an effort to avoid the time delay needed in obtaining regular vine cuttings. The number of plants obtained from bedded roots is reduced when bed cuttings are made because additional sprouts are not produced as quickly as where plants are pulled from the roots.

Growing a seed stock plot or a field from vine cuttings to help insure against the spread of diseases is highly recommended. Except in the southernmost areas, however, any other advantage of cuttings is very doubtful. Wherever the use of cuttings delays planting enough reduce the value of yields much more than the saving in cost of seed stock, cuttings should be used only for the production of a clean seed stock plot.

Obtaining the vine cuttings from the mother patch requires considerable labor, and cuttings are harder to handle in most planting machines than are transplants. Furthermore, early removal of one-half to three-fourths of the vine growth for cuttings reduces the yield of the mother patch about 15 to 20 percent. Later and heavier prunings of the mother patch plants will reduce yields from the mother patch even more.

Planting small pieces of seed roots directly in the field, in a manner comparable to the planting of Irish potato tubers, has been suggested and investigated. Propagation in this way would eliminate the high costs involved in producing plants in beds and should permit better timing of planting. Studies have shown, however, that plant stands were invariably poorer, weed control was more difficult, and total and marketable root yields were lower from direct seed piece plantings than from later plantings made with transplants obtained from comparable roots bedded in unheated field beds at the same time the seed pieces were planted in the field. From 10 to 20 percent of the total yields from the seed piece plantings were greatly enlarged, unmarketable, rough, mother roots resulting from continued growth of the original seed pieces. This method of propagation cannot be recommended.

Use of Clean Seed Stock

For bedding, the grower should use only seed stock that is known to be free of any signs of disease and that has been carefully selected *in*

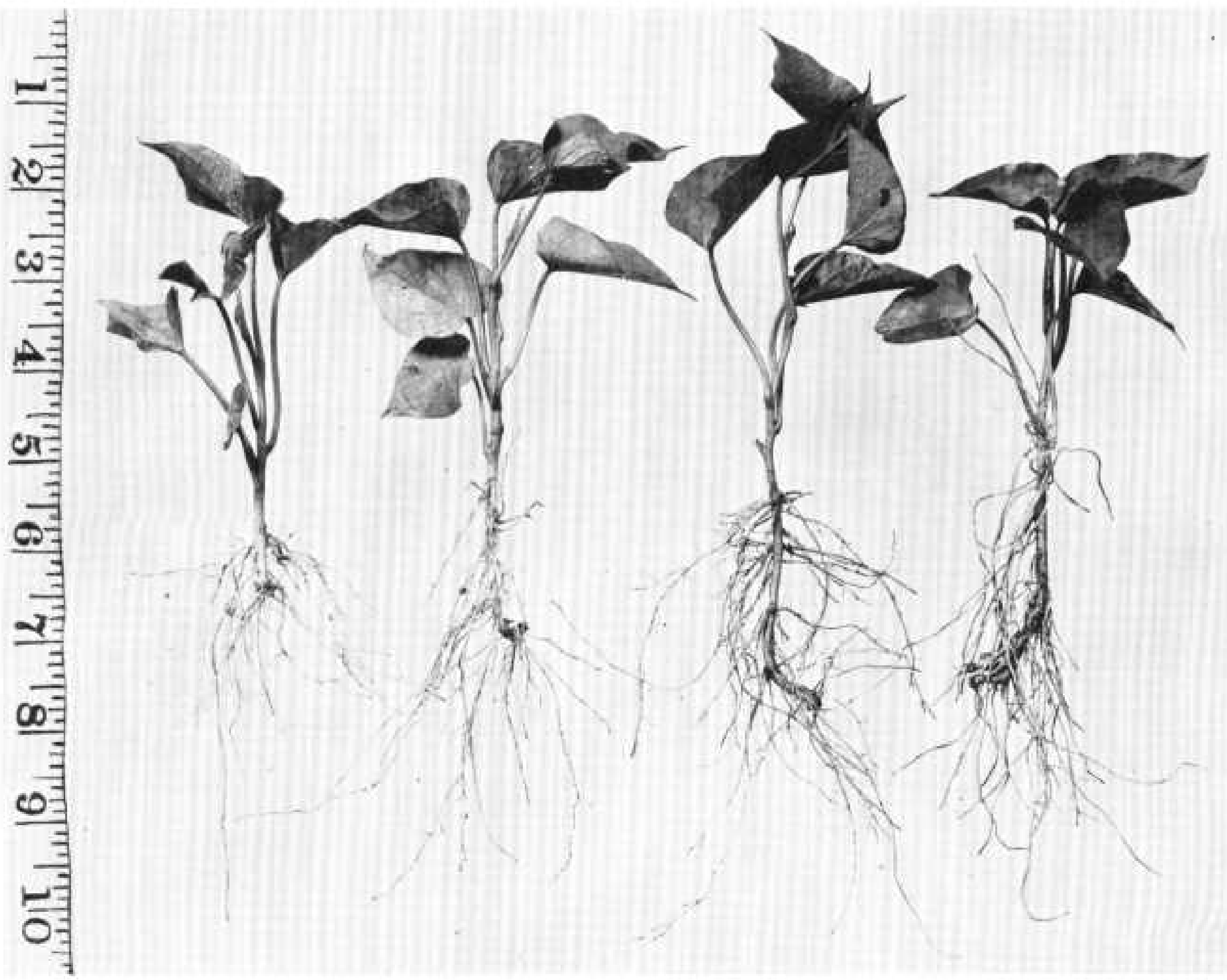

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FIGURE 3.—Sweetpotato plants (draws, slips, transplants) for transplanting. All four of these plants are good growing quality, but the one at the left is too short for easy handling. The second and fourth plants are satisfactory, but the third plant is the best size. Scale is in inches.

the field at harvest for seed purposes. Only at that time can the proper precautions be taken to insure that the roots have come from productive hills that are true to the variety and free from disease. Furthermore, seed stock should have better care than is usually given the bulk of the crop. *Sorting out seed roots from field-run or commercial lots at the packing house or storage house is a bad practice.* It is desirable, wherever feasible, to grow a separate patch or field especially for seed purposes.

The procedures described above for selecting clean seed stock are basic requirements that entail much skill, care, and effort. Some growers concerned mainly with producing stock for the market or for processing may not feel justified in spending the time and effort demanded for an effective seed stock maintenance program. If the grower has saved no clean seed stock of his own, he should try to get it from another grower who is known to produce seed of dependable quality, reasonably free from disease. Lacking such a source, he should inquire through his county agricultural agent or State agricultural extension service representative about sources of certified seed or plants. For the small grower who needs only a few thousand plants, purchase of plants from a dependable source may be less expensive than producing his own.

Foundation, Registered, and Certified Seed

For careful growers, particularly those engaged in extensive commercial production on a permanent, self-sufficient basis, or for private or public agencies distributing high-quality selected seed stocks of established or new varieties, in addition to producing seed for general cropping uses, it is essential to follow a continuing program for developing and maintaining superior stocks by best possible procedures. Repeated and continuing reproduction by vine cuttings; reselection on individual hill bases for trueness to varietal types, colors, and other characteristics and for freedom from diseases; and observance of adequate sanitary precautions during growing, storage, and handling, all are essentials in effective seed programs.

New varieties are usually developed by State or Federal agricultural experiment stations. The original or basic stocks of these varieties are maintained and controlled as *foundation* seed by the originating agency directly, or through designated public or private foundation seed-producing agencies. *Registered* seed stocks are produced *directly* from the foundation stocks by selected growers. *Certified* seed stocks must be produced either from the foundation stocks or directly from registered stocks. In other words certified stocks must be no further than two successive steps from the basic originator's seed.

High-quality seed stocks may be distributed as registered or certified only after they have met exacting requirements and been subject to careful inspections by qualified State inspectors for trueness to type, form, and color and freedom from diseases and pests in the plant bed, in the field, and in storage. Several States maintain certification services and have well-defined regulations and procedures to insure that seed stocks and plants sold shall be virtually disease free and have true varietal characteristics (table 14).

TABLE 14.—*Production of foundation, registered, and certified sweetpotato seed stocks, 1965* [1]

State	Varieties reported	Acreage grown			Production		
		Foundation	Registered	Certified	Foundation	Registered	Certified
	Number	*Number*	*Number*	*Number*	*Cwt.*	*Cwt.*	*Cwt.*
Georgia	5	38.0	0	0	4,625	0	0
Louisiana	11	14.3	0	558.3	1,220	0	23,105
Mississippi	5	4.4	3.8	.8	876	750	150
North Carolina	9	13.1	118.0	134.6	838	16,125	14,450
South Carolina	4	3.3	2.0	12.3	260	0	1,436
Virginia	5	4.1	0	6.1	456	0	890
Totals	---	77.2	123.8	712.1	8,275	16,875	40,031

[1] Prepared from data assembled by the International Crop Improvement Association.

PRODUCING PLANTS

Location of Plant Beds

Plant beds, whether temporary or permanent, shoud be conveniently located on well-drained sites where there is no danger of contamination by water draining off higher lying, disease-infested land. Sites with southern exposure and some wind protection are desirable. The sand or sandy soil used in plant beds should be in or obtained from a field or other source where sweetpotatoes have never been grown or have not been grown for at least 4 or 5 years, and from a field or some other source that is free of possible contamination by diseases.

A good source of water is essential to the location of a good plant bed. About 15 square feet of plant bed space per bushel of medium-size roots bedded are required for all types of plant beds.

Types of Plant Beds

Hotbeds

In the cooler production areas plants are usually produced in some type of hotbed. Wherever it is necessary to provide any structure for protection of the plant bed and to raise its temperature, heat is supplied most commonly by specially designed electric heating elements. Electric heating can be readily adapted to any size hotbed operation (fig. 4). Other, less frequently used means of supplying heat are by fermenting manure or other suitable organic material and by heated flues or pipes. These are discussed in Farmers' Bulletin 2020 (*2*). In this handbook only general features of electrically heated hotbeds are discussed. Details of hotbed construction can be found in Farmers' Bulletin 1743 (*17*) and Leaflet 124 (*18*). Details concerning electrical wiring, heating equipment, and controls and estimated costs of electric heating should be obtained directly from qualified representatives of local power companies or cooperatives.

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FIGURE 4.—Large electrically heated hotbeds. Alternate sashes are opened for ventilation.

Plant beds to be heated electrically should be well built and thoroughly insulated to hold the power cost down to a reasonable figure. Even at relatively low rates for electricity, a poorly built hotbed will be too costly because of the power that will be wasted. Where electric heat is used, permanent structures have many advantages over temporary ones. In the cooler areas where much heating is necessary, fairly elaborate provisions against heat loss are justified. Suitable conditions can usually be supplied at a lower cost for a period of years by a well-planned, well-built structure that does not have to be rebuilt every year.

Permanent locations for electrically heated beds are also desirable to avoid the considerable costs of relocating power lines that serve the beds whenever locations are changed. For permanent beds, good weatherproofed electrical installation and fittings will save much time and trouble over a period of years. Crude, temporary installations may be satisfactory for any one year, but they require more labor for repeated installations and also are shorter lived than permanent ones.

Because of the increasing costs and diminishing supplies of farm labor and the accompanying increasing mechanization of farm operations, permanent-type hotbeds (and coldframes) are now sometimes constructed with removable ends and semirigid "floors" that permit direct filling and removal of bedding media by front-loading tractor scoops or other mechanical means.

Hotbed frames are covered with cloth in warm areas and with glass sash or glass substitutes in cool areas. Glass sash protects the bed more effectively from cold and allows much more sunlight to reach the bed than does a cloth cover. Glass sash sheds hard rain, much of which may otherwise go through cloth and thus chill the beds and make them too wet. The initial cost of glass sash is much higher than that of cloth covers, but sash can be used for many years if handled with care. Cloth covers can rarely be used more than two or three seasons.

In areas too far north for cloth covers to be suitable, glass sash is better than the commonly available plastics or other "glass substitutes" because it transmits light better than the other materials. The sturdiness of glass sash makes it much easier to put on and take off straw or mats needed for additional protection during cold periods. In areas where much heating is required, much of the higher cost of glass sash will be offset through savings in heating costs.

Use of a standard, lead-sheathed or plastic-coated hotbed heating cable is recommended. This cable is made so that single elements or "loops" must be 60 feet long for operation on 110 to 115 volts, or 120 feet long for operation on 220 to 230 volts. Under most conditions in a well-built bed, a 60-foot element is recommended for each two-standard sash, or 6 by 6 feet of bed. Similarily, a 120-foot element will heat the equivalent of four-standard sash, or 6 by 12 feet of bed. Figure 5 shows one practical method of arranging the cable in the bed to give uniform distribution of heat. The loops of the cable should be no more than 7 to 8 inches apart in the bed.

Automatic temperature control is furnished by effective thermostats that are available at reasonable cost. In locating thermostats and laying the heating elements in large beds, it is generally better to arrange the thermostats by groups of sash than to have part of the area under any group of sash controlled by one thermostat and part by another.

In preparing the hotbed in cool areas, excavate the bottom of the bed about 1 foot below the soil level. Put about 4 inches of coarse gravel or coarse cinders in the bottom to keep the heated part of the bed well away from the cold, wet soil below. Cover this with a layer of clean straw or other coarse litter that will settle down to a thickness of about 2 inches when soil and sand are put on top if it. The coarse litter gives further insulation from the cold bottom of the bed and thus keeps much heat from being lost downward. Cover the litter with a thin layer of medium-texture soil, just enough to keep the bedding sand or light soil from sifting down through the litter. Finally, carefully level an inch of sand over the entire bed. Arrange the heating cable on the

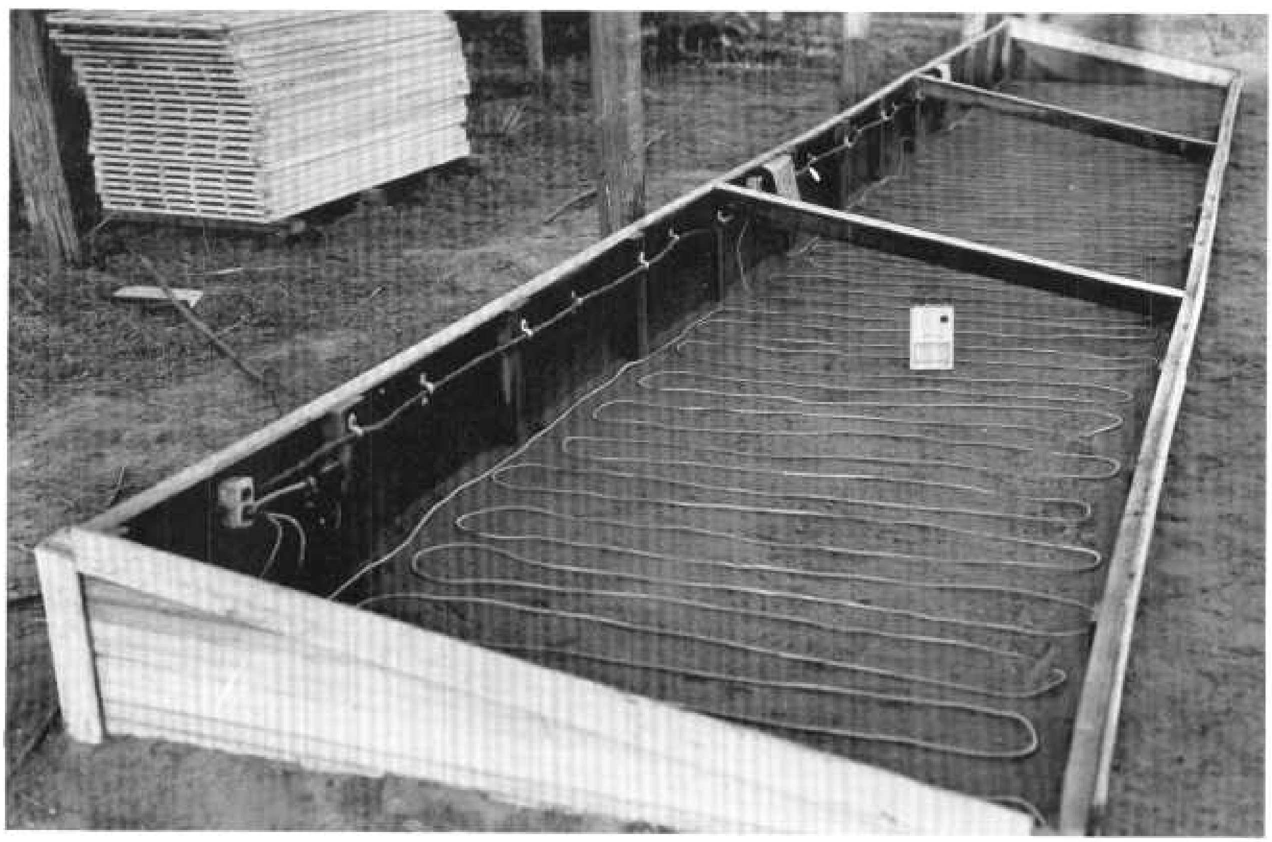

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FIGURE 5.—One practical method of arranging hotbed-heating elements in a bed 6 feet wide.

surface of the sand and complete the electrical connections (fig. 5). Add 4 inches of sand or sandy soil over the cable and put the thermostat bulbs and thermometers in place. After the thermostat is adjusted so that the electric current will be turned on and off as near 80° F. as possible and the glass or other bed cover is put on, the bed is ready for operation.

Some variations in the directions just given may be made, depending upon local weather conditions and materials available for preparing the hotbed. However, good drainage, tight construction, tight covers, and thorough insulation must always be provided.

Coldframes

Coldframes are used in certain areas that are somewhat warmer than those in which hotbeds must be used. In the Eastern Shore area of Maryland and Virginia, for example, sweetpotatoes are commonly bedded in coldframes placed in more or less protected locations but without any sources of bottom heat. Muslin or other cloth or plastic covers are used to protect against low air temperatures. In general practice in most other areas, however, coldframes are not widely used for sweetpotato plant production.

Field Beds in the Open

In the warmer areas of the South, where little freezing occurs, seed sweetpotatoes are usually bedded in the open on ridges or in field beds, with no frame protection or heat applied (figs. 6 and 7).

For best results with field beds, choose only well-drained, light soils that warm up early and that have had no sweetpotatoes on them for several years. When bedding is to be done on land where root-knot or other nematodes are a problem, after the land is worked up but before bedding, treat the soil with a registered nematicide or soil fumigant, following the manufacturer's directions. Proceed with bedding when the nematicide has disappeared sufficiently to cause no injury to the roots. Additional information on application of nematicides has been published by Good and Taylor (*6*).

In preparing ridge-type field beds, plow the soil deep in late January or February, disk thoroughly, then construct ridges about 12 inches high and 3 feet apart. Work about 500 to 600 pounds per acre of suitable fertilizer, such as 4-12-4, 5-10-5, or 6-12-6 mixtures, into the top 5 or 6 inches of soil in the rows. Let the ridges settle and the soil warm up for 2 or 3 weeks, open shallow furrows atop the ridges,

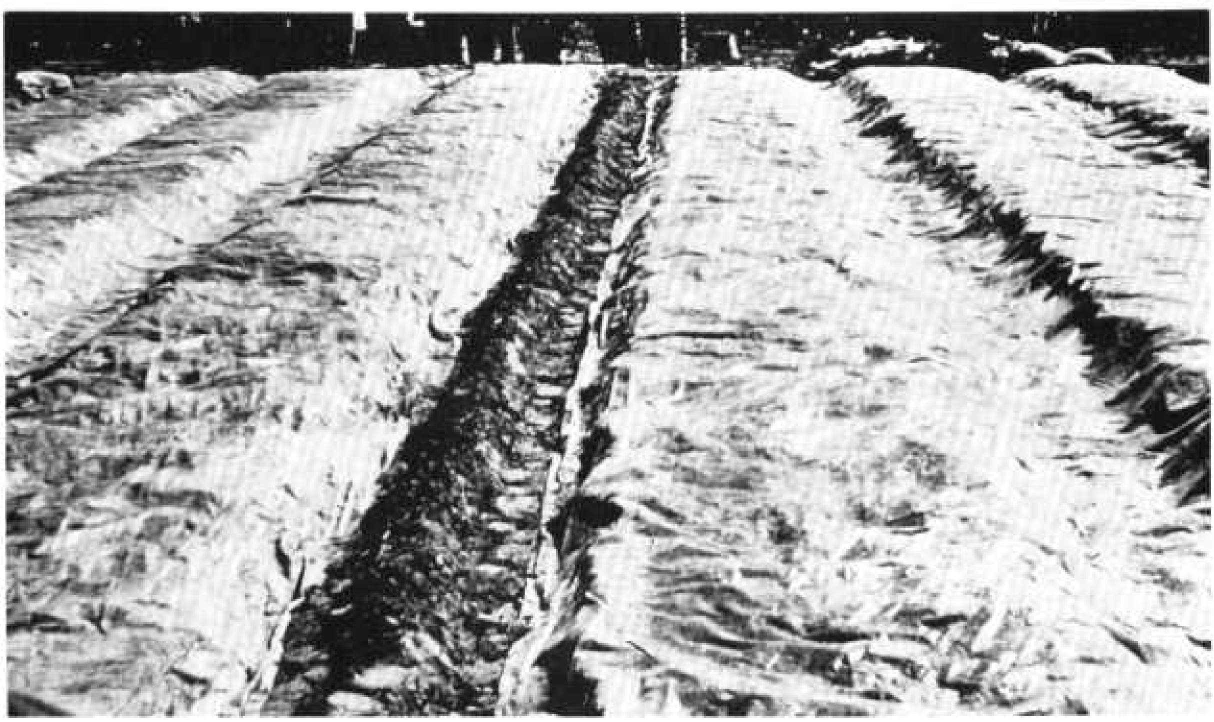

FIGURE 6.—Plastic-covered open field beds with 15-foot-wide plastic sheets covering three field beds. (Photo courtesy of North Carolina State University.)

FIGURE 7.—Sweetpotato plants in open field beds. The crew in the background is pulling plants. (Photo courtesy of North Carolina State University.)

and place the seedroots a few inches apart, lengthwise of the ridges, and cover them with about 2 inches of soil.

In preparing broader field beds, plow and thoroughly prepare the bedding area, then rake, drag, or otherwise smooth and level the land into beds 5 to 6 feet wide and as long as desired. Place seed potatoes by hand, leaving 6 to 12 inches on each side of the bed, cover them uniformly with about 2 inches of soil, and then apply and work fertilizer into the bed surface. These beds are usually covered with plastic kept in place by soil plowed over the edges. The beds may be covered individually, or a single wide sheet of plastic may be used to cover two or more beds (fig. 6). When sprouts begin to emerge, remove the covers. Alleys about 3 feet wide are needed between adjacent beds to provide soil for covering the roots and to permit access for bed care and plant-pulling operations.

Open field beds should be relocated each year to prevent buildup of disease-causing organisms in the bedding area.

Plants are produced slower in field beds than in hotbeds, but at less cost. Earlier sprouts can be obtained from open beds if the seed roots are presprouted before bedding. (See p. 26.)

Preparation of Seed Stock for Bedding

Upon removal from storage, sort seed stock to eliminate all roots that show any evidences of disease or that do not have a bright, smooth, firm, external appearance. "Nick" or notch each root with a knife by cutting a small wedge through the cortical layer at the stem end (end usually showing some sprouts) and discard any roots that have inferior flesh colors. This practice is especially important in producing foundation, registered, or certified seed.

Before roots are bedded, they should be treated with a registered, effective, chemical disinfectant to eliminate any surface contamination by disease organisms. Such treatment aids in preventing seed-piece decay in the plant beds. In cases where presprouting heat treatments or cutting of seed roots may be used to increase the earliness or numbers of plants produced (pp. 26 and 27), suitable disinfectants for use are applied after the preparatory treatments and immediately before bedding. A number of chemicals such as sodium *o*-phenylphenate tetrahydrate (SOPP) are effective for seed-root treatment when used in proper concentrations. Manufacturers' directions should always be followed.

Bedding Procedures and Bed Care

Previously used plant hotbeds and coldframes should be cleaned out and disinfected with a registered, effective fungicide and all old bedding materials removed from the bedding area before starting the bedding operation.

Where bedding is in hotbeds, the bed temperatures should be observed carefully and adjusted to 80° F. before the roots are placed in the beds and covered. Thereafter the temperature should be maintained between 75° and 80°. A good supply of plants should grow in about 6 weeks in this temperature range. Bury the elongated thermostat bulb horizontally in the bed at the level of the lower part of the bedded roots. Place it near the middle of the area controlled by the thermostat, and set a good soil thermometer next to it with the thermometer bulb at the same depth. Read the thermometer from time to time to insure that the thermostat is properly adjusted. One or 2 inches of pine shatters, wheat straw, or other clean litter applied over the bed surface will help conserve moisture. It should be removed when sprouts appear.

Whatever the type of bed used, as far as practical, bedding should be done on sunny, warm days and covers should be placed over beds as promptly as possible to avoid unnecessary chilling of roots and beds.

Bed roots of similar size together so that they can be covered to equal depths. Mixed sizes result in unequal covering. Place roots on the sand or soil of the bed with about a one-half-inch space left between roots (fig. 8). Cover with about 2 inches of clean sand or sandy soil. Water the beds to settle the soil about the roots. On bright, warm days the temperature will rise rather high under glass sash or plastic covers. When this occurs, lift some of the sash or open the ends of plastic covers to keep the temperature down (fig. 4). It should not exceed about 95° F. As large numbers of good plants develop, bed covers should be left off whenever the weather is warm. For about 10 days before transplanting starts and thereafter, covers should be left off all the time unless there is danger of an untimely frost or near frost.

The beds will need watering from time to time, the frequency depending on the amount of

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FIGURE 8.—Bedded sweetpotato seed roots ready to be covered with sand or soil.

ventilation given to help control the temperature. The bedding material around the roots should be examined through its depth every few days to insure that it does not become too dry for plant growth. Excess watering tends to chill the beds, waste heat, and check plant development. Whenever possible, watering should be done during warm, bright periods to avoid chilling the beds or plants. Before the sprouts appear, very little water is needed. As large numbers of plants develop, the need for water increases rather rapidly.

After each pulling of plants, the beds are usually fertilized lightly, then watered to resettle the soil. Most growers use some commercial fertilizer in their plant beds. This is usually applied and worked into the surface soil after roots have been covered in the bed. As a means of saving labor, however, where open field beds are used, sometimes the fertilizer is applied and worked into the soil during land preparation before the beds are laid out. Fertilizer composition and application are varied according to local experience and practice. In experiments conducted in South Carolina, about 17 percent more plants were produced when 4-8-4 fertilizer was thoroughly mixed with the bedding soil at a rate of 300 pounds per acre than when no fertilizer was added.

The North Carolina Experiment Station recommends use of 3/4 pound of 8-8-8 fertilizer per square yard, raked lightly into the soil after bedding in open field beds, supplemented by 1/5 pound of nitrate of soda per square yard applied before watering after each pulling of plants.

Amounts of Seed Stock Required

The number of plants required per acre varies with the spacings used within and between rows (table 15). For average recommended spacings of 12 to 15 inches in the row and about 3½ feet between rows, roughly 10,000 to 12,000 plants are needed for setting one acre. As a general guide, a good sprouting variety may be expected to produce, in the first one to two pullings, up to 1,000 plants per bushel of good-quality, medium-size seed roots bedded. For later plantings about 500 additional plants per bushel can be expected from each of one or two later pullings spaced at 7- to 10-day intervals.

Factors to consider in determining more definitely the quantities of seed stock to be bedded in particular cases include:

(1) Location of Production Area.—Abundant supplies of early sprouts are especially important for plantings made in intensive culture areas having relatively short growing seasons. In such locations planting at earliest safe dates is imperative for high yields. This means bedding sufficient roots to supply the desired plants at one early pulling. A delay of only 10 days to 2 weeks in planting, occasioned by waiting for sprouts to develop for second or third pullings, can mean differences in marketable yields of 20 to 30 or more bushels per acre for each planting delay. In the warmer areas of the South where the growing season is longer, plants from successive pullings can still give reasonably high yields and therefore less bedding stock will be needed for supplying plants.

(2) Varietal Sprouting Characteristics.—Ideally, a good sweetpotato variety should produce an abundance of strong plants within a reasonably short time after bedding of good stock. The best of the older, commercially important varieties such as the Porto Ricos and Jerseys possess this characteristic. Unfortunately, however, some of the recently developed, high-yielding varieties sprout slowly or do not develop sprouts in sufficient abundance (table 16). To properly estimate amounts of stock to bed, the grower must consider the sprouting characteristics of the particular variety to be grown.

Special presprouting and seed-piece cutting techniques can be applied to increase plant production and thus to reduce the amounts of stock to be bedded. These are especially useful with poorer sprouting varieties. When stored roots are held under conditions of high humidity and temperatures of about 80° F. until sprouts are about 1 to 2 inches long before bedding, the numbers of sprouts available at the first pullings are considerably increased. In most cases

Table 15.—*Approximate numbers of plants required to set 1 acre at different plant and row spacings*

Spacing within rows (inches)	Plants required to set 1 acre at row spacings of—				
	36 inches	40 inches	42 inches	44 inches	48 inches
	Number	*Number*	*Number*	*Number*	*Number*
6	29,040	26,130	24,890	23,760	21,780
8	21,780	19,620	18,670	17,820	16,310
10	17,420	15,680	14,960	14,490	13,080
12	14,520	13,070	12,440	11,870	10,890
14	12,440	11,200	10,670	10,180	9,330
15	11,610	10,430	9,960	9,500	8,710
16	10,890	9,800	9,330	8,910	8,170
18	9,680	8,710	8,300	7,920	7,260
21	8,300	7,470	7,110	6,780	6,220
24	7,260	6,530	6,220	5,940	5,440

TABLE 16.—*Relative abundance and earliness of sprout production of sweetpotato varieties compared in 10 States, 1965 and 1966* [1]

Variety	Mean ratings for—			
	Plant production [2] in—		Earliness [3] in—	
	1965	1966	1965	1966
Centennial	3.2	3.7	2.0	1.6
Gem	3.5	3.0	1.7	2.1
Goldrush	4.0	4.4	1.5	1.4
Julian	2.0	2.1	2.5	2.6
Nemagold	---	5.0	---	2.0
Nugget	2.0	3.0	2.0	3.0
Porto Rico	5.0	5.0	1.0	1.0

[1] Unpublished data: National Sweetpotato Cooperator Group.
[2] Plant production rated 1 (poor) to 5 (good).
[3] Earliness of plant production rated 1 (early) to 3 (late).

the total numbers of sprouts developed for all pullings are also increased by the treatment. The average total number of plants produced per bushel of presprouted and nonpresprouted roots of three varieties in eight tests conducted in North Carolina was 1,673 in 1960 and 862 in 1961. Table 17 shows results obtained in one test with the Goldrush variety in 1960. Presprouting is particularly advantageous where coldframes and plastic-covered open field beds are used. Presprouting permits delaying of bedding until soils have warmed up sufficiently to promote rather rapid plant growth. Plant production almost as good as that from heated beds is attained without the much more expensive construction and operation costs involved with the heated facilities.

Cutting seed roots crosswise into about equal

TABLE 17.—*Plant production of presprouted and nonpresprouted Goldrush sweetpotatoes bedded in a plastic-covered field bed at Wake Forest, N.C., April 11, 1960*

Date of pulling	Plants per bushel of seed roots	
	Presprouted	Nonpresprouted
	Number	*Number*
May 16	1,300	400
May 26	175	425
June 8	300	300
Total	1,775	1,125

parts before bedding increases the number of sprouts produced by a given quantity of stock. Although some reduction in average plant size usually accompanies the increased numbers of plants produced with this procedure, except with very small stock, plant size is usually adequate for field planting. When seed roots are crosscut, the cut roots must be treated with a registered, effective fungicide before bedding to prevent excess rotting of the seed pieces. Results of crosscutting seed roots of the Canbake variety in one test at the Georgia Experiment Station in 1960 are shown in table 18.

(3) SIZE OF SEED ROOTS BEDDED.—Small to medium-size bedding roots produce more plants *per bushel of bedded stock* than do larger roots although the larger roots produce more and somewhat larger plants *per bedded root*. Ordinarily it will be more economical to use the small to medium-size selected roots for production of plants. Where larger size roots are used, larger quantities of bedding stock must be provided and more bed space will be required to furnish enough plants for planting a given area.

TABLE 18.—*Number and size of plants produced from whole roots and plants produced by crosscutting Canbake sweetpotatoes before bedding at Experiment, Ga., 1960* [1]

Cutting treatment	Roots used	Plants pulled				Average plants produced per root	Average weight per plant
		May 5	May 17	June 10	Total		
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Grams*
Whole roots	272	319	1,430	741	2,490	9.1	11.6
Crosscut roots	272	649	2,113	826	3,558	13.2	8.9

[1] All roots of comparable size, bedded April 6 in electrically heated beds, after being dipped in a fungicide.
SOURCE: Cross-Cut Bedding Sweet Potatoes to Increase Sprouts *(3)*.

FIELD PLANTING

Methods of Transplanting

Sweetpotatoes are set in the field either by hand or with machine transplanters. Handsetting is generally a relatively slow and inefficient method of planting this crop and requires much greater expenditures of labor for setting a given area than machine transplanters require. Handsetting is used mostly in planting small areas or on small farms where machine transplanters are not available. Most large sweetpotato operations today use single- or multiple-row machine transplanters (figs. 9 and 10). A number of different makes and types suitable for sweetpotatoes are available. Small growers who cannot buy a machine transplanter or cannot make it profitable in their small operations should consider the joint purchase and operation of a machine with a few of their neighbors.

In handsetting, the plants are dropped by one person at the desired intervals on the prepared ridges. One or more workers follow and do the actual planting with the aid of trowels, dibbles, or special "sticks." Handsetting is best done when the soil contains adequate moisture.

Machine transplanters not only save man labor but also transplant the plants more uniformly and generally more satisfactorily than handsetting. These machines are equipped with watering devices that apply a small quantity of water around each plant just before the soil is drawn around it. Under some conditions rapid recovery of plants following transplanting is facilitated when dilute "starter" nutrient solutions are used instead of plain water. High-analysis, soluble starter fertilizers are available commercially for use, at manufacturers' recommended rates, in the transplanting water supply, or 2 to 3 pounds of a moderately high nitrogen content, regular fertilizer may be dissolved for use in 50 gallons of water. Where the available nutrient levels in sweetpotato soils are adequate, it is not always economical or necessary to use starter fertilizer but, in general, water should be used when transplanting by machine because the soil is usually dry enough at planting time for the plants to benefit from the water applied. The low cost of application of water by machine makes the grower less dependent on the weather in determining when he can plant. In view of the losses in yield that follow late planting (or delayed starting of growth after planting), this advantage of the machine is often an important one.

Three men with a one-row planter can set 3,500 to 4,000 plants per hour—one man driving and two men handling plants. With a two-row planter, five men can set 7,000 to 8,000 plants per hour. If the soil is moist enough for setting

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FIGURE 9.—Single-row machine transplanter. Note ridge-leveling plow and water supply tank.

FIGURE 10.—Planting with 4-row machine transplanter. (Photo courtesy of North Carolina State University.)

the plants without water, considerably larger numbers can be set per hour because stops for filling the water tanks are unnecessary.

For efficient results with machine transplanters, the work crews must have some experience and skill, the field must be well prepared, the water tanks must be refilled quickly, and the plants must be of medium size and neatly arranged for rapid handling. Waiting for plants or water is costly. Water should be brought to the field in large tanks or barrels. Plants that are too large or too small or that are tangled or disorderly in the bundles can easily waste 25 percent or more of the time of the planting crew.

Plants that are delayed in starting active growth fail to catch up with neighboring plants that start growth promptly. Imperfections in the plants or the transplanting operation and cloddy or trashy spots in the ridges where plants are set may retard plants enough to make them unproductive laggards throughout the entire season. Plants next to skips often produce oversize roots too large to be marketable. Planting skips or replacing dead or defective plants 2 or 3 weeks after the field has been transplanted is unprofitable. Late replacements become so crowded by their early starting neighbors that they rarely yield enough to pay for the trouble of transplanting them. It is most important to get a full stand of good plants all at a single transplanting.

Preplanting Fungicidal Treatment of Plants

Normally, sweetpotato plantings are made with clean plant materials on soils believed to be essentially free of serious sweetpotato disease-producing organisms. No preplanting fungicidal treatments of plants are ordinarily used. Sometimes plantings must be made in fields where certain disease-producing organisms, such as those causing stem rot (wilt) or scurf, are suspected of being present or are known to be present in small amounts. Under such conditions dipping the basal parts of clean plants in a solution of a registered, effective fungicide immediately before planting often gives measurable protection against early field infections by some pathogenic organisms.

Sweetpotatoes should never be grown on land known to be heavily infested with disease-producing organisms or from plants produced in disease-contaminated plant beds. Preplanting fungicidal applications can be of little practical value under such adverse conditions.

Size of Plants

Good, sturdy plants are essential in obtaining full stands in the field. Small, weak plants with few leaves have a much poorer survival rate and give poorer yields and for these reasons should be discarded when they are pulled at the plant beds. About 20 percent of the plants are ordinarily this small, weak type, not suitable for field setting.

Best plants for field setting of most varieties should average about 8 inches long (including the rooted parts of the plants). (See fig. 3.) Sturdy, disease-free plants ranging from about 6 inches to 10 inches long and each having 6 to 8 leaves handle best in transplanting, establish well, and give best stands and overall production. Plants less than 6 inches and more than 10 inches long are usually somewhat more difficut to handle, particularly where they are machine transplanted. Plants that are excessively long before pulling may have to be trimmed off at the basal ends to facilitate handling. As far as practicable, plants that are excessively long should be avoided by timely and judicious regulation of plant bed temperatures, ventilation, and watering practices.

Plants of those varieties having "bunch" or "bush" growth habits usually do not grow long enough for most effective handling during field planting operations. Therefore, plantings of these varieties are made with stocky, vigorous, but short plants.

Vine cuttings for field planting should be made only from vigorously growing, healthy plants in field beds or in early-transplanted fields. Cuttings suitable for planting should be about 8 to 10 inches long and made from terminal or middle portions of vigorously growing vines. Cuttings made from the older, more or less hardened, basal portions of vines do not root and establish well in the field, and as a rule resulting plants are not sufficiently productive.

Bed cuttings are made by cutting off the 6- to 8-inch tops of vigorous sprout plants at or near the surface of the media in plant beds.

Time of Planting

Time of planting is very important in sweetpotato production. Total and marketable yields are best from plantings made as early in the spring as plants are available and weather is warm enough after the frost-free date for the particular area. Delay in planting reduces both the total crop yields and the yields of prime market-size potatoes. Early planting is especially important in areas where the normal effective growing season is comparatively short. Yields are satisfactory but not maximum with some delays in planting times in warmer parts of the South where the growing season is sufficiently long.

In an experiment conducted with two varieties at four locations over a 3-year period, a 2-week delay in planting after the earliest planting dates reduced total yields nearly 40 bushels per acre and yields of No. 1 grade 30 bushels per acre. A 4-week delay reduced total yields 86 bushels per acre and yields of No. 1 grade 43 bushels per acre. Further delays reduced yields even more.

Setting the plants closer together in the rows will not make up for the yields lost as a result of late planting (table 19). The importance of transplanting as soon as the weather is warm enough can hardly be overemphasized. Planting on time will greatly improve average yields, with only a moderate increase in cost of producing the crop, mainly in the higher cost of producing plenty of early plants.

Plant Spacings

On most well-drained, light soils adapted to intensive sweetpotato culture, rows for sweetpotatoes are usually spaced from 3 to 3½ feet apart. Under these conditions the crop is grown on ridges of low to moderate heights—up to about 1 foot. Where suitable soils are somewhat heavier and where somewhat higher ridges may be required for adequate drainage, rows are spaced as far as 4 feet apart.

A number of factors must be considered in determining the plant spacings to be used within sweetpotato rows: (1) Growth habit and root-setting characteristics of the variety grown; (2) sizes of roots needed for the principal end use(s) for which the crop is produced; (3) type and fertility level of soil and intensity of fertilization program followed; (4) length of growing period; and (5) economic considerations: relationships of expected net returns to labor, plant material, and other production costs involved for cropping at varying plant spacings.

Some varieties, usually certain vigorously growing types, have inherent tendencies to set their storage roots early and to produce significant proportions of their crop as large roots, particularly from early plantings and when harvest is delayed beyond the optimum digging

TABLE 19.—*Effect of hill spacing on total yield and yields of No. 1, No. 2, and Jumbo grades of Porto Rico sweetpotatoes from 5 successive plantings* [1]

Hill spacing and grade of sweetpotato	Yield per acre for—					Average yield per acre for spacing
	First planting	Second planting	Third planting	Fourth planting	Fifth planting	
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
8-inch:						
Total	329	304	242	199	134	242
No. 1	161	138	100	99	56	111
No. 2	86	73	56	50	29	59
Jumbo	23	23	14	6	1	13
12-inch:						
Total	319	287	240	206	128	236
No. 1	147	126	104	99	50	105
No. 2	81	72	53	46	32	57
Jumbo	36	31	23	8	1	20
16-inch:						
Total	319	271	223	184	126	225
No. 1	139	118	97	86	49	98
No. 2	79	69	51	43	30	54
Jumbo	50	40	26	13	3	26
Average yield per acre for spacing:						
Total	322	287	235	196	129	---
No. 1	149	127	100	95	52	---
No. 2	82	71	53	46	27	---
Jumbo	36	31	21	9	2	---

[1] Coordinated tests conducted from 1940 through 1942 at Blackville, S.C., Experiment, Ga., Gilmer, Tex., and Laurel, Miss. Row spacings 3½ feet. First plantings soon after average dates of last killing frost in spring, with successive plantings at intervals of approximately one-twelfth of normal growing season for each location. Yields in 55-pound bushels.

SOURCE: Regional Studies of Time of Planting and Hill Spacing of Sweetpotatoes *(1)*.

period for the variety. Closer spacing of plants in the row, slightly delayed planting times, and earlier harvests usually reduce the yields of oversize roots of such varieties without significantly reducing total yields or yields of marketable and canning-size roots.

High root yields are always important. Root size requirements, however, vary with the principal intended use(s) for the crop. They are different for fresh market use, for whole-root canning, freezing, or other food-processing uses, or for use in feed production or industrial processes. For the fresh market, high yields of uniform-size and uniform-shape roots of the No. 1 and No. 2 market-size grades are very important. For whole-root canning and freezing, large parts of the crop need to be roots with small diameters (1 to 2 inches) and short to medium lengths (3 to 6 inches). For feed production, industrial processes, and some food-processing uses such as baby food puree canning, dehydrated flake manufacture, and frozen dice stock preparation, root size characteristics are less critical, but large roots are often preferred because of greater ease of handling and relatively less waste losses during peeling and other preparation operations.

Plant spacings of 12 to 15 inches in the row are generally preferable for economical production of roots of best grades for the fresh market. Results of extensive plant-spacing experiments have shown that for a designated planting period, the average total yield per acre and yields of No. 1 grade and small roots are increased and yields of Jumbo and oversize roots are decreased by decreasing plant spacings within the row (table 19).

Because of the costs of additional plants and problems associated with transplanting and handling plants at close spacings, it may not always be economical to use spacings much less than 12 inches as a means of attaining desired yield increases of market-size roots. (See table 15 for numbers of plants required per acre at different plant and row spacings.) Where increased yields of small roots are needed for canning, assuming that adequate returns can be expected for these roots, increasing plant densities makes attainment of this objective possible without materially altering production of market-size roots. Yield effects obtained by setting two plants per hill at twice the distance between hills can be the same as yields obtained by uniform close spacing of single-plant hills.

Practical considerations make machine planting difficult at uniform, very close plant spacings.

When production of large roots is desired for special food-processing, dehydrating, industrial, or feed purposes, widening the plant spacings makes it possible to obtain greater proportions of the total production as large roots. Total production of roots of all sizes, however, may be smaller than at closer plant spacings.

Plant spacings can be somewhat closer on good, fertile soils than on less desirable, less fertile soils. On soils not adequately supplied with plant nutrients, apply enough fertilizers to support efficient plant densities rather than depend on wider spacings but lower yields to insure adequate root development of this crop.

WEED CONTROL AND CULTIVATION[2]

Control of weeds and maintenance of ridges at proper height and shape are the two main purposes in cultivation of sweetpotatoes. Many annual and perennial weeds, including pigweed, ragweed, jimsonweed, crabgrass, goosegrass, and nutsedge, infest sweetpotato fields. The most serious weeds are annual and perennial grasses and nutsedge. Effective control of weeds is particularly important during the early part of the growing season when the sweetpotato plants are getting established and before vines have grown extensively. One or two hand hoeings are often needed to destroy weeds in the rows when the sweetpotato plants are small. If weeds are allowed to get ahead of the sweetpotatoes in this early period, much labor and expense are needed later to remove these weeds. Because of the spreading growth habit of sweetpotatoes and their luxurious foliage that shades the weed seedlings during the middle and late parts of the season, sweetpotatoes compete comparatively well with weeds at these times. Sweetpotatoes also develop extensive root systems and therefore compete strongly with the weeds for moisture and nutrients. The average cost of weed control by usual cultural methods is approximately $20 to $30 per acre. Use of improved control methods, particularly the use of registered herbicidal chemicals, should reduce this cost significantly.

Weed Control by Cultural Methods

As far as possible, sweetpotato land should be free of weed seedlings at the time of planting. To keep down new grass and other weed growth as much as possible and to prevent any serious crusting of soil on the crowns of rows, the first cultivation should be within a week or 10 days after planting. Two to four subsequent cultivations are usually required to control weeds adequately and to maintain the ridges. If for any reason the ridges become grassy, especially during the early part of the season, the sides should be barred off with shovels, disks, or small plows and the soil pulled back to the ridges with sweeps or other suitable tools. Make the last or "lay-by" cultivation when vine growth becomes so extensive that further cultivation is difficult. Throw the soil well up toward the rows to smother out small grass and other weeds and to maintain the ridges.

The types and arrangements of tools to be used for cultivation will depend on the kind of power and equipment available and on the particular soil and field conditions. Various arrangements of sweeps, disks, and shovels are used successfully on both horse-drawn and tractor-powered cultivators. Sweeps are particularly useful tools in weed removal and ridge maintenance. Sweeps of the type designed for plow stocks are often mounted to follow disk hillers. The disks are set to cut away part of the ridge and throw the weeds into the middle. The sweeps immediately follow, restoring the soil to the ridge and weeding the upper part of the ridge at the same time. Today cultivation is usually done with tractor-powered equipment. Each design of tractor and of tools used with it presents a separate problem that must be worked out according to the particular field conditions and the job to be done. By trial and adjustment and by careful control of tractor speed, work can be done very accurately. Effective cultivation and ridge maintenance with tractor tools demand that ridge construction and transplanting be done in a regular, precise manner. Precision is especially necessary for two-row equipment or larger. Tractor tools are so mounted that when the tractor is in motion, the principal control lies only in the driving of the tractor. Wavering of the row on the ridge and variations in distances between rows and in ridge height seriously interfere with doing a job satisfactorily. Tractor tools are not flexible enough to deal with such irregularities.

[2] The section "Weed Control and Cultivation" was prepared in cooperation with L. L. Danielson, plant physiologist, Crops Protection Research Branch, Crops Research Division, Agricultural Research Service.

Chemical Weed Control

Herbicides are generally used on sweetpotatoes to control weeds early in the season to reduce the amount of cultivation needed and to maintain weed control after the lay-by cultivation with a minimum expenditure for hand labor. Herbicides are usually used in combination with mechanical cultivation operations for weeding, ridging, and fertilizing the crop. There are situations in which herbicides used under favorable conditions immediately after transplanting will effectively control weeds throughout the growing season without supplemental cultivation.

A large number of registered, effective herbicides are available for control of weeds in sweetpotatoes. Several of these are used successfully in field practice. These include: Sodium salt of *N*-1-naphthylphthalamic acid

TABLE 20.—*Weeds controlled by preemergence applications of herbicides* [1]

Weeds	Herbicides						
	Amiben	CDAA	DCPA	Diphenamid	EPTC	Naptalam	Vernolate
Broadleaf weeds:							
Carpetweed		X	X	X		X	X
Chickweed	X		X			X	
Cocklebur	X					X	
Coffeeweed	X						X
Deadnettle					X		
Dock	X						
Florida pusley			X				X
Goosefoot, nettleleaf				X			
Jimsonweed	X						
Knotweed				X			
Lambsquarters	X		X	X	X	X	X
Morningglory, ivyleaf	X						
Mustard						X	
Nightshade, hairy					X		
Pigweed, prostrate					X		X
Pigweed, redroot	X	X	X	X	X	X	X
Purslane		X	X		X	X	X
Ragweed	X					X	
Shepherdspurse						X	
Smartweed	X			X			
Spurge, spotted			X				
Velvetleaf	X					X	
Weed Grasses:							
Annual bluegrass		X	X				
Barnyardgrass		X	X	X		X	X
Cheat		X		X			
Crabgrass	X	X	X	X	X	X	X
Foxtail, giant	X	X		X		X	X
Foxtail, green	X	X	X			X	
Foxtail, yellow	X	X	X	X		X	
Goosegrass				X		X	X
Johnsongrass (seedling)	X						X
Lovegrass			X				
Quackgrass					X		
Sandbur						X	
Stinkgrass		X		X		X	
Witchgrass			X				X
Sedge:							
Nutsedge, yellow					X		X

[1] X = Satisfactory control.

(naptalam); *N,N*-diallyl-2-chloroacetamide (CDAA); *S*-ethyl dipropylthiocarbamate (EPTC); dimethyl tetrachloroterephthalate (DCPA); 3-amino-2,5-dichlorobenzoic acid (amiben); *N,N*-dimethyl-2,2-diphenylacetamide (diphenamid); and *S*-propyl dipropylthiocarbamate (vernolate). These herbicides kill germinating weed seeds, and vernolate and EPTC also control sprouting weed rootstocks.

Climate, soil composition, and cultural practices are critical factors in the successful use of herbicides. Each herbicide kills certain weeds and requires certain specific conditions and methods of application for best results. Choice of a herbicide will therefore depend on the particular weed problem. Crops and herbicides should be rotated to reduce the number and kinds of weed seed in the soil. Using different herbicides on sweetpotato plantings and other crops in the rotation in successive years will control many different kinds of weeds and minimize the possibility of accumulating herbicide residues in the soil.

Information in table 20 shows which preemergence herbicides effectively control the most commonly encountered broadleaf weeds, weed grasses, and nutsedge. This information can be used as a guide in choosing the herbicide for controlling weeds in particular fields. In general, preemergence herbicide treatments should be made when soil moisture and temperature are optimum for rapid weed seed germination.

The method of application depends on the herbicide. The herbicides listed in this handbook are usually available for making spray or granular application. Some herbicides are applied to the soil and deeply incorporated by disking before planting. Others are applied immediately after planting or after clean cultivation soon after planting. When late-season weeds that emerge after the lay-by cultivation are a severe problem, the herbicide treatments may be repeated immediately after the lay-by.

Carefully planned use of registered herbicides can improve sweetpotato production efficiency. Herbicides are being constantly improved and methods of application are changing as new research information is developed. *To insure correct and most effective use and to keep residues within tolerance limits, you must carefully follow the directions on the label of the container.* State experiment station weed specialists can help the grower to select herbicides and methods of use that have proved most successful for local conditions. All precautions for storage and use of herbicides should be carefully observed.

WATER REQUIREMENTS AND IRRIGATION

The sweetpotato is not a dry-weather crop although it may be considered as a moderately drought-tolerant one. Once growth is well established, the sweetpotato can survive rather long dry spells during the summer, and with subsequent rainfall is able to resume growth and produce storage roots. Drought tolerance is made possible, at least in part, by the rather extensive and moderately deep root system that enables the plants to obtain some water even when the surface soil layers become seriously moisture deficient. However, quality and yields of roots will be poorer when inadequate moisture levels develop during the growing season.

The most severe yield reductions result from prolonged water shortages 50 to 60 days after planting, when vine elongation is slowing down and storage root initiation has begun. Yield reductions are less severe when droughty periods occur either a little earlier or a little later than this. Drought reduces the number of storage roots more than it reduces their size.

The total solids, total carbohydrate, and starch contents are lower and the moisture content is higher in roots of a variety produced in very dry years (without irrigation) than in roots of the same variety produced in years of adequate or abundant rainfall. Apparently, where the moisture supply is deficient, plants are unable to synthesize and to accumulate the normal amounts of carbohydrates and other solids in the storage roots.

Highest yields of best quality sweetpotatoes can be expected only where the crop is planted in sufficiently moist soil and where adequate supplies of soil moisture are maintained throughout the growing season up to about 2 or 3 weeks before harvest. Approximately 18 to 24 inches of water, well distributed throughout the growing season, supplied by rainfall or by irrigation or by rainfall supplemented by timely irrigation, are needed for best sweetpotato production. Irrigation water may be supplied either by overhead sprinkler systems or, where conditions permit, by furrow irrigation methods.

In Louisiana the average daily water requirement for a sweetpotato crop is approximately one-tenth acre-inch per day during the early part of the growing season. This increases to about one-fourth acre-inch per day in midsummer.

When to apply irrigation water to keep the moisture supply adequate has been the subject of much research. A sweetpotato grower who is thoroughly familiar with the growth of the crop on his soil and under his growing conditions will learn to recognize the symptoms of moisture shortage in his plants and can gage irrigation accordingly. Various types of soil moisture measuring equipment such as moisture meters and tensiometers are available to aid the grower in ascertaining when irrigation is needed. In studies in Alabama and Arkansas where irrigation was provided only when the available soil moisture level in the main rooting zone fell to about 20 percent of the total available moisture capacity for those particular soils, yields of marketable roots were as high, or almost as high, as when irrigation was applied more frequently (when the available soil moisture level in the main rooting zone fell to more than 20 percent of the total available moisture capacity).

The major part of the sweetpotato crop in the United States is grown in more or less humid areas where the annual rainfall is at least 40 inches and where a good part of this amount is received fairly regularly during the growing season. The advantages of irrigation to supplement the moisture supplied by rainfall are now widely recognized and practiced by good sweetpotato growers.

Portable overhead sprinkler-type irrigation is widely used in humid areas. Lightweight, seamless, aluminum pipe with quick coupling joints is often used for movable feed lines and laterals. A smaller but increasingly larger part of the crop in the United States is produced under irrigation in otherwise suitable, but low-rainfall areas of the West and the Southwest. Furrow irrigation methods are widely used in those areas.

Frequently, facilities for irrigation are already in use on farms where other crops are produced. Where new installations are proposed, competent engineering advice should be obtained from private or local public sources. Nature and topography of land and technical engineering details, as well as costs of installation and operation, must be considered for any proposed installation. A dependable water supply is essential to any successful irrigation system.

HARVESTING THE CROP

Methods and Equipment

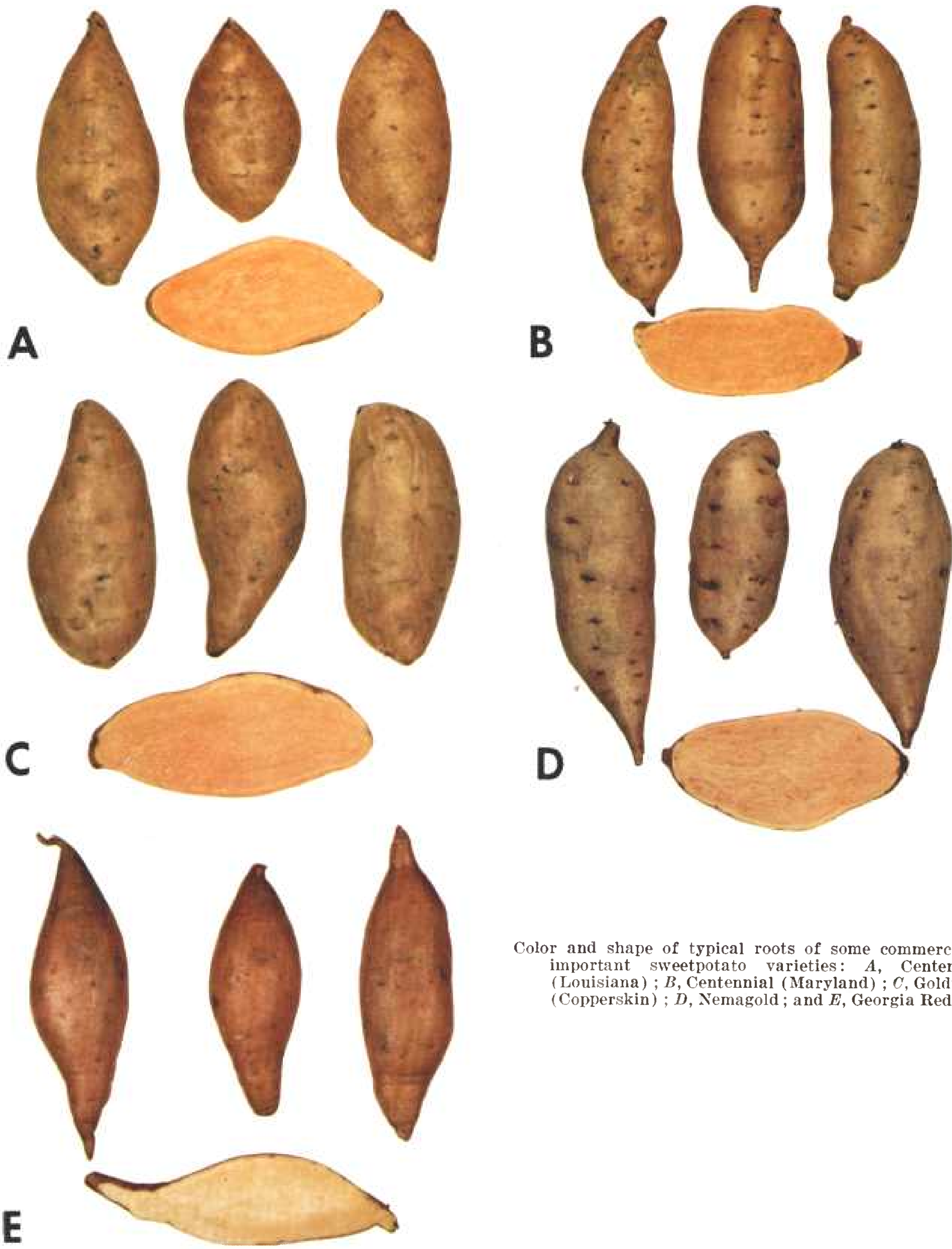
Methods used in digging and handling sweetpotatoes during harvest greatly influence subsequent storage and market quality of the crop. Care should be exercised in all operations to keep injuries to a minimum. The sweetpotato root has a thin, delicate skin that is easily broken and flesh that is readily bruised, cut, or otherwise wounded. Injuries provide opportunity for entrance of decay-producing organisms, and may constitute grade defects or lower the quality of the roots from an appearance standpoint.

The usual steps in harvesting sweetpotatoes are: (1) Vine cutting or removal; (2) either (a) plowing out or digging, followed by scratching out of roots and picking up into field containers (usually with some selection for grade) or (b) digging with a combine-type harvester unit that permits placing roots directly into field containers; (3) loading field containers and hauling them to the packing shed or storage house; and (4) either (a) grading and packing the roots preparatory to direct shipment to the fresh market or (b) placing them in the curing room preparatory to storage.

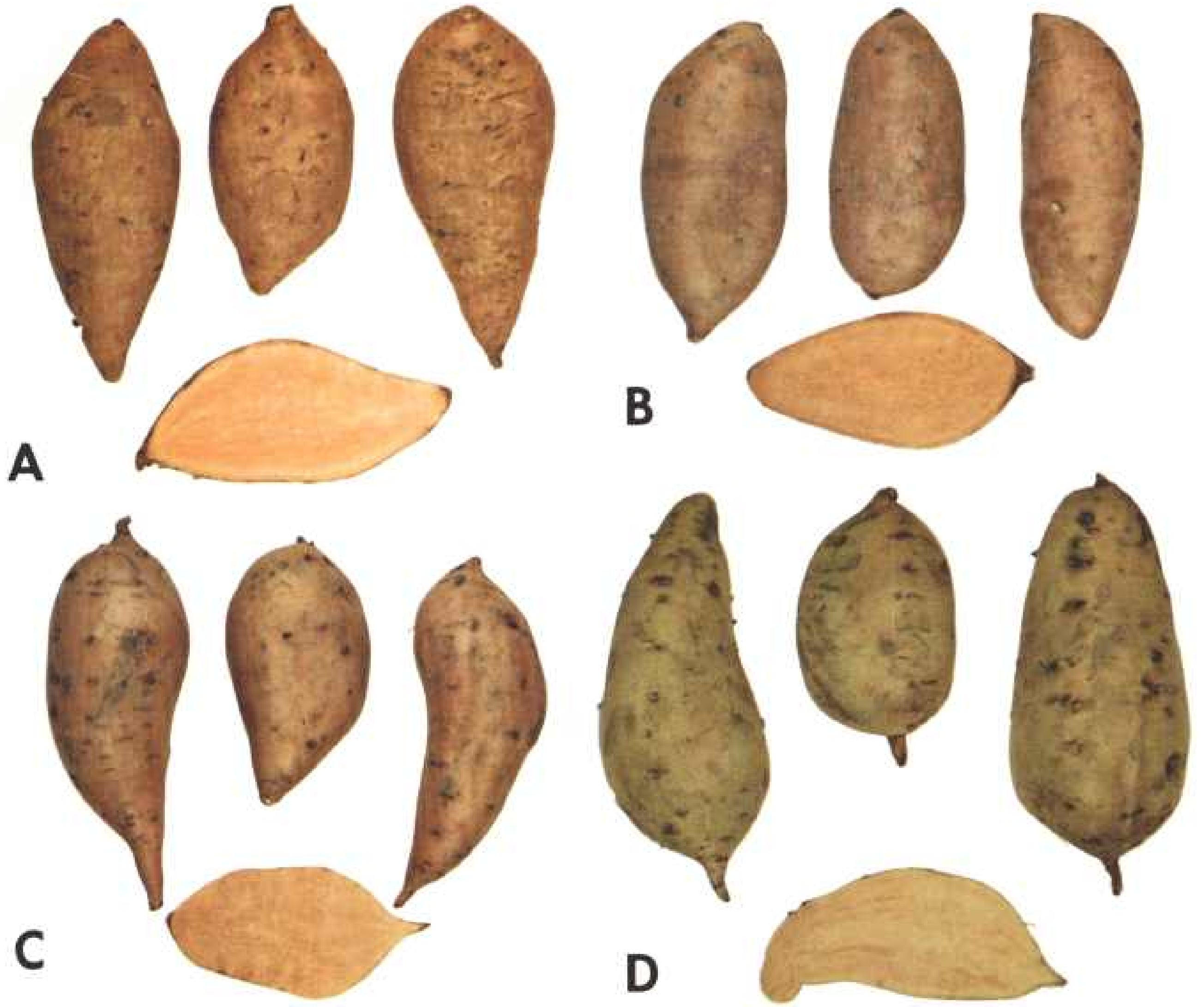
Practically all varieties of sweetpotatoes grown extensively in this country produce a vigorous vine growth. Vine cutting or removal from the crown of the rows is necessary, especially for efficient use of mechanical harvesters. Even with simpler types of digging equipment such as middlebusters or plows, unless vines are cut or removed, they become tangled around the equipment and digging operations must be stopped frequently. Vines are cut or removed either as a separate operation before digging or as a part of the digging operation itself. Numerous devices are used for cutting vines but are of three general types: (1) Vertical cutting tools such as fixed knives, colters, or disks; (2) rotary horizontal cutting blades; and (3) flail- or beater-type equipment.

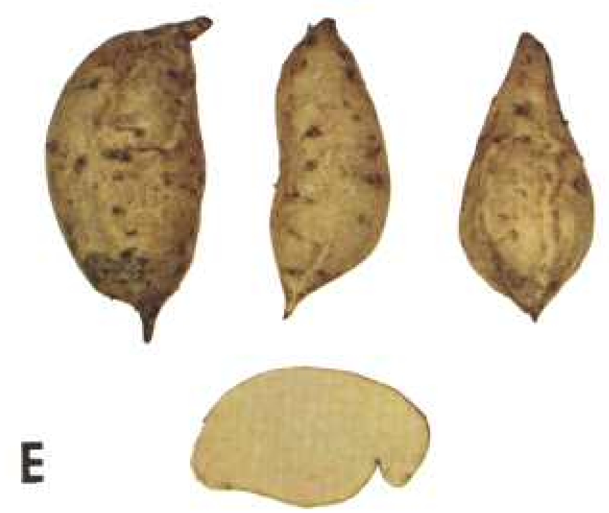
Frequently fixed knives, colters, or disks are tractor mounted or are attached to the plow or some other type digger. These cut the vines shallow and about 6 inches from row centers on one or both sides of the rows, just ahead of the digging tool. Where they can be used, shielded types of colters about 8 inches in diameter are preferred because the cutting depth can be kept shallow. Unshielded, larger colters or disks must be properly adjusted or they may run too deeply and thus cause extensive cutting of roots.

In large-scale operations vines are often removed by one- or two-row, tractor-operated, rotary-type mowers (fig. 11) in a separate operation ahead of the actual digging. Successful use of this type equipment depends on



Color and shape of typical roots of some commercially important sweetpotato varieties: *A*, Centennial (Louisiana) ; *B*, Centennial (Maryland) ; *C*, Goldrush (Copperskin) ; *D*, Nemagold ; and *E*, Georgia Red.





Color and shape of typical roots of some commercially important sweetpotato varieties: *A*, Unit I Porto Rico; *B*, Julian; *C*, Nugget; *D*, Jersey Orange; and *E*, Yellow Jersey.

FIGURE 11.—Modified chain-type harvesters with sorting conveyers, digging sweetpotatoes. Two-row, rotary-blade vine cutter in operation to left of center harvester. (Photo courtesy of The Progressive Farmer.)

having uniform-height ridges so that vines are cut off uniformly at or very near to the row surface without significantly cutting the sweetpotatoes that may be growing at shallow depths or may even be slightly exposed. This type cutter is not satisfactory for use on land where many stones are present.

Occasionally tractor-powered, flail- or beater-type equipment has been used in vine removal. On the whole, this type has not been too satisfactory for use on sweetpotatoes, particularly where metal flails are used. Costs of equipment and operation are high and damage to sweetpotatoes may be excessive where ridge heights are uneven.

Removal of vines by herbicidal chemicals has been tried experimentally but results have not been encouraging. In the tests, foliage was killed by the chemicals but the vines usually became tough and even more difficult to cut and remove by vine-cutting devices.

Horse-drawn equipment such as smaller turnplows and middlebusters is used to a limited extent in harvesting sweetpotatoes, particularly on small farms, but most of the crop is harvested with tractor-powered equipment. Much hand labor has always been required in sweetpotato harvesting, and decreasing the amount of hand labor required has been a prime objective in the continuing search for better digging equipment.

The most widely used, reasonably satisfactory, tractor-powered equipment for digging sweetpotatoes is the modifications of large (14- to 18-inch) moldboard turnplows and large middlebusters. These are usually power-lift operated and drawn deeply enough to avoid excessive cutting of marketable-size roots. Moldboards or middlebuster wings are often modified to better expose the sweetpotato roots. Moldboards are usually shortened somewhat to leave the plowed-out row only partly turned over and roots better exposed. In other modifications, parts of the moldboard or middlebuster wings are replaced by various designs and arrangements of rods that allow more of the soil to drop away during digging, thus leaving more of the sweetpotatoes on the soil surface (fig. 12).

Chain-type Irish potato diggers have been modified for digging sweetpotatoes. Both towed and tractor-mounted types have been developed (fig. 13). Various machines have been developed for digging the crop and permitting sorting of the roots off a conveyor without letting them drop back on the ground (fig. 11). Although these chain-type diggers usually remove more of the potatoes from the soil, generally they cause more skinning and bruising than do tractor-mounted turnplows or middlebusters modified for sweetpotato digging. For the fresh market, root appearance is a prime concern and skinned and bruised areas impair appearance and keeping quality. Where the crop is to be canned or otherwise processed shortly after harvest, bruising is a relatively minor concern unless damage has been severe; consequently, combine-type machines can be used for harvesting roots for these uses (fig. 14).

No completely satisfactory mechanical harvester is yet available, not even for digging stocks for canning, processing, or industrial uses. The greatest need, however, is for better machinery to harvest fresh market stocks that will avoid most of the skinning and bruising and significantly reduce the amounts of hand labor needed to recover and handle the roots. For additional information concerning harvesting machinery, consult publications by Park, Powers, and Garrison (*13*) and Poole (*14*).

When to Harvest

The bulk of the sweetpotato crop in the United States is normally harvested in October and early November. Earlier harvests are made, however, and often begin in July in the southernmost producing areas. Roots harvested in July, August, and September usually are shipped directly to market. Although the bulk of the crop harvested in October and November is placed in storage, nevertheless, many sweetpotatoes dug in this period are also shipped directly to market.

Early harvests made in July and August are possible from early plantings of varieties that

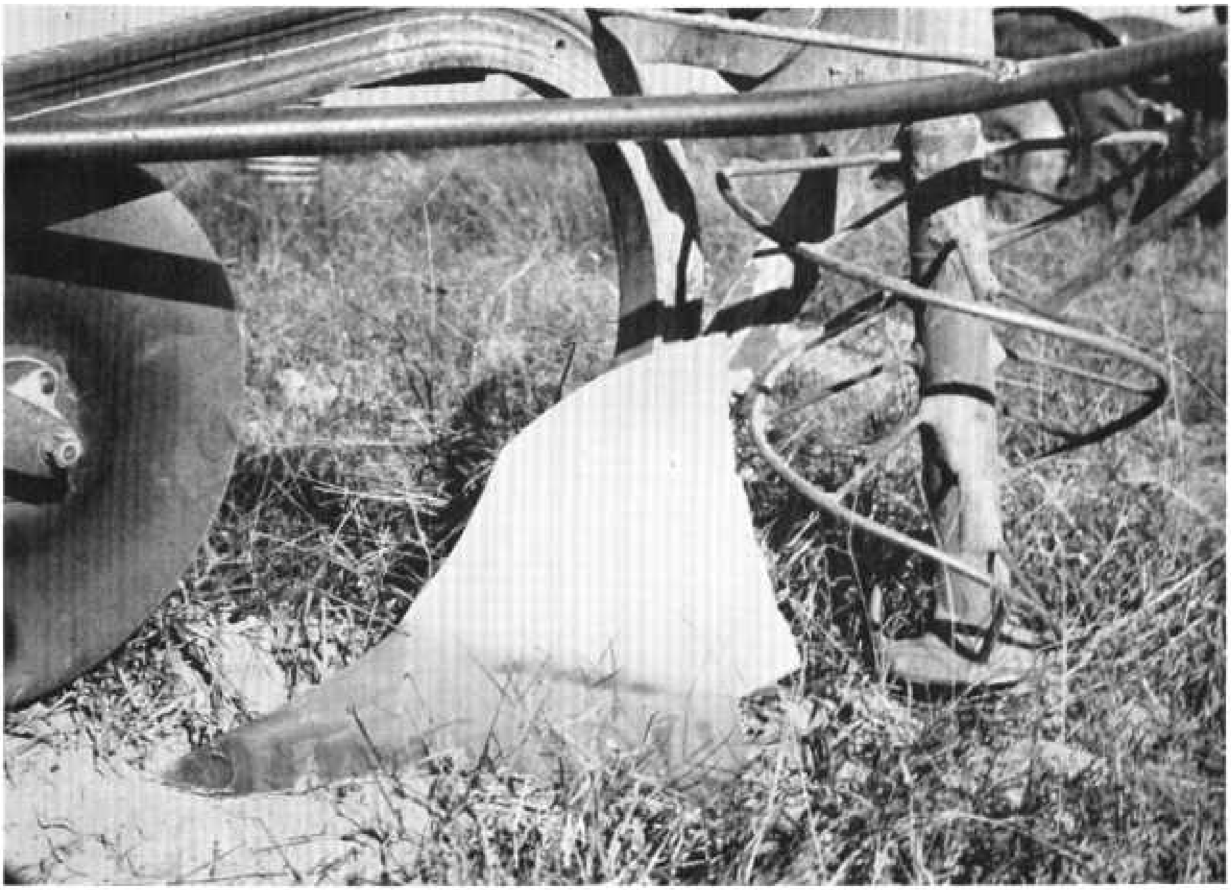


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FIGURE 12.—Modified plow with moldboard shortened and revolving spiral rod attachment added to better expose sweetpotatoes during digging.

produce marketable-size roots quickly. The times of making such early harvests depends largely on sufficiently high market prices and on yields of marketable-size roots sufficient to insure a reasonable net profit. Sometimes a grower profits more by harvesting at least a part of his crop early when yields are only fair but when market prices are high than by harvesting all of it later when yields are higher but selling prices are substantially lower. Under very favorable growing conditions, fair yields may be obtained about 100 days after planting but usually profitable yields are not obtained until about 120 days after planting.

The time for harvesting sweetpotatoes for storage usually is when the highest yields of No. 1 grade roots can be expected for the particular field and growing conditions and when the grower can complete all harvesting by the time the frost kills the vines, or soon thereafter. Usually 130 to 150 days from planting are needed to give best yields. The storage roots will continue to grow until frost kills the vines but yields will not increase after that. The danger of losing all or part of the crop still in the field increases after frost has killed the vines. Such losses may result from a hard freeze that damages roots near the surface of the soil or from chilling injury to all roots as the soil temperature drops to 50° F. or lower.

The greatest danger from delayed digging, however, is in the effect that wet soil has on the roots. Excessive moisture in the soil, either before or after frost kills the vines, causes physiological changes in the roots. Under such conditions, the roots cannot heal injuries properly, and decay-producing organisms gain entrance into the roots. Before frost, warm weather and evaporation of moisture from the soil and vines help to overcome the excessively wet condition of the soil. After frost, the soil does not dry out easily and this further delays digging and increases the possibilities of root damage.

Where sweetpotatoes are known to have been exposed to chilling soil temperatures or to un-

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FIGURE 13.—Chain-type sweetpotato diggers: *A*, Tractor-mounted form; *B*, towed form.

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FIGURE 14.—Combine-type harvester digging sweetpotatoes for canning and processing or industrial uses.

favorably wet soil conditions, immediate disposal for fresh market use is recommended rather than storage of the crop for later sale. In general, therefore, harvesting should be done when the soil is in good working condition and the weather is fair, due consideration being given to the condition of the crop and to its anticipated use.

Handling and Grading in the Field

Whatever the digging equipment used (except that of the combine type), after plowing out, those roots remaining in the soil must be scratched out by hand and the sweetpotatoes picked up and placed in the containers in which they will be transported or stored. Care should be exercised during the scratching out, picking up, and handling operations to avoid unnecessary skinning and bruising of roots, which will result in poor appearance, rotting, and inferior quality. In handling the crop, avoid practices such as throwing the sweetpotatoes into "heap rows" in the field, throwing them directly into trucks or wagons for transport, or carrying them from the field in bags—all of which lead to unnecessary skinning and bruising.

Someone has aptly said that for the best quality sweetpotatoes the roots should be handled "like eggs." The amount of handling can be lessened if the grower will at least partly grade the crop in the field by putting the roots of separate grades directly into the baskets or crates in which they will be stored or marketed. The sound, uninjured, best quality sweetpotatoes should be picked up and stored separately from smaller ones and from those that have been cut or are otherwise inferior.

Any sweetpotatoes harvested from field areas where black rot infected roots are found should be sorted, graded, and shipped to market as soon after harvest as possible. It is impossible to tell how many sweetpotatoes from such field areas were infected during harvesting and handling. Curing of infected roots will not prevent development of black rot if the roots are stored.

To facilitate surface drying and removal of adhering soil, some exposure of roots after digging will usually be required before the crop is graded and packed into field containers. However, care must be exercised not to allow the roots to be injured by too long exposure. As little as 30 minutes' exposure in bright sunshine during hot weather may sunscald freshly dug sweetpotatoes. This detracts from their appearance and often causes them to decay. Vines placed over filled containers will protect the sweetpotatoes from exposure until they can be hauled from the field. Because sweetpotatoes are injured by exposure to low temperatures, the harvested roots should not be left in the field overnight when air temperatures are likely to drop to near freezing.

Several kinds of containers are used for picking up, hauling, and storing sweetpotatoes. The most commonly used containers are tub-bottom bushel baskets, various types of wirebound straight-side wooden crates, and either nailed or nailed and metal-reinforced field boxes. Roots are usually bruised more when packed and handled in bushel baskets than in crates or field boxes. This bruising occurs because baskets, which are usually stacked in a pyramidal manner both in hauling and in storage, are packed with a bulge in the lid and have somewhat less rigid sides than crates or boxes. Consequently, the sweetpotato roots must support more of the load weight in the baskets.

Some of the various types of wooden handling containers such as the James and Hybrid crates are used not only for transporting roots from the field and for storing but also for shipping to market. The Durabox, designed essentially to use in palletized handling from the field and in storage, is also used for shipping. In some of the larger sweetpotato operations, filled field crates or boxes are loaded in the fields onto pallets placed on truck beds, in a systematic pattern that gives stability to the stacks of loaded containers and permits unitized handling with forklift equipment during subsequent curing, storing, and handling operations (fig. 15). Some or the bruising of roots that occurs during rehandling of individual containers is thus avoided.

Sweetpotatoes for processing may be transported in baskets or crates but more often are transported to the processing plant in bulk in open-bodied trucks or vans. Sometimes the roots for processing are dumped into one-half-ton capacity field pallet boxes and hauled from the field on trucks. The boxes are subsequently handled with forklift equipment at the processing plant.

Selecting and Storing Seed Stock

As far as possible, fields planted for production of sweetpotato seed stock (bedding roots) should be grown from vine cuttings to minimize the amount and possibility of spread of diseases. In addition, any plants showing any symptoms of disease should be removed from the field during the growing period. Seed stock must be dug and selected before the plant stems have suffered frost damage.

Hills that are much less productive than those nearby should be looked upon with suspicion. Disease is often, but not always, the cause of such unproductiveness. Choosing seed stock from only the productive hills, however, helps to avoid disease that is not otherwise evident. The smaller sweetpotato roots (not "strings") from a *clean, productive* hill are just as valuable for seed as the medium-size ones and are preferred to the large ones, which will produce fewer plants per bushel of stock bedded than medium and small roots. (See p. 27.)

Recommendations often have indicated that the incidence of stem rot (fusarium wilt) in seed roots may be significantly reduced by splitting the stems at harvest and eliminating roots from hills showing discoloration in the stems. While some reduction in wilt incidence may be obtained with this procedure, the improvement is usually not as good as desired. Too many infested hills escape detection and, in addition, roots are infected from the wilt organism present in the soil. It is more practical to discard or sell roots from fields showing significant amounts of stem rot than to try to clean them up for use for seed by splitting stems. Obtain a new source of stock known to be essentially free of stem rot. Use of seed produced in certified seed programs is especially recommended.

Wherever possible, seed stock should be dug and selected during warm, sunny, dry weather. It should be handled carefully to avoid unnecessary bruising or skinning, placed in clean containers, then transported promptly to a clean storage house, and properly cured and stored. Roots should not be injured by unnecessary handling, once they are placed in storage.

To allow a safe margin for shrinkage and other possible losses in storage and for roots that might have to be discarded because of defects at bedding time, at least 15 bushels of seed stock should be saved for each acre to be planted with transplants the next year. (See discussion on amounts of seed stock required, pp. 26 to 27.)

CURING AND STORING

Purposes and Requirements

The primary purpose of curing and storing sweetpotatoes is to keep them in good condition for marketing during the winter and spring and to preserve seed roots to be used in producing plants for the next crop.

Regardless of how carefully sweetpotatoes are handled during harvesting, some wounding of the roots is inevitable. To prevent infection of wounds by disease-producing organisms, the roots are brought into storage as soon after digging as practical and are cured for 4 to 7 days at from 80° to 85° F. and from 85- to 90-percent relative humidity. Under these conditions injuries are healed rapidly through the formation of new wound-cork layers beneath the wounded areas. The rate of healing is slower at temperatures below 85° or above 95° F. and at relative humidities below 85 percent. Slow healing allows more decay-producing organisms to gain footholds in the roots than does rapid healing. Rapid healing of the broken ends, skinned areas, and other wounds immediately after harvest usually prevents such injuries from becoming unsightly blemishes that cause roots to be placed in lower grades or to be passed up by the housewife on the retail display counter. Providing good curing conditions should not, however, be used as a substitute for observing good harvesting and handling practices that keep root injuries at a minimum.

The conditions to which the roots are subjected for the first 3 or 4 days after harvest determine the degree of success to be attained in controlling decay. Extending the curing time beyond about 7 days cannot compensate for the use of less effective temperatures or humidities. Even with optimum conditions, the time of curing should not be extended unnecessarily because this leads to excessive sprouting and shrinkage and to shortened storage life of the roots. Roots that have been properly cured usually have produced a few very short sprouts and have a somewhat velvety feel.

Where roots are to be shipped *soon after harvest,* the curing period may be extended and the humidity reduced during the last few days as a means of "setting" the skin so that the roots may be graded, packed, and shipped without excessive loss of skin.

In addition to healing wounds, curing also speeds up those physiological changes that make the sweetpotatoes more palatable after cooking than they are if they are cooked immediately after harvest. The major change involves the conversion of starch to sugars and dextrins. Freshly dug roots convert less of their starch to sugars and dextrins during cooking than do comparable roots after they have been cured. Although the sugar content of the raw roots usually increases somewhat during curing and increases still more during storage at recommended temperatures, the greatest change occurs during cooking.

Varieties of sweetpotatoes differ in the extent of conversion of starch to sugars and dextrins during cooking and these differences are recognized in the trade when classifying varieties as moist-flesh (or "yam") or dry-flesh type. (See p. 7.)

After curing, the storage room temperature is lowered to 55° to 60° F. but the relative humidity is kept at 85 percent to 90 percent for the duration of storage. The temperature is lowered to reduce the physiological activities of the roots and thus to keep the sweetpotatoes in good condition as long as possible. The lowered temperature also reduces the activity of most decay-producing organisms.

Although lowering the storage temperatures below 55° F. will reduce the physiological activities of the roots and retard decay-producing organisms still further, sweetpotatoes cannot be stored for long periods at temperatures much below 55°. Sweetpotatoes are damaged by temperatures below this point and the degree of injury is about proportional to the time and temperature of exposure. Damage resulting from a few days' exposure at 50° often may not be noticeable, but that from 1 or 2 days' exposure at 32° usually is. Chilling temperatures can result in internal discoloration and breakdown, increased susceptibility to decay, poor cooking quality, and reduction of the sprouting ability of the roots. Roots will freeze and become worthless at temperatures below 30°.

Although rapid healing of wounds by curing at the recommended ranges in temperature and humidity will help prevent decay-producing organisms from gaining entry into sweetpotato roots, there is one noteworthy exception. Where black rot (see p. 53) is in the field at harvest, it may cause many roots to develop the black spots typical of this disease in storage, even though the roots are properly cured. Therefore, when black rot is present, the crop should be marketed as soon as possible after harvest. Fortunately, this disease, which was once very troublesome, is not often found today because effective control measures are usually used during production of the crop. Black rot can be controlled reasonably well during marketing by good sanitation practices in the packinghouse and by treatment of roots with SOPP or other registered, effective fungicides. (See "Preparing Sweetpotatoes for the Fresh Market," p. 46.)

When infected with the internal cork virus disease, storage roots of most sweetpotato varieties, such as Centennial, Georgia Red, Goldrush, and Porto Rico, develop characteristic corky flesh lesions if they are stored at temperatures above 60° F. (See p. 68.) Although some lesions may be present at the time of harvest, especially when harvest is preceded by a period of warm weather, most lesions develop and enlarge during storage when temperatures are kept higher than recommended. Some sweetpotato varieties, however, are symptomless carriers of the internal cork virus and do not develop corky lesions in infected roots even if they are stored at temperatures above 60°.

During curing, sweetpotatoes may lose up to 5 percent of their weight. The weight loss continues during storage but at a much slower rate. It is not uncommon for sound roots that have been properly cured and stored to lose approximately 15 percent of their weight during 5 months' storage. Decay adds to the weight loss.

The development of pithiness is accelerated by the same conditions that cause weight loss. High temperatures during storage increase respiration and sprouting of roots, thus increasing pithiness. Low relative humidities during storage also increase weight losses and accelerate development of the pithy condition. Varieties differ in the rates at which they lose weight or volume and consequently differ considerably in the rates at which they become pithy. (See table 9, column 7 and footnote 3.) Roots of the varieties Goldrush, Nugget, and Porto Rico, for example, become pithy slowly —even after 6 or more months in storage; whereas roots of the varieties Gem, Jersey Orange, and Nemagold become pithy quickly—often after only 2 or 3 months in storage. Since pithiness is evidence of reduced cooking quality, varieties that become pithy quickly should be marketed soon after harvest or after short periods of storage.

Storage House Operation

In managing a storage house the objective should be to provide the most effective conditions of temperature, humidity, and ventilation for proper curing and storing of the roots. This is more difficult than might be supposed.

The construction of the storage house will affect to a large extent the manner of house operation. Weather conditions, type of storage containers used, and nature of market outlets will also affect the operations. Storage facilities and containers should be clean. They are usually fumigated with suitable materials and procedures, especially when black rot or other decay-producing organisms have caused noticeable losses during the preceding storage season.

From the standpoint of good management, it is usually recommended that the storage house be divided into several compartments or rooms. One room at a time should be filled with sweetpotatoes within a period of a week or less. Proper conditions for curing should be provided during the filling period and for a few days afterward, then the temperature should be reduced to the level required for the duration of storage. This sequence is repeated with each storage room, and avoids holding some of the sweetpotatoes under curing conditions throughout an extended harvest period, a situation that cannot be avoided where all of the roots from an extensive operation are cured in one large room. The stored roots should not be disturbed more than necessary after curing is completed because unhealed injuries open the way for infection and decay.

A recently devised system offers considerable opportunity for improved curing and storage house management. Under this system, the roots are handled from the field in field boxes or pallet boxes and placed on pallets, then the palletized units are placed in a curing room operated at proper temperature and humidity. At the end of the curing period, the palletized units are picked up by fork-lift equipment and moved to areas where proper storage conditions are maintained (fig. 15). Handling in this way is so gentle that the cured roots are injured very little and wounding is usually not detectable. This system permits close control of curing time and of curing and storage conditions, requires less expensive construction than compartmentalized storage, and offers opportunities for segregating the palletized units according to grower, field of production, variety, and grade.

FIGURE 15.—Palletized handling of sweetpotatoes with fork-lift equipment. (Photo courtesy of North Carolina State University.)

In the late summer and early fall, especially in the warmer producing areas, the weather at harvest and shortly thereafter is often so warm that no heat need be supplied to the storage to obtain temperatures approximating those needed for curing. Later in the season and in cooler growing areas, some heat is usually supplied. The routine opening and closing of doors usually provides sufficient ventilation to take care of the oxygen requirements of the respiring roots and the dissipation of carbon dioxide produced by them. Except in particularly dry seasons or in dry climates, the stored roots, adhering soil, and storage containers usually provide sufficient moisture to keep the humidity up to the required level.

When heat is added to the storage, it should be supplied and distributed in a manner that will provide essentially uniform warming of all the stored roots as the heat rises in the storage room. To accomplish this, heat is released under a slatted false floor, from registers located either in the cement floor or low on the walls or, in a more recently devised procedure, from trenches in the floor. Trenches permit better distribution of heat than can be obtained with a few scattered registers, but they do not distribute the heat as well as when the heat is released under a slatted false floor. Trenches, usually measuring about 12 inches wide and 12 to 16 inches deep, permit the use of fork-lift trucks whose weight would not be supported by the usual slatted false floor. The trenches are covered with short pieces of 2- by 6-, 2- by 8-, or 2- by 10-inch lumber recessed into the cement floor to make the floor level. These pieces are spaced to allow the heated air to rise in the amounts estimated to be needed in the various parts of the storage room. Some mechanical circulation of air is usually desirable if the filled containers are stacked more than about 10 feet high.

To provide ventilation for cooling the storage or for removing condensation, air intake ventilators are usually placed near the floor or below the level of a slatted false floor of the storage room, and exhaust vents are placed in the ceiling or roof. The warm air at the top of the storage rooms is often exhausted with fans. The introduction of cold air into the bottom of storage rooms often causes chilling injury to roots stacked near the intake vents while temperatures at the top of the rooms may become too high. The warm temperatures near the top of the rooms are usually accompanied by high relative humidities, conditions that often induce excessive sprouting of roots in this part of the storage.

Another ventilating system has been installed in some storage facilities (fig. 16). In this system fans blow air into the top of the storage rooms at a rate of 1 to 2 cubic feet per minute per bushel of storage capacity. Exhaust vents are on outside walls at ceiling level. A baffle is usually used to distribute the cold air over the stacked sweetpotatoes. The fans are controlled by time clocks and thermostats that permit them to operate when the room is warmer than desired (above 60° F.), but only at night or whenever the outside air temperature is cooler than the room temperature near the ceiling. This system uses the well-known principles that warm air rises and cold air settles. Heat, when needed, is introduced as uniformly as possible into the bottom of the storage. Cold air is introduced as uniformly as possible into the top to help maintain more nearly uniform temperatures throughout the storage. The introduction of cold air into the

FIGURE 16.—Modern curing and storage facility, designed for palletized handling of sweetpotatoes. Curing area at left; storage rooms on right provided with top air intake and exhaust ventilation. (Photo courtesy of North Carolina State University.)

top puts the cold air where it is most needed to control temperature without danger of causing chilling injury. Since cold air can carry relatively less moisture, the introduction of cold air reduces the relative humidity in the top of the storage, but usually not below the required level. The reduction of temperature and humidity in the top of the storage helps reduce excessive sprout growth of roots stored in the upper parts of the room.

A small part of the sweetpotato crop is usually stored until the succeeding new crop is available. Mechanical refrigeration is usually used when the crop is stored through the summer months because summer air temperatures are too high to maintain satisfactory storage temperature control by ventilation alone. The refrigerated air is distributed over the top of the stacked sweetpotatoes in a manner similar to that provided in the overhead ventilation system described above. Since the refrigerated air is continually recirculated, some air is introduced from the outside to maintain fairly normal oxygen and carbon dioxide levels in the storage atmosphere. Construction details, weather conditions, and product loads influence the amount of mechanical refrigeration needed. With reasonably good insulation many refrigerated storage rooms operate with a ton of refrigeration capacity per 1,000 bushels of sweetpotatoes. Qualified refrigeration engineers should be consulted for specific recommendations for a particular installation.

Storage temperatures are easily measured and fairly easily controlled by adding either heated or cold air. However, relative humidities are not easily measured and usually less is done to control them. Immediately after harvest, the roots give off moisture through injuries and moisture is added to the storage by soil adhering to the roots and sometimes by the storage containers that have picked up moisture while sitting on damp soil in the field. As a storage room is filled with sweetpotatoes, the volume of air left in the room is correspondingly reduced. Since 100 pounds of roots (about 2 bushels) will give off approximately 3 pounds of water during curing, most of this during the first few days, and since 1 pound of water is enough to completely saturate 500 cubic feet of dry air, one can easily understand why the relative humidity in a storage room is usually sufficiently high, and often so high that some ventilation is needed to prevent condensation. When wounds have healed, moisture is given off less readily by the roots. However, less moisture is required to maintain the relative humidity near 85 to 90 percent at the lowered storage temperature.

In arid climates or where considerable heat must be added to the storage, the relative humidity may drop below desired levels. Often sprinkling water on the floors of the storage rooms, especially on dirt floors, increases the humidity sufficiently. Sometimes mechanical atomizing units controlled by humidistats are used. In storages using trenches, water can be added in the trenches or in the furnace duct system.

Proper insulation of the walls and ceiling of the storage structure is very important in the maintenance of high relative humidity. Moisture will condense on inner wall or ceiling surfaces of the storage room if the temperature at these surfaces drops to 78° F. at any time while the curing temperature of 85° is being maintained in the room and while the relative humidity of the air adjacent to the wall surfaces is above 80 percent. As far as practical, therefore, storage buildings should be sufficiently insulated to prevent the inside surface temperatures from becoming cold enough to allow such moisture condensation. Some ventilation of the room may be required where moisture condenses appreciably on storage walls and ceilings.

PREPARING SWEETPOTATOES FOR THE FRESH MARKET

Sweetpotatoes should be carefully prepared for market. Operations involved in such preparation vary considerably, depending principally upon market demand and custom. Some sweetpotatoes are transported directly to the fresh market, following digging and grading in the field. (See p. 41.) More often they are taken to a packing shed or storage house on the farm or to a commercial packing house for additional preparatory treatment either before transport directly to market or after a period of storage.

Whether performed on the farm or in a commercial packinghouse, the usual preparatory operations include washing, sorting and grading, sometimes treating with registered fungicides to prevent decay, packaging, and finally loading for shipment. Sometimes wax is applied to enhance the appearance of the roots for certain market outlets. Equipment used in these operations should be constructed and used in a manner that will keep injuries to the sweetpotatoes at a minimum. Skin is easily removed from freshly harvested roots and such skinning detracts from their appearance. Sweetpotatoes removed from storage are also rather easily injured, allowing decay to develop.

Washing

The sweetpotatoes are first washed. They may be dumped directly from the field containers onto a roller conveyor or into a tank of water with an inclined roller conveyor for removing them. In either case the sweetpotatoes then pass under several nozzles on the washing equipment, which spray water on the sweetpotatoes while they are scrubbed from below with pintle rubber-, nylon-, or tampico fiber-covered rollers. The number of nozzles and rollers used depends to some extent on the type of soil adhering to the roots.

Washing aids in subsequent detection and removal of defective sweetpotatoes, especially those showing insect injuries or skin discolorations caused by the scurf disease.

Sorting and Grading

The sweetpotatoes next pass from the washer onto a conveyor where defective and diseased or other cull roots as well as roots too large or too small for the fresh market are first sorted out and removed.

Where sweetpotatoes are treated with registered fungicides to reduce losses from decay during marketing (discussed below), the treating unit follows this first conveyor. The remaining roots then pass to a second conveyor from which they are separated, according to required standards of size and other characteristics, into desired market grades. Federal grade standards are usually followed (*20*). However, since the quality requirements of specific market outlets vary a great deal, sorting and grading often are done according to the demands of the specific market, following local or State regulations applicable to the sorting and grading operations. At this stage the roots are packed in suitable shipping containers or are set aside for later final grading and packing.

Sorting and grading are very important, and if done improperly, can result in buyer dissatisfaction and direct monetary loss, depending upon whether sorting is too strict or not strict enough.

Treating to Prevent Decay

Some injury to sweetpotatoes is bound to occur during handling, washing, sorting, and grading. The bruised or crushed tissues offer favorable locations for decay to develop. Soft rot causes most decay but other diseases such as black rot, surface rot, and fusarium rot may also cause losses during marketing. To prevent or greatly reduce such losses, the sweetpotatoes are often treated with registered fungicides after washing and before the roots are graded and packed for market. One effective treatment is to thoroughly wet the roots with a solution of SOPP. This treatment is followed by a brief rinse with water or wax emulsion (see "Waxing" below). SOPP is effective against the soft rot and black rot organisms. Another material, 2,6-dichloro-4-nitroanaline (Botran), is effective against the soft rot organism but does not control black rot. Botran is simple to apply, relatively inexpensive, and less likely than SOPP to cause root discoloration.

Instructions supplied with each fungicide should be followed carefully to avoid injury to the sweetpotatoes or to the people working in the packinghouse, and to comply with pesticide residue requirements.

Waxing

Waxes registered by the Food and Drug Administration may be added to the roots to meet the demands of some market outlets. Wax may be sprayed on as a water-wax emulsion or brushed on the sweetpotatoes with a hot wax applicator.

The spray application of wax may serve as the rinse recommended after treatment of the roots with SOPP.

Packaging

Sweetpotatoes may be packaged in bushel baskets, wirebound crates (James, Hybrid, 3-way Durabox), or corrugated cardboard boxes for shipment to market from either farm or the commercial packinghouse. Whatever container is used, the roots in the top layer are usually arranged in an orderly manner ("faced") to present an attractive pack (fig. 17). The wirebound James and Hybrid crates are stacked on their sides to prevent damage to roots in the bulge that develops in the top of the container when it is filled. Because corrugated boxes do not injure the roots as much after they have been treated to prevent decay during sorting and grading, decay occurs less frequently during shipment of roots in these boxes than in some other types of containers.

Cost, convenience, and market preference also influence the choice of shipping container.

Sweetpotatoes vary considerably in specific gravity, and a package labeled to contain "50 pounds net" must contain 200 to 300 cubic inches more volume for roots that have been

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FIGURE 17.—Orderly arranging of sweetpotato roots ("facing") on top layer of marketing container to present an attractive pack.

stored 4 to 5 months than a package containing 50 pounds of freshly harvested roots. Most of the shipping containers can provide this much flexibility. Because of weight loss in transit and handling, a package labeled "50 pounds net" is usually packed with 51 or more pounds of sweetpotatoes at the shipping point.

Shipping

A large part of the sweetpotato crop is shipped to the fresh market from the farm or the commercial packinghouse by truck. Special provision for air circulation in or around the packages in a load is usually unnecessary with bushel baskets or wirebound crates. Loads shipped in corrugated boxes, however, should be stacked to maintain air channels along the side walls and through the bunker so that air can circulate, especially in winter months when heat is added to the load to prevent chilling or freezing. Because of the sensitivity of sweetpotatoes to chilling injury, temperatures should not be allowed to drop below 55° F.

Additional detailed information concerning these various operations, the equipment involved, and precautions to be observed in treating, grading, handling, and shipping may be obtained by consulting Marketing Bulletin 38, "Preparing Sweetpotatoes for Market" (*10*), and other publications of the U.S. Department of Agriculture (*9, 11, 12, 20*).

Part II: DISEASES[3]

Sweetpotatoes are damaged by a number of important fungus and virus diseases and by nematodes. Such damage results in serious losses in yield and quality. Some of the diseases affect sweetpotatoes primarily in the field, others primarily during storage, handling, and marketing. Some are serious both in the field and during storage.

Damage to the crop may be through a stunting or lowering of the vitality of the plants and, as a consequence, in reduced yield; or damage may be through reductions in the quality and, thus, marketability of the sweetpotatoes by causing less desirable root shapes, appearance, colors, textures, and flavors. Losses may be heavy during storage as a result of soft rots and other diseases, which may either make damaged roots unsalable or at least materially shorten the storage life of the roots and the period of time over which they may be marketed.

Since about 1945 several virus diseases have become increasingly serious in sweetpotato production. Some progress has been made in learning the nature of some of these virus diseases, the modes of dissemination, and procedures that aid in their control. More information is needed, however, regarding these aspects of the virus diseases, particularly those regarding effective, practical measures that can be applied by growers to control or eliminate the diseases. We must find sources and means of providing growers with adequate supplies of virus-free propagating stocks. Virus diseases are usually difficult to diagnose in the field since sweetpotatoes ordinarily fail to exhibit foliage symptoms characteristics of the diseases until midseason or even later, if at all.

Organisms causing the diseases considered in this publication are identified in the tabulation that follows. Still other diseases can injure sweetpotatoes in the field and during storage and handling. However, economic losses from these other diseases are usually less important than from the diseases discussed here.

[3] The section "Diseases" was prepared by revising and supplementing information contained in U.S. Department of Agriculture Farmers' Bulletin 1059, "Sweetpotato Diseases" (*8*), now out of print. E. M. Hildebrand, plant pathologist, assisted in preparing the discussion on virus diseases.

AGENTS CAUSING SWEETPOTATO DISEASES

Fungi

Disease	*Causal organism*
Field diseases:	
Stem rot	*Fusarium oxysporum f. batatas*
Black rot	*Ceratocystis fimbriata* (formerly *Endoconidiophora fimbriata*)
Foot rot	*Plenodomus destruens*
Scurf	*Monilochaetes infuscans*
Root rot	*Phymatotrichum omnivorum*
Mottle necrosis	*Pythium ultimum*; *P. scleroteichum*
Soil rot	*Streptomyces ipomoea*
Phyllosticta leaf blight	*Phyllosticta batatas*
Septoria leaf spot	*Septoria bataticola*
White rust	*Albugo ipomoeae-panduratae*
Storage rots:	
Soft rot	*Rhizopus stolonifer*
Black rot	*Ceratocystis fimbriata* (formerly *Endoconidiophora fimbriata*)
Surface rot	*Fusarium oxysporum*
Dry rot	*Diaporthe batatatis*
Java black rot	*Diplodia theobromae* (*Botryodiplodia theobromae*)
Charcoal rot	*Macrophomina phaseoli*

Nematodes

Common name	*Scientific name*
Root-knot nematodes	*Meloidogyne spp.* (formerly *Heterodera marioni*)
Lesion nematodes[1]	*Pratylenchus* spp.
Reniform nematodes[1]	*Rotylenchulus reniformis*
Spiral nematodes[1]	*Helicotylenchus* spp. and *Scutellonema* spp.
Dagger nematodes[2]	*Xiphinema americanum*
Lance nematodes[2]	*Hoplolaimus galeatus*
Sting nematodes[2]	*Belonolaimus longicaudatus*
Ring nematodes[2]	*Criconemoides* spp.

[1] Cause root decay.
[2] Cause root pruning.

Viruses

Internal cork
Chlorotic leafspot
Yellow dwarf
(Feathery mottle)
Russet crack

GENERAL PROCEDURES FOR CONTROLLING SWEETPOTATO DISEASES

Several general procedures for controlling sweetpotato diseases have been considered in various preceding discussions in this handbook. The following outline summarizes these practices:

Field Diseases

(1) Plant on essentially "clean" land. Ordinarily, sweetpotatoes should be included only every 3rd or 4th year in rotations with other crops that are not hosts for diseases affecting sweetpotatoes.
(2) As far as practical, plant roots that are: (a) Produced on plants grown from vine cuttings or bed cuttings; (b) carefully selected in the field for type and freedom from diseases; and (c) stored separately from other sweetpotato stocks.
(3) Clean and treat the beds and bedding media with registered fungicides to free them of sweetpotato disease-producing pathogens.
(4) At bedding time treat roots with registered fungicides to control disease organisms present on root surfaces.
(5) Grow disease-resistant varieties when available. In the absence of such resistance, propagate only from clean stocks and control insects or other vectors that may spread disease infections in the field.

Storage Diseases

(1) Store only sweetpotatoes that: (a) Are as free as possible of diseases; (b) have been carefully dug and handled; and (c) have been placed in clean field and storage containers.
(2) Store in properly constructed and cleaned storage houses.
(3) Cure freshly harvested roots at effective temperatures (80° to 85° F.) and relative humidities (85 percent to 90 percent) to insure healing of wounds and minimal development of soft rots or other rots. Maintain storage thereafter at 55 to 60° F. and 85 to 90-percent relative humidity.
(4) Move stocks only when necessary during the storage period to keep at a minimum injuries that may result in losses by decay.

Specific field and storage diseases and methods for their control are considered in more detail in the sections that follow. The reactions of 23 commercially grown sweetpotato varieties to six important diseases are indicated in table 21.

TABLE 21.—*Reaction of 23 commercially important American sweetpotato varieties to 6 diseases* [1]

Variety	Disease reaction of [2]—					
	Stem rot	Black rot	Scurf	Soil rot	Internal cork [3]	Root knot
Allgold	S	S	S	I	R	S
Carogold	I	S	S	---	S	R
Centennial	I	S	S	S	I	S
Georgia Bunch Porto Rico.	S	S	S	S	S	I
Earlyport	S	S	S	S	R, I	S
Earlysweet	I	---	---	---	I, S	---
Georgia Red	S	S	S	S	S	S
Goldrush	R	S	S	S	S	S
Jersey Orange	S	S	S	S	R	I
Kandee	S	S	S	S	R	R, I
Nancy Hall	S	S	---	---	R	---
Nemagold	S	S	S	I	I	R
Nugget	I, S	I, S	S	I, S	R	S
Oklamar	I	I	I	I	---	S
Orange Little Stem	S	S	S	S	I	I
Unit I Porto Rico	S	S	S	S	S	S
Redgold	I	I	S	S	I	S
Sunnyside	S	I	S	S	R	R
Triumph	R	S	R	---	I	S
Virginian	S	I	S	---	R	S
Yellow Jersey	S	S	S	---	R	S
Pelican Processor [4]	R, I	S	S	S	R	S
Whitestar [4]	R, I	S	S	S	R	---

[1] Ratings supplied by researchers in National Sweetpotato Cooperator Group.
[2] Reaction symbols used: S = Susceptible (severe symptoms under a wide range of conditions); I = Intermediate (mild disease symptoms ordinarily, but ranging up to severe under some conditions); R = Resistant (very mild or no disease symptoms under a wide range of conditions).
[3] Tentative ratings pending further confirmatory tests.
[4] Industrial-type varieties, low in carotene.

FIELD DISEASES AND THEIR CONTROL

Stem Rot

(Fusarium Wilt, Blue Stem, Yellow Blight)

Description

In the field, the first indication of stem rot is a slight change in the appearance of the youngest leaves. These become dull, then yellow between the veins, and pucker somewhat. Then the vines wilt and eventually the entire plant collapses and dies (fig. 18). The stems of diseased plants darken inside and sometimes split open near the ground level. This discoloration of the stems sometimes extends 3 to 5 feet from the hill, a sure sign of stem rot. The fungus causing stem rot may also invade the fleshy roots and cause a blackened ring about one-fourth inch below the surface (fig. 19). Sprouts produced from such sweetpotatoes are likely to be diseased.

In the plant bed, the symptoms of stem rot are similar to those in the field. Diseased plants can generally be detected by the purplish tint that shows through the white basal part of the stem and by the yellow color of the leaves.

Prevalence and Loss

Stem rot is an important field disease. It occurs in every State where sweetpotatoes are grown. From 10 to 50 percent of the crop of susceptible varieties may be destroyed in infested plantings, and stem rot has been known to kill 95 percent of the plants in some fields.

Means of Distribution

The stem rot fungus can overwinter in the soil on the remains of dead sweetpotato vines and in the roots in storage. The disease may be carried from one field to another in the same locality by insects, farm animals, farm implements, drainage water, wind, and discarded diseased roots dumped on the fields, either before or after being fed to stock.

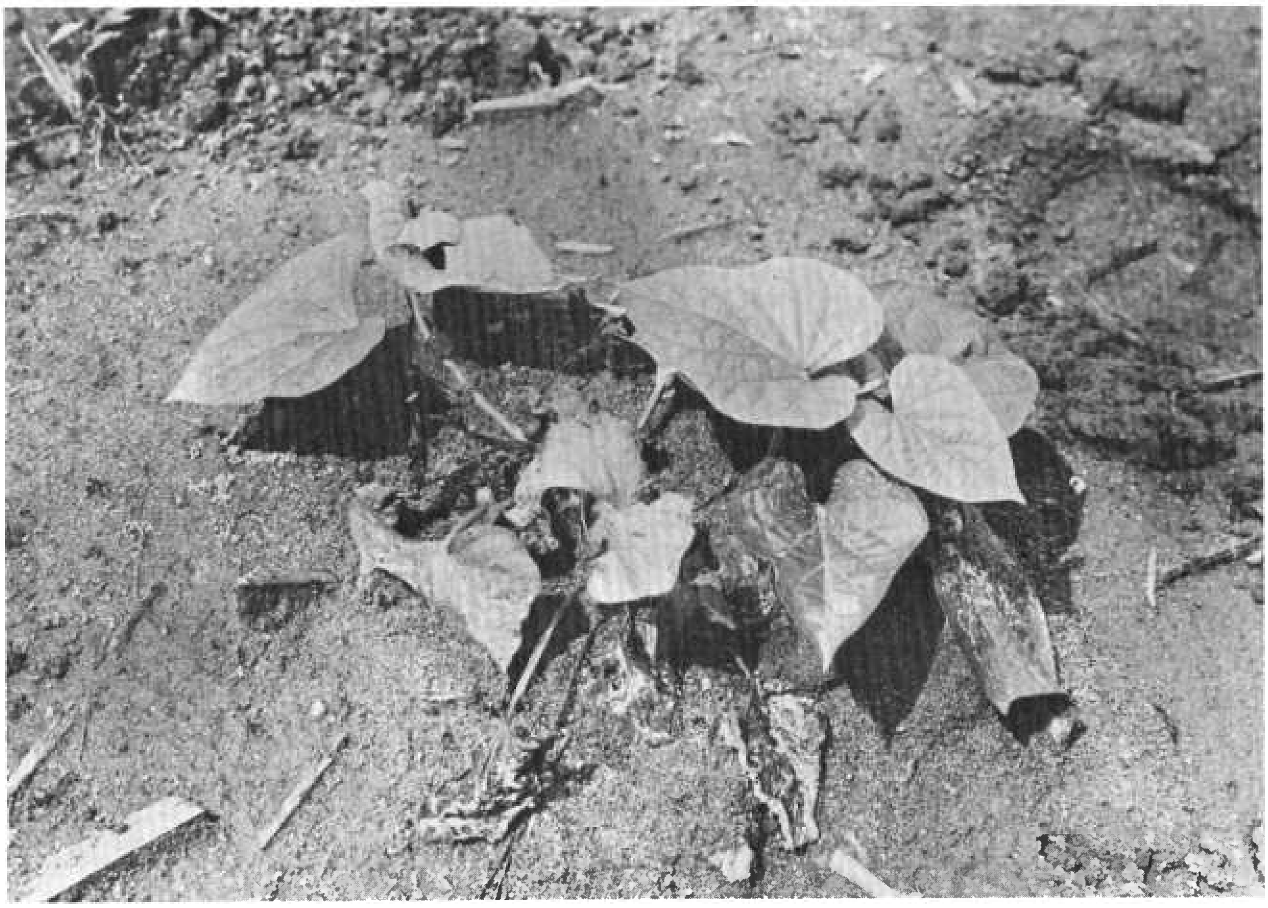

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FIGURE 18.—Stem rot (fusarium wilt) symptoms of a sweetpotato plant.

The disease is spread from one locality to another primarily by the exchange or sale of infected seed sweetpotatoes and plants.

Cause

The fungus that causes stem rot can live for several years on decayed vegetation in the soil until it again comes in contact with the sweetpotato.

Infection takes place both in the plant bed and in the field. The fungus in diseased seed stock planted in the plant bed grows into the plants. Such infected plants die soon after they are set in the field. Healthly plants may become infected after they are set in the field when the fungus in the soil grows into the roots.

The mycelium (threadlike web) of the fungus develops rapidly and grows up through the conductive vessels of the stem. After the vines die, the fungus lives on the decaying vegetation. Numerous very small fruiting bodies, or spores, develop on the dead vines. The spores are readily carried by the wind and insects or on tools to infest other fields.

Control

Other than growing sweetpotato varieties possessing more or less inherent resistance to stem rot, the most important factors in control of this disease are using clean, healthy seed stocks for plant production and growing the crop in rotation with other crop plants not attacked by the stem rot fungus on land as free as possible of stem rot contamination.

No varieties are known that are completely immune to attacks by the stem rot fungus. Although some varieties, grown formerly for market use, were sufficiently tolerant of stem rot to permit their culture on infested soils, some of the most important and most widely grown varieties and improved selections developed from them have been highly susceptible to infection and damage by this disease. In recent years plant breeders have developed

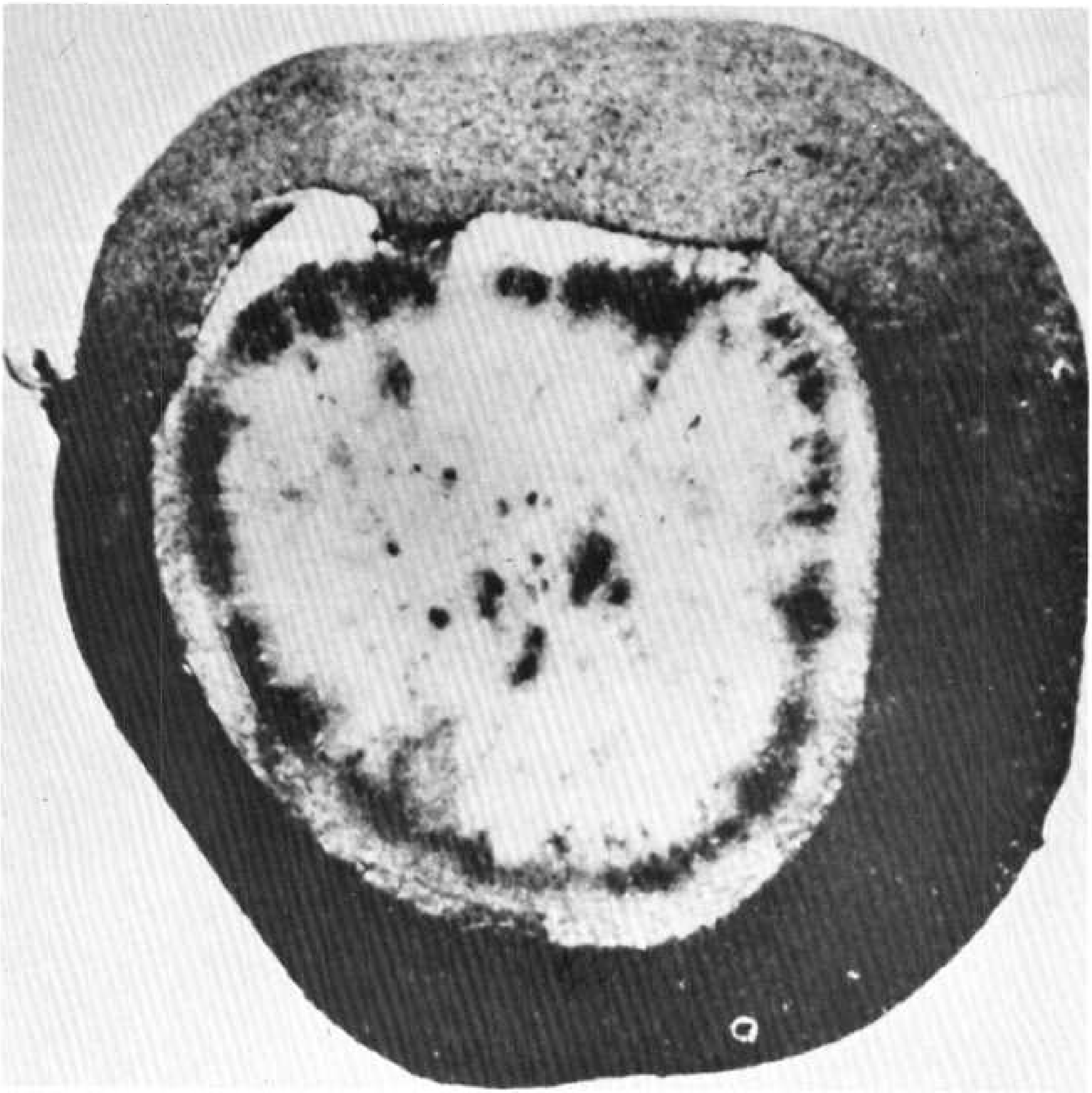

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FIGURE 19.—Section through a sweetpotato showing the blackened ring caused by the stem rot fungus.

several improved sweetpotato varieties that possess practical levels of resistance to stem rot under usual field conditions (table 21). Genetic sources for resistance to this disease are available and are being used in breeding programs to incorporate high levels of resistance in new, horticulturally superior, productive varieties. Wherever possible, resistant varieties should be grown in areas where stem rot is a serious problem.

The importance of proper selection, care, and use of clean, healthy seed stock for the control of stem rot and other diseases cannot be overemphasized where susceptible varieties must be grown. Since the stem rot fungus overwinters in stored infected sweetpotatoes, plants grown from infected seed roots are very likely to be diseased also, hence the necessity of using seed roots free of infection. Surface disinfection with registered fungicides at the time of bedding will not control stem rot within infected roots. Similarly, stem rot within infected plants cannot be controlled by fungicidal dip treatments applied at the time plants are set in the field.

Applications of lime and gypsum to the soil are of no value in controlling stem rot.

The stem rot fungus will live in the soil for several years, even in the absence of sweetpotatoes. For that reason, as a general rule, sweetpotatoes should not be planted on the same ground oftener than once in 3 or 4 years. This rotation will not eradicate the fungus but will reduce the losses. No other crop except tobacco is known to be attacked by this fungus; therefore, any crop except wilt-susceptible types of tobacco commonly grown in the region may precede sweetpotatoes in the rotation. In some areas *stem rot-resistant* varieties of tobacco are planted *after* sweetpotatoes in the cropping system.

Black Rot

(Black Shank, Black Root)

Description

Black rot may occur on any of the underground parts of the plant. Infection on the young plants begins as small black spots on the underground part of the stem. The spots enlarge until the whole stem is rotted off. Frequently the infection extends up the underground part of the stem to the surface of the soil (fig. 20). The name "black shank" is commonly applied to this phase of the disease.

Black rot produces dark to nearly black, somewhat sunken, circular spots on the surface of sweetpotatoes (fig. 21). At first these spots are small and nearly round, but under favorable conditions they enlarge and often cover nearly the whole sweetpotato. Fruiting bodies, or spores, of the fungus may often be found in circular areas about one-fourth to one-half inch in diameter in the center of the spots. The surface of the diseased spot has a somewhat metallic luster and the tissue just beneath is greenish black. If sweetpotatoes affected with black rot are used for seed, the plants produced from them are likely to have the disease.

Prevalence and Loss

Black rot occurs in most States where sweetpotatoes are grown. The disease can occur on the plants or sprouts in the hotbeds, in the fields, and on the roots in storage houses in the winter. When disease-infected roots are put in storage, under favorable conditions the black rot develops rapidly, rendering the sweetpotatoes unfit for sale and causing heavy losses. Sweetpotatoes affected by black rot have a very disagreeable, bitter taste when cooked.

Means of Distribution

Black rot is spread in about the same way as stem rot. Unlike stem rot, however, black rot continues to develop in the storage house, and infected roots that appear sound when stored may become badly affected within a few weeks.

Cause

The black rot fungus overwinters on the dead vines and other decayed vegetable matter in the soil and on the sweetpotatoes in storage. Other than sweetpotatoes, no host plants, are known. If roots affected by black rot are used as planting stock, the fungus usually grows into the plants in the plant bed. Infection also takes place through the roots after the plants are set in the field. Plants that become infected early soon die, and those that continue to grow rarely produce sweetpotatoes.

Control

Black rot is controlled by using disease-free seed stock, root disinfection, and clean plant beds and bedding media to produce clean transplants. The crop should be planted on clean land in rotation with other plants. The most practical way to obtain disease-free bedding stock is to produce the seed sweetpotatoes on plants grown from vine cuttings or sprout (bed) cuttings. (See p. 18.) Since black rot affects only the underground parts of the plant, these cuttings will be free of the disease. If the cuttings are planted in fields that are free of black rot, clean bedding roots should be produced. Sorting out black rot-infected sweetpotatoes, either at harvesttime or before bedding in the spring, is *not* a satisfactory way to obtain clean bedding stock. Many small infections escape detection and the disease continues to develop on such roots in storage or in the plant bed.

Seed roots should be disinfected with SOPP or other registered, effective fungicides to destroy disease spores on the root surfaces, then they should be bedded promptly after treatment in a properly prepared clean plant bed. (See p. 25.) Disinfection does *not* kill the fungus *inside* of black rot-infected roots.

Although none of the present (1970) commercial varieties of sweetpotatoes are highly resistant to black rot, a few of the recently developed varieties are moderately resistant to infection under usual field conditions (table 21).

Plantings should be made on new ground or

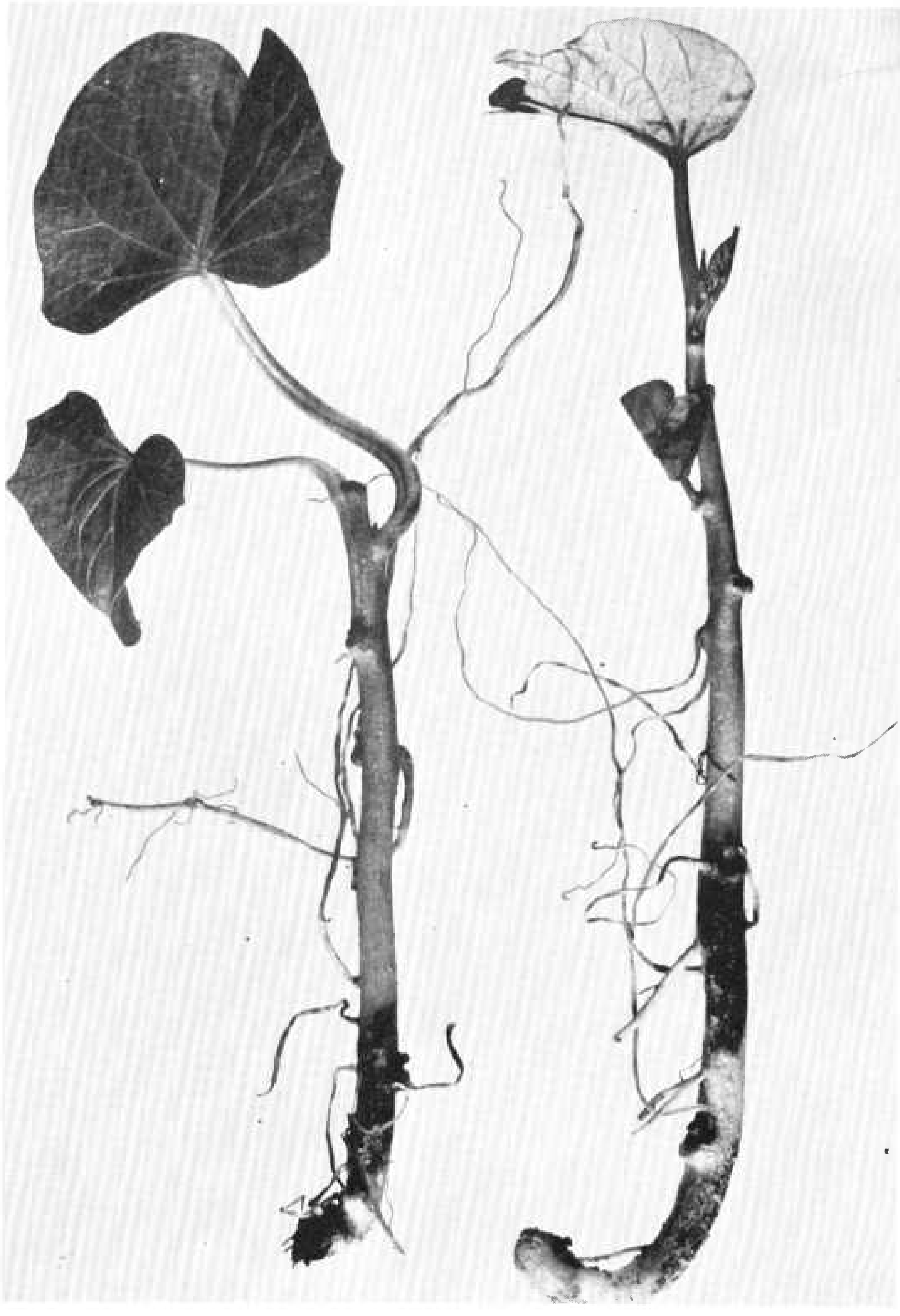

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FIGURE 20.—Small sweetpotato plants showing the characteristic blackening of the underground parts of the stems caused by the black rot fungus.

in fields that have not been used for sweetpotatoes for at least 2 or 3 years. Rotation of sweetpotatoes with other crops helps control black rot because the fungus does not affect other crops and is only able to live about 2 years in the soil.

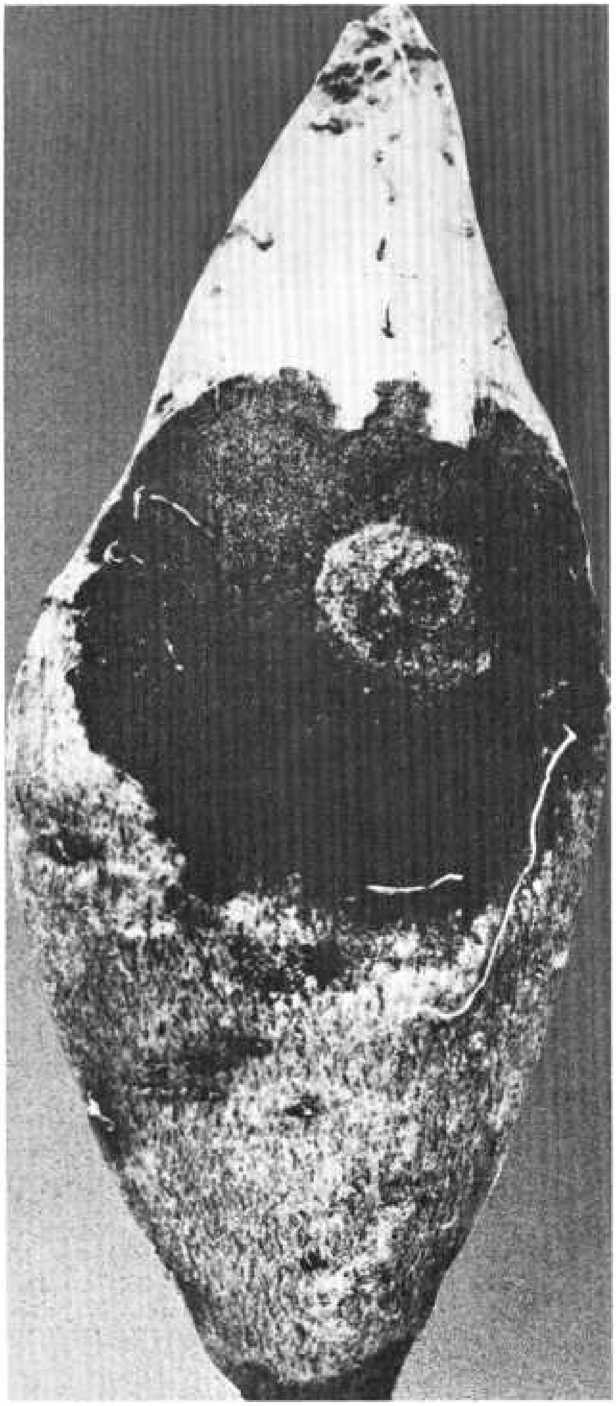

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FIGURE 21.—Black circular spot on sweetpotato caused by the black rot fungus.

Although animal manures are no longer generally available for use on sweetpotatoes, in those cases where they are used, care must be taken that they have not come from sources where sweetpotatoes infected with black rot have been fed to livestock. The black rot organism is able to survive the digestive process in animals and can subsequently reinfect sweetpotatoes if contaminated manure is spread on the land.

Foot Rot

(Die Off)

Description

In the field, foot rot infections usually appear first as small brown to black spots on the stem of the plant near the soil line. The growth of the foot rot fungus is very slow at first, but eventually it girdles the plant and extends up the stem 4 or 5 inches. Soon the plant wilts and rather numerous round, black fruiting bodies of the fungus, just visible to the naked eye, appear in the diseased areas. This disease progresses rather slowly from field infections and the plants do not die off until about midsummer or later.

Often the affected plants bear no sweetpotatoes even though they may have produced long vines. In those hills in which sweetpotatoes develop, the infection may spread from the stem to the roots and cause a brown, rather firm rot. Later, fruiting bodies develop close together on the root surface in the form of pimplelike protuberances (fig. 22). Many wounds and bruises on sweetpotatoes in storage become infected by the foot rot fungus.

Prevalence and Loss

Foot rot is distributed in the same way as stem rot and black rot. It occurs in several States in various parts of the United States. Because it is not as widely distributed as stem rot or black rot, the total loss from foot rot is much less than from stem rot or black rot. In a few places, however, it has caused heavier losses than either.

Cause

Most of the initial infection by the foot rot fungus takes place in the hotbed, spreading from diseased seed roots to the plants. When set in the field, such infected plants usually die early in the season. Although infection occurs primarily through the roots and underground parts of the plant, vines may become infected at the nodes several feet from the plant stem during wet periods when the growth in the field is very luxuriant.

Spores, borne in great numbers, escape from the pimplelike protuberances of the diseased tissue and are carried by insects or other agencies to other plants, where new infections may result. If a diseased plant produces sweetpotatoes, the fungus often grows down the stem and infects them. The fungus may remain dormant during the storage period, but it will develop on the sprouts in the plant bed. As in the cases of stem rot and black rot, therefore, diseased seed stock produces diseased plants, which in turn may produce diseased sweetpotatoes in the field.

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FIGURE 22.—Sweetpotato rotted by the foot rot fungus.

Control

For control of foot rot, follow recommendations for stem rot and black rot—seed selection, the use of clean plant beds, seed treatment, and crop rotation.

Scurf

(Soil Stain, Rust, Jersey Mark)

Description

Scurf produces a brown to black surface discoloration of the root (fig. 23). The discolored areas may take the form of spots of different sizes and shapes with no definite outline, or there may be a uniform rusting of the surface of the sweetpotato. The skin of the sweetpotato is not broken by scurf and the brown or black discoloration is only skin deep and can be scraped off easily with the fingernail.

Prevalence and Loss

Scurf occurs in most places where sweetpotatoes are grown and on all varieties.

The losses in production caused by scurf are relatively small in comparison with those caused by some other diseases. On the other hand, the economic losses resulting from this disease are large. The market prices offered for scurfy sweetpotatoes are significantly lower than for clean ones, even though the food value of roots is not impaired by the presence of scurf.

Scurf may damage the sweetpotato skin. Then when the storage house becomes rather dry, the root loses moisture and becomes shriveled and dried.

Cause

The scurf fungus overwinters in storage and on the decayed vines and other decayed vegetable matter in the field. If infected sweetpotatoes are used for seed, the fungus grows up on the stem of the plants and is carried on the plants to the field. Later, the organism in the field grows or is washed by rains down onto the roots. Scurf damage is most severe on heavy soils and on those rich in organic matter. It is likewise more severe during a wet season and on low, wet ground.

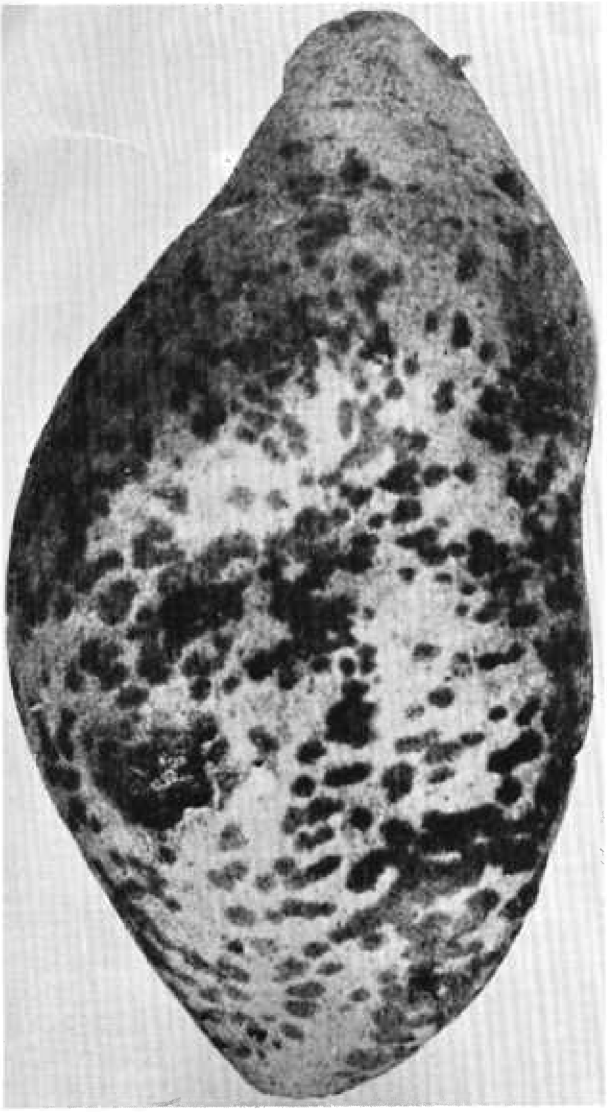

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FIGURE 23.—Sweetpotato showing discoloration caused by the scurf fungus.

Control

Use clean planting stock, produced wherever possible from cuttings grown in scurf-free soil. Since scurf affects only the underground parts of plants, the cuttings will be free of the fungus. Bed the scurf-free sweetpotatoes produced from the cutting plants in a clean plant bed and pull the sprouts in the usual manner.

Selection of seed roots by sorting is impractical and not very effective *if any scurf is present in the stock* because many of the scurf spots are too small to be easily seen.

Make field plantings in 2- to 3-year rotations with other crops on lighter sandy and sandy loam soils, or in 3- to 4-year rotations on heavier soils and those rich in organic matter. The scurf organism survives longer in these latter types of soils.

Root Rot

(Texas Root Rot)

Description

Root rot causes a firm, brown rot and results in complete destruction of the sweetpotato (fig. 24). Above ground, the growth is within the stem and may be detected by the brown color produced. Coarse brown or gray strands of the fungus on the surface of the roots can be detected easily with a hand lens.

Prevalence and Loss

Root rot has been found in Arizona, Arkansas, California, Nevada, New Mexico, Oklahoma, and Texas. When the disease once gets into a field, a crop may be destroyed. The growing crop may appear normal when viewed from a distance, but by harvesttime nearly all the sweetpotatoes may be destroyed.

The causal organism lives from one season to the next in the soil on dead vegetable matter and probably on growing winter crops and weeds. It is killed by hard freezing, and this alone probably restricts the disease to the Southern States. The disease may be observed occasionally as early as May or June, but it does not become serious until August when the vines are usually well developed and the sweetpotatoes are of considerable size. From August on, the disease increases in severity, and by harvesttime in September and October, a large percentage of the roots may be destroyed. The disease may occur in spots of various sizes within a field. Not all hills and not all sweetpotatoes in a hill are necessarily destroyed.

Cause

The root rot fungus lives from one season to the next in the soil and on seed sweetpotatoes. The organism gains access to the underground parts of sweetpotato plants and spreads in both stems and roots, invading the vines from 6 to 12 inches aboveground. It may enter the end of the sweetpotato or may cause spots of varying sizes on the surface.

Control

Root rot is most severe on black, poorly drained soil and during wet seasons. The disease is very difficult to control or eradicate because it affects a great variety of plants. It is particularly destructive on cotton and alfalfa. To control root rot, cultivate deep and clean, aerate the soil, apply stable manure, rotate crops, and use disease-free sweetpotatoes for seed. Use grasses, corn, and other cereals in the rotation because they are partly or completely immune to the disease.

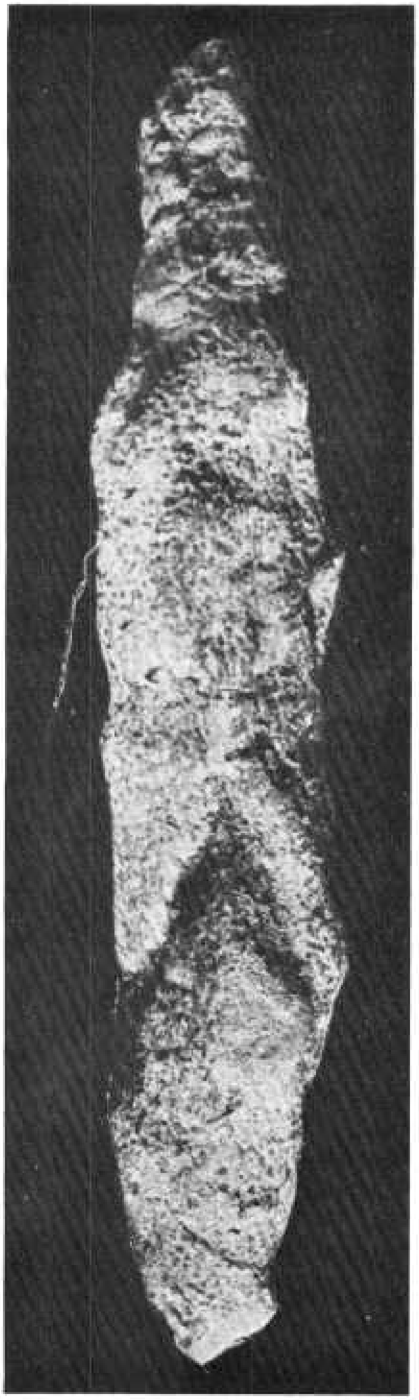

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FIGURE 24.—Characteristic shriveling of sweetpotato caused by the root rot fungus.

Mottle Necrosis

Description

Mottle necrosis, a field disease of the sweetpotato, produces brownish, somewhat sunken spots, which are irregular in shape and size, on the surface of the roots. Usually the sweetpotato remains more or less firm. Cutting the root crosswise through one of the brown, sunken surface spots reveals the most striking symptom of the disease: irregularly shaped patches of chocolate-brown dead tissue, which appear to have no connection with one another and give the cross section a mottled, or marbled, appearance (fig. 25). The entire root may be diseased even though there is only one small spot of diseased tissue on the surface.

Prevalence and Loss

Mottle necrosis occurs in most States where sweetpotatoes are grown. It is not as prevalent, however, in the southern as in the northern part of the sweetpotato-growing area. The loss varies from year to year, depending upon soil and weather conditions and upon the varieties grown. The entire loss throughout the country is relatively small. However, in certain isolated districts where varieties such as the Yellow Jersey are grown, as much as 40 percent of the crop may be lost during seasons especially favorable to the disease.

Cause

Mottle necrosis may be caused by either of two fungi. These fungi probably enter through

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FIGURE 25.—Cross section through a sweetpotato root severely infected with mottle necrosis.

the small fibrous roots and spread through all parts of the sweetpotato.

Control

No method for the control of mottle necrosis is known. The disease is most severe during seasons of abundant rainfall and in soils that are fairly light and sandy, although some infection may occur in fairly heavy soils. Triumph, Yellow Jersey, and Big Stem Jersey are very susceptible varieties. Occasionally other varieties may be slightly infected. Susceptible varieties should not be planted in soils where mottle necrosis has occurred in the preceding 3 or 4 years.

Soil Rot

(Pox, Ground Rot)

Description

Soil rot produces symptoms very different from those of other sweetpotato diseases. In a heavily infested soil the plants are dwarfed and often produce only one or two short vines. The leaves are small, thin, and pale green. The aboveground symptoms are the result of injury to the roots, caused by the disease. Any of the underground parts of the plant may be attacked. Many of the lateral feeding, or fibrous, roots are destroyed, and those that remain are often more or less malformed. Nearly black flecks, or spots, of varying sizes and shapes occur on the feeding roots and underground part of the stem. The decayed spots may occur on only one side of the root or may girdle it, thereby cutting off the food supply. In the early stages of soil rot the diseased spots are covered by the skin of the sweetpotato, which later breaks and leaves conspicuous holes or pits. On the swollen roots these pits are often one-half inch, or more, in diameter and have jagged margins (fig. 26). The enlarged root is sometimes girdled; the sweetpotato root continues to enlarge on each side of the point of infection, often growing more or less in the shape of a dumbbell.

Prevalence and Loss

Soil rot occurs in practically all States where sweetpotatoes are grown. It has become a limiting factor in sweetpotato production in Louisiana. The disease does not occur generally throughout a State, but is more or less localized. It may be severe in one field or locality and absent in another only a few miles away.

The loss caused by soil rot may range from virtually no loss to almost complete failure in different fields and different seasons. Losses are most severe during dry seasons and on poor soils. Soil rot is especially severe on soils that

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FIGURE 26.—Sweetpotato showing typical soil rot pits.

are alkaline or only slightly acid. It does not develop much in fairly acid to acid soils; that is, with a soil reaction of pH 5.2 or less.

Cause

The soil rot fungus lives in the soil from one season to the next. Most of the infections probably occur after the plants are set in the field, although infection may result from infested soil in the plant bed and from infected seed sweetpotatoes.

Control

No fully adequate control measure for soil rot is known. Some research results indicate that application of sulfur to reduce the soil reaction to pH 5.2 or less will increase acidity, reduce the amount of soil rot, and increase the yield. Sulfur should be applied with considerable care; otherwise, it may make the soil too acid for other succeeding crops. The amount of sulfur to be used will depend on the soil type and pH. Apply the sulfur broadcast and incorporate it thoroughly into the soil 2 to 4 weeks before the plants are set out. Other control measures are the use of stable manure and green-manure crops to improve the soil and rotation with other crops.

Avoid introduction of the soil rot organism into new fields and new localities. Since cattle or other livestock can carry the germs on their feet, do not allow them to roam from infested to disease-free fields. Plows and other farm implements used to cultivate infested fields should be thoroughly cleaned before they are taken into clean fields. Use disease-free bedding stock for producing clean transplants to be set in new fields. (See p. 18.) If plants are obtained from outside sources, be sure they are free of soil rot.

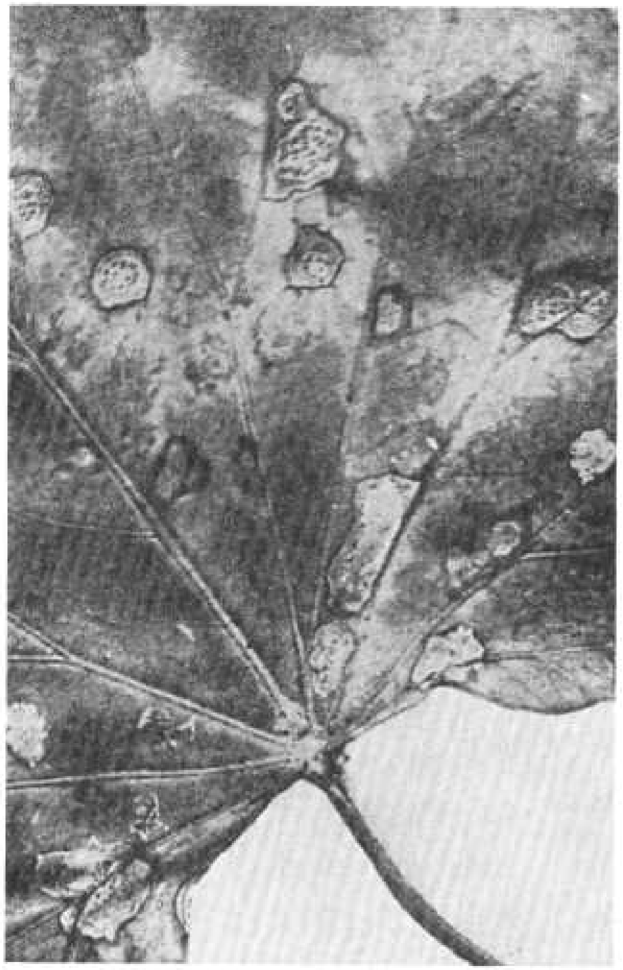

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FIGURE 27.—Circular phyllosticta leaf blight lesions on a section of sweetpotato leaf.

Phyllosticta Leaf Blight

Phyllosticta leaf blight causes circular or angular, brownish spots one-eighth to one-half inch in diameter on the upper sides of the leaves (fig. 27). A number of black bodies about the size of a pinpoint and just visible to the naked eye are scattered within the spots. The bodies are slightly raised and round and contain numerous colorless spores.

The fungus does not live on any other plant, nor on any other part of the sweetpotato plant. It probably overwinters on the dead leaves in the field.

The disease occurs every year in practically all the Southern States, but less commonly in some of the more Northern sweetpotato-producing States.

Septoria Leaf Spot

Septoria leaf spot is characterized by circular, white spots about one-eighth inch in diameter on the upper surface of the leaves (fig. 28). Within these white areas are one or more black specks, just visible to the naked eye. These specks contain numerous spores that, upon escaping, may be carried by insects or other agents to other leaves and start new infections.

Like the organism causing phyllostica leaf blight, this fungus does not live on any other plant nor on any other part of the sweetpotato plant. It probably overwinters on the dead leaves in the field.

Septoria leaf spot is very widely distributed

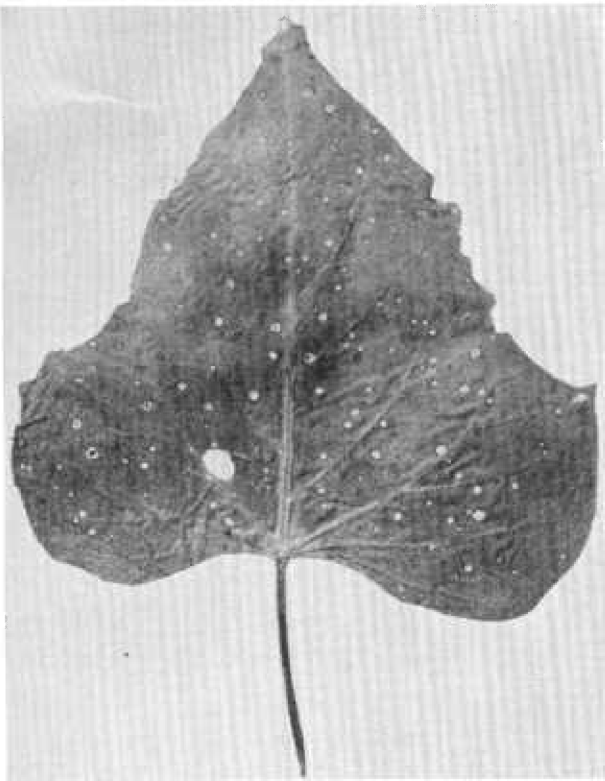

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FIGURE 28.—Sweetpotato leaf showing white spots caused by the septoria leaf spot fungus.

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FIGURE 29.—Sweetpotato leaf injury caused by the white rust fungus.

and has been observed in most States where sweetpotatoes are grown.

White Rust

(Leaf Mold)

The first symptom of white rust is the loss of the green color in spots on the underside of the leaf (fig. 29). Later these spots become brown and covered with a whitish, viscid growth, which finally becomes more or less powdery. This powdery white mass is made up of numerous spores. If these spores fall on other leaves, under favorable conditions they will germinate and cause new infections. No great harm results from the attack of this fungus, although it may sometimes produce swellings on the stems and petioles (leaf stems) and cause malformations of the leaves and young shoots. White rust is widely distributed and occurs on a number of other plants, among them the wild morning-glories.

White rust is more prevalent during wet seasons than dry. It occurs on sweetpotato plants in most of the Southern States. Under favorable weather conditions it also occurs in Northern States where sweetpotatoes are grown.

NEMATODES AND OTHER CONTROL[4]

Description

Plant-parasitic nematodes reduce yield and quality of sweetpotatoes, destroy root systems, and cause inefficient use of nutrients and water. The vines are seldom killed, but usually have poor growth and are yellowish. On hot days the vines often will wilt.

Several species of root-knot nematodes cause galling (or knots) on the feeder roots, roughening and frequent cracking of tubers, and generalized decay of the entire fiberous root system (fig. 30). Root-knot nematodes develop in colonies in the tuber, which appear as small discolored areas about one-sixteenth inch, or smaller, in diameter. However, these areas sometimes occur deep in the fleshy tissue.

Lesion nematodes cause irregular dark-brown, sunken areas of decay on the surface

[4] The section "Nematodes and Their Control" was prepared by J. M. Good, nematologist, Crops Research Division, Agricultural Research Service.

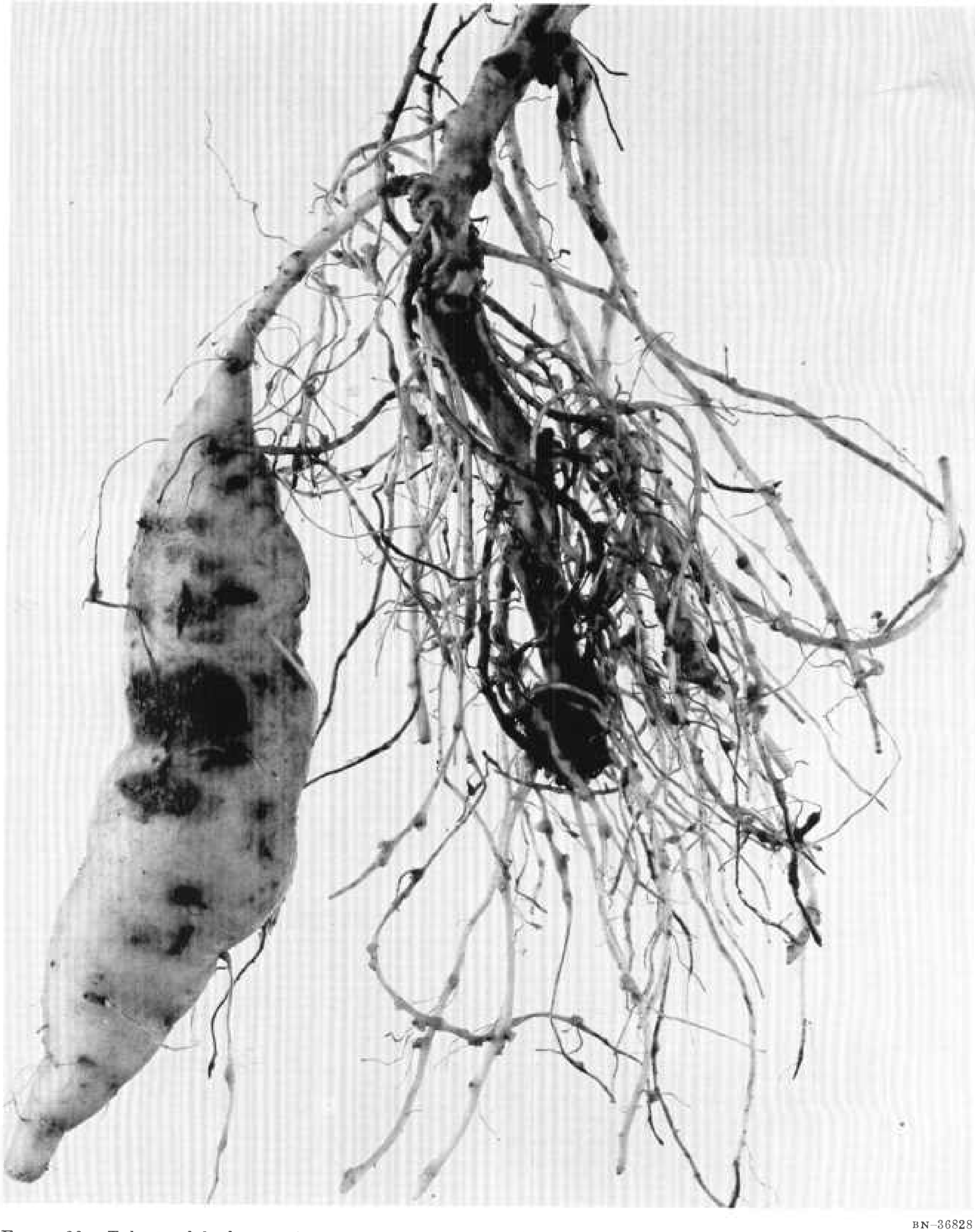

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FIGURE 30.—Tuber and feeder sweetpotato roots showing heavy root-knot infection. Note the small galls on the roots caused by root-knot nematode, and the decay, cracking, and roughness of the developing tuber.

of the tuber. These spots contain the minute nematodes.

Prevalence and Loss

One or more species of plant-parasitic nematodes occur in all sweetpotato-producing areas. Crop losses often exceed 50 bushels per acre on heavily infested land.

Five species of root-knot nematodes (*Meloidogyne* spp.) attack sweetpotatoes. The southern and cotton root-knot nematodes (*M. incognita* and *M. incognita acrita*) cause greatest damage in the Southern States. The northern root-knot nematode (*M. hapla*) occurs in both southern and northern climates. The peanut root-knot nematode (*M. arenaria*) and the oriental or peach root-knot nematode (*M. javanica*) occur most frequently on farms where peanuts and peaches are grown or in the extreme Southern and Western United States.

Reniform nematodes (*Rotylenchulus reniformis*) cause severe losses in Louisiana and in parts of Alabama and Mississippi. Other nematodes such as lesion (*Pratylenchus* spp.), spiral (*Helicotylenchus* spp. and *Scutellonema* spp.), dagger (*Xiphinema americanum*), lance (*Hoplolaimus galeatus*), sting (*Belonolaimus longicaudatus*), and ring (*Criconemoides* spp.) cause an unknown amount of damage to sweetpotatoes, especially those growing in the Atlantic and Gulf Coastal Plain soils.

Causes

Plant-parasitic nematodes are microscopic round worms that live part of their lives in soil. Some types feed externally on the plant roots; others enter the root and tuber tissues and feed there. All disrupt root development and interfere with translocation and transport of plant nutrients and water. They often incite decay of fiberous roots and tubers by providing entry, into otherwise healthy tissue, for other micro-organisms that cause decay. Plant-parasitic nematodes are spread on farms in drainage and irrigation water, by the wind, and by movement of farm animals and implements. Root-knot and lesion nematodes are frequently introduced into noninfested farmland in nematode-infected seed sweetpotatoes and plants, or in other infected transplanted crops.

Eggs, larvae, and adults of all nematodes except the root-knot nematode are found in soil. After hatching larvae and adults feed on plant roots. The lesion nematodes penetrate fiberous roots or tubers and migrate during feeding within the root tissues. This migration causes extensive necrosis or decay. Most other plant-parasitic nematodes feed externally on the roots. During feeding they puncture root cells, which usually results in death of the injured cells. Continued feeding and death of hundreds of cells prevents normal root development and function.

The larvae of root-knot nematodes enter the roots as slender worms about one-twentieth inch long; the female becomes embedded in the root tissues and feeds in one site. Each female produces several hundred eggs. The feeding of the root-knot nematode at one site causes the plant to produce the characteristic root-knot gall around the bodies of one or more females.

Control

To prevent nematode damage the grower must control these pests in both seedbeds and field plantings. Failure to control nematodes in the seedbed will assure damage to field plantings because the nematodes can be carried from the seedbed to the fields in seed sweetpotatoes or plants. Seedbeds should be treated with a registered nematicide. If root-knot-resistant varieties are not used, field soil should also be treated with a registered nematicide to prevent losses when nematode populations are high. Nematicides that can be used in seedbeds and in the field include DD; 1,3–D; EDB; 1,3–D–EDB; SMDC; and DD–MENCS (table 11).

Of several control methods available, nematicides and soil fumigants provide the best means of controlling all types of nematodes that attack sweetpotatoes. However, because of the relatively high cost, nematicides cannot be used routinely as a production practice. These chemicals are practical and increase yields and profits only when nematodes are present in sufficient numbers to seriously limit production. The best means of determining whether nematodes are reducing yields and profits is to apply nematicides on a trial basis to each field where sweetpotatoes are grown. Do not apply nematicides to the entire field; leave untreated rows to determine if nematode control is profitable in each field. If high yield increases are obtained, similar increases can be expected from use of nematicides whenever sweetpotatoes are grown. This is because once nematodes become established in soil they seldom disappear, but remain a problem year after year. Nematicides do not permanently rid the soil of nematodes, but reduce their numbers so that a crop can be grown profitably without significant damage. Re-treatment of soil will usually be necessary each time sweetpotatoes are grown.

Details concerning methods of applying nematicides and soil fumigants have been published by Good and Taylor (*6*).

Strict adherence to the manufacturers' directions for applying nematicides is a necessity. Application of insufficient amounts of chemicals will not control nematodes. Application of excessive amounts of chemicals may injure plants and reduce yields, or may contribute to unlawful chemical residues in the sweetpotatoes.

In the field, all types of nematodes cannot be controlled by crop rotation. Since suitable rotation crops vary in different parts of the country, you should consult your county agent or State agricultural experiment station before starting a nematode-controlling rotation. Rotations can be designed to control one or more species of nematodes. Root-knot nematodes are more easily controlled by crop rotations than are other nematodes.

Nematode infestations can be reduced in field soil by removing all potatoes from the field at harvest. Unmarketable potatoes that are left on the ground contain large numbers of nematodes that will reinfest the soil and cause severe damage to subsequent crops. Unmarketable potatoes should be burned or buried some distance from cultivatable land.

A number of sweetpotato varieties have resistance to the southern and cotton root-knot nematodes, but none have complete resistance to all species of root-knot nematodes or even to all populations of the southern and cotton root-knot nematodes that occur in all parts of the country. A few of the root-knot-resistant varieties are listed in table 21. The varieties Heartogold and Nemagold have the best resistance to all species of root-knot nematodes. The root-knot-susceptible variety Goldrush has moderate resistance to the reniform nematode; otherwise, resistance to the many other types of nematodes is not available. When root-knot nematodes are the principal cause of damage, use of resistant varieties can reduce yield losses and will prevent increase of soil populations of nematodes that damage subsequent crops grown on the land.

STORAGE ROTS AND THEIR CONTROL

Soft Rot

(Ring Rot, Collar Rot)

Soft rot, caused by the so-called bread mold, is a very destructive disease of sweetpotatoes in storage. It may start soon after the crop is placed in storage and continue to spread throughout the storage period. The decay begins in unhealed wounded areas, often at the ends of the root. It progresses rapidly. Only a few days with favorable temperatures and humidity are needed to completely destroy the sweetpotato root. At first the soft rot-affected sweetpotatoes are soft, watery, and stringy. A copious growth of spore-bearing fungus strands, sometimes referred to as "whiskers," usually develops quickly on the ruptured root surface (fig. 31). After decay and the escape of moisture, the shriveled roots gradually become firm, hard, shrunken, and brittle.

Soft rot sometimes spreads from one root to another by contact. Spores of the mold produced on the root surface may be carried by flies, rodents, or air currents to other roots in the storage house. The spores also may be spread in handling the potatoes. New infections may occur if the spores fall on fresh, unhealed, wounded surfaces, especially those of crushed tissues, when the temperature and moisture conditions are favorable for development of the fungus.

In the ring rot or collar rot forms of soft rot, both caused by the same organism, the decay usually begins at one or more points between the ends of the root. From the points of infection, the decay forms rings or collars around the sweetpotato and then extends slowly toward the root ends. Under conditions favorable to the mold the root may be entirely destroyed. If conditions unfavorable for the mold's further development exist, such as relatively low humidity and low temperatures, only depressed rings or collars varying in width from about 1 inch to 3 inches may be formed (fig. 32).

The soft rot causal organism is found everywhere and is therefore impossible to exclude from storage houses. The fungus generally gains entrance to the sweetpotato through fresh wounds and bruises caused by digging, rough handling, or bites of rats and mice. Soft rot develops in roots injured by cold or wet soils and is often most serious following such damage. Timely digging of sweetpotatoes during fair weather, allowing surface drying of roots before picking up in the field, handling roots carefully to keep bruising and injuries at a minimum, promptly transferring the crop from the field to storage, and maintaining proper temperature and humidity during curing and storage periods, all are important factors in keeping soft rot losses at a minimum.

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FIGURE 31.—Sweetpotato showing the moldy growth, or "whiskers," of the fungus causing soft rot.

Black Rot

Where adequate precautions are taken to eliminate black rot infection or keep it at minimal levels during propagation and culture of sweetpotatoes in the field, this disease should ordinarily cause only minor losses during storage and subsequent marketing of the crop. However, where appreciable infection and spread of the disease occur in the field for any reason, then the dangers of serious losses during and after storage may be great. For this

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FIGURE 32.—Sweetpotato with ring rot.

reason, roots from fields where black rot is present should be marketed as soon after harvest as possible.

At harvesttime, roots from contaminated field plantings may have relatively few readily visible black rot lesions. Large numbers of roots, however, may have infections with lesions too small to be seen with the naked eye. If these roots are placed in storage where temperature and humidity are favorable for development of the black rot fungus, the lesions will gradually enlarge. They may grow to be an inch or two in diameter and penetrate as much as one-half inch in depth after a month or two in storage (fig. 33). The number of infections and the size of the lesions increase rapidly at temperatures between about 60° and 85° F. (Note that temperatures during the curing period are within this range.) Development of black rot infections is slow when temperatures are near or below about 55°.

From the fungus lesions, innumerable fruiting bodies are developed, from which immense numbers of one-celled spores are exuded. Infections are spread during storage by these spores being carried from root to root by rats and mice, insects, and possibly air currents; by settling of roots in containers; or by handling of stock during preparation for market.

Washing sweetpotatoes in preparation for marketing can be a potent means of spreading

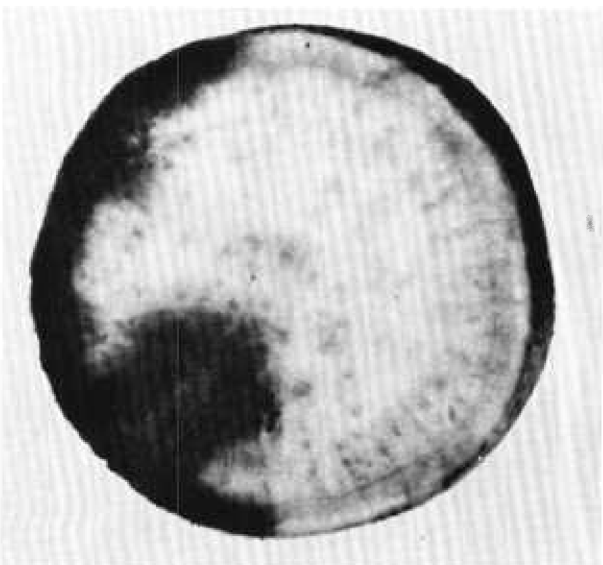

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FIGURE 33.—Cross section through sweetpotato with black rot lesion, showing depth of penetration by the black rot fungus.

black rot infections if the disease is present on any roots. Adequate precautions must be observed to sterilize washing equipment and to prevent build-up of the black rot spore load in the wash water. Treatment of roots with a registered, effective fungicide such as SOPP and sanitizing grading equipment with 27.6 percent sodium dimethyl dithiocarbamate and 2.4 percent sodium 2-mercaptobenzothiazole (Vanicide 51) between lots in connection with the washing operation can greatly reduce losses from black rot during marketing.

Surface Rot

In the early stages, surface rot is characterized by nearly circular, somewhat sunken spots (fig. 34) on the surface of the sweetpotato. These vary in number and their size increases with time after infection. The rot is shallow, seldom extending more than one-fourth to one-half inch below the surface. The sweetpotato shrinks later, especially at the margins of the spots.

Infection occurs at about digging time, especially if the ground is wet, or early in the storage period when small decayed spots can often be found at the base of the small rootlets. The infected areas gradually enlarge in storage and become conspicuous in 6 to 8 weeks. If the storage house is kept rather warm and dry, moisture escapes from the affected areas and the sweetpotato gradually becomes hard and mummified. Injury from exposure of roots to sun and wind after digging increases the loss from this rot.

Surface rot has some characteristics in common with black rot. Surface rot spots may become grayish brown and 1 inch in diameter during storage. Black rot spots are nearly black and may become 2 inches in diameter. The surface rot spots are more regular in shape and size than spots caused by bruises.

The loss from surface rot is sometimes more than that of any other storage disease. Occasionally the sweetpotatoes are so badly shrunken that they have no market value. Some varieties are much more susceptible to surface rot damage than are others. No varieties are completely immune to this disease.

Proper handling, curing, and storage practices will reduce losses from this disease.

Java Black Rot

Java black rot, so called because it was discovered on sweetpotatoes grown from an importation from Java, is a widely distributed storage disease. It is more prevalent in the South than elsewhere.

Java black rot is strictly a storage disease. The affected sweetpotatoes rot slowly and become dry, hard, brittle, and coal black within and are difficult to break (fig. 35). The disease is spread by spores that develop beneath the

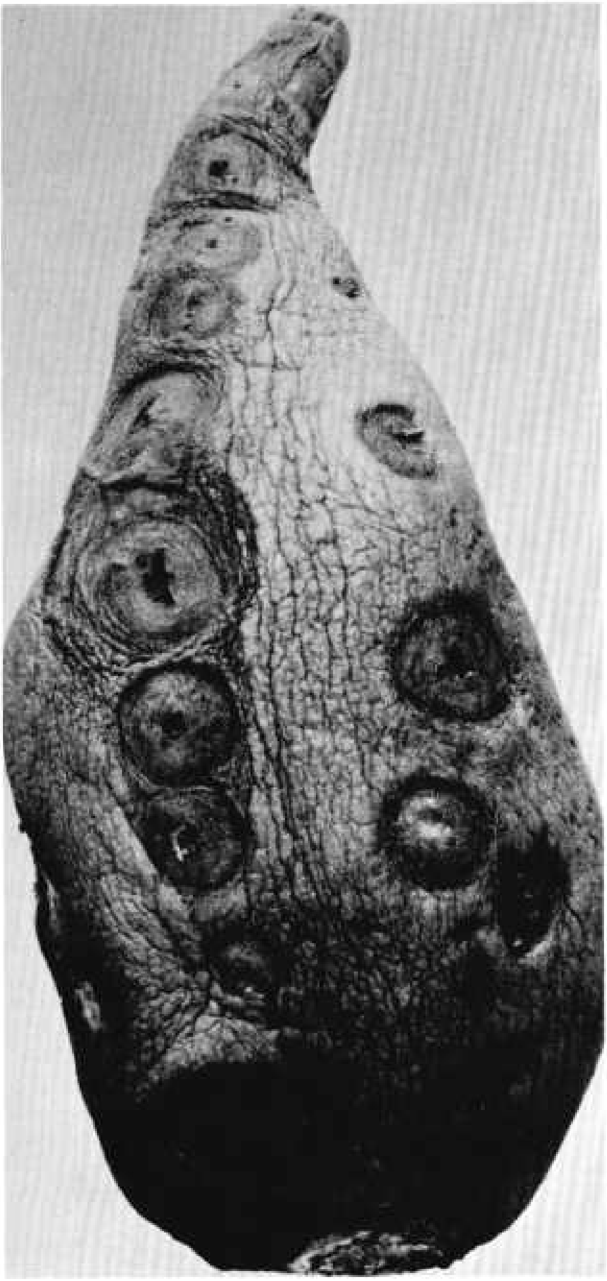

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FIGURE 34.—Sweetpotato after several weeks in storage, showing a number of circular lesions associated with surface rot.

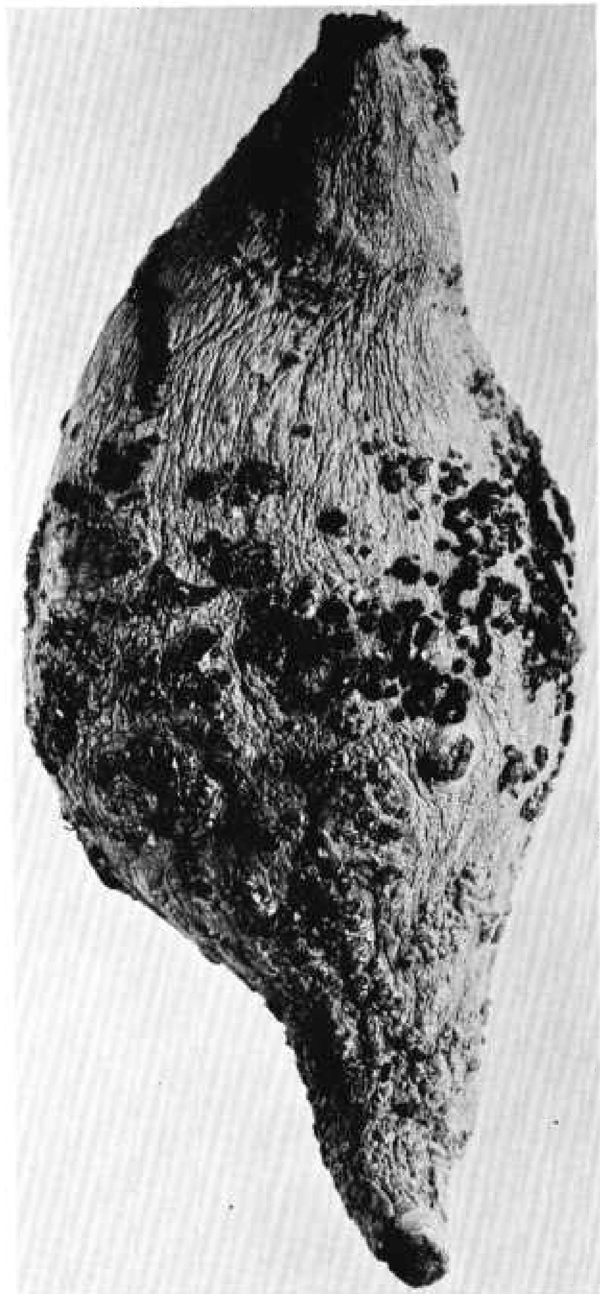

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FIGURE 35.—Sweetpotato showing the dry, mummified condition caused by the Java black rot fungus.

surface of numerous pimplelike protuberances. When the surface of the root is broken, these spore bodies are set free. Java black rot begins usually at the end of the root and progresses very slowly. Under normal storage conditions, the disease can completely destroy a sweetpotato in from 4 to 8 weeks.

Careful handling and prompt curing are valuable methods for reducing losses from this disease.

Dry Rot

Dry rot generally begins at the ends of the sweetpotato and produces a firm, brown decay. The sweetpotato decays slowly and finally becomes dry, hard, and mummified (fig. 36). Small domelike or pimplelike protuberances just visible to the naked eye finally cover the entire surface and contain large numbers of colorless spores of the fungus. The tissue just beneath the skin is coal black. Under normal conditions, the fungus can completely destroy a sweetpotato in several weeks.

The dry rot fungus grows on the stems and vines aboveground in fields, and probably some sweetpotatoes become infected in the field. Dry rot has also been found on the stems of young plants in hotbeds.

Dry rot, although widely distributed throughout the United States, is not regarded as one of the more serious storage disorders.

BN-23964

FIGURE 36.—Characteristic appearance of sweetpotato decay caused by dry rot.

VIRUS DISEASES AND THEIR CONTROL

Internal Cork

Internal cork was first reported in 1944, in South Carolina. This disease occurs in every State where sweetpotatoes are grown commercially in the United States, and its occurrence has also been reported in many other countries. Internal cork symptoms have been observed in most of the numerous varieties and selections examined in the United States. Some varieties are very susceptible to infection by this disease, whereas others are much less susceptible (table 21).

A few varieties are carriers of the internal cork virus without themselves developing the corky lesions found in roots of most varieties infected with this disease.

Plants infected with the cork virus have yellow spots on the leaves when the latter are about 1 month old. These spots become masked and less discernible as the leaves grow older. Yellow spots that develop on the new growth later in the growing season may be surrounded by purple-pigmented borders (fig. 37).

Internal cork is primarily a root lesion disease. The virus causes formation of dark-brown to black, hard, corky spots or lesions in the flesh of susceptible varieties (fig. 38). Small, corky lesions sometimes may be found in some roots at digging time. Usually, however, extensive development of the corky lesions occurs only after storage at relatively high temperatures (60° F. or higher) for periods of from several weeks to about 6 months. The corky spot may occur singly or in groups and are most readily detected by cutting the roots into thin slices. Severely diseased roots may develop so many corky lesions that they become practically useless for food.

Two viruses, internal cork and chlorotic leafspot (see below), always occur in both the leaves and roots of plants showing internal cork symptoms. These two viruses persist from one season to the next in fleshy sweetpotato roots. Both are spread in the field by aphids, especially during the cool weather early in the growing season.

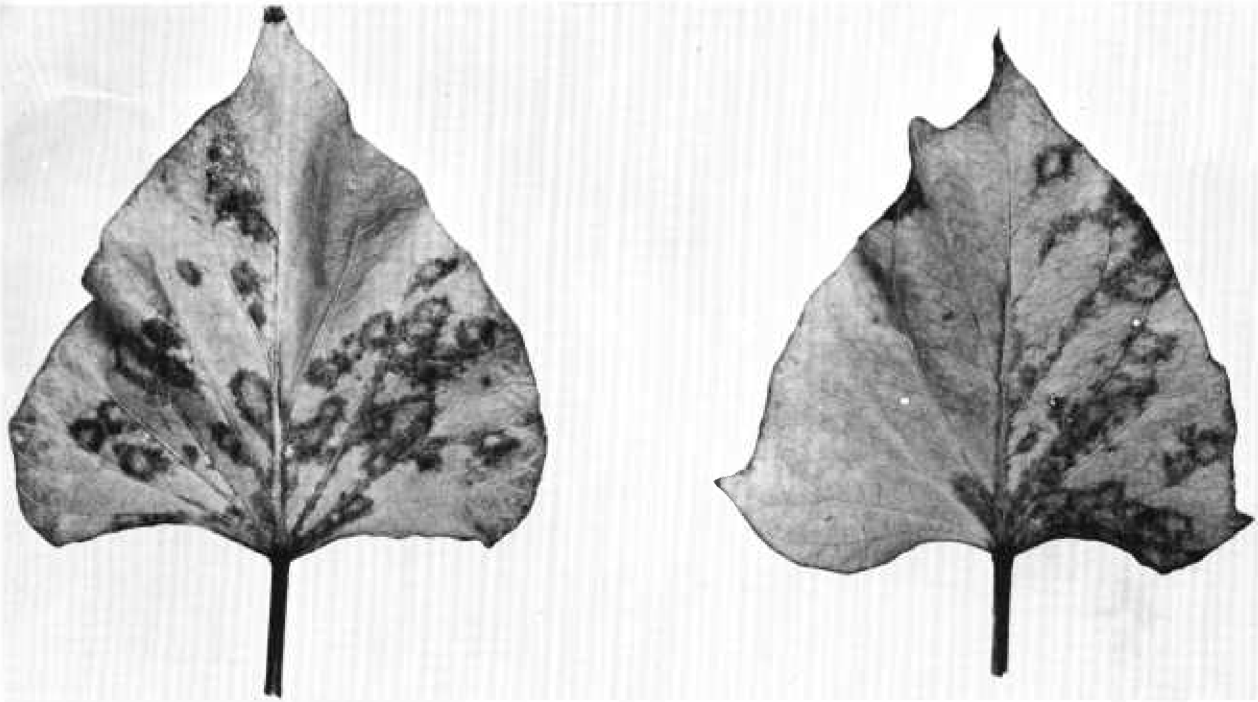

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FIGURE 37.—Purple-bordered chlorotic leaf spots of internal cork disease on sweetpotato leaves.

Chlorotic Leafspot

Chlorotic leafspot is one of the most widespread virus diseases of sweetpotatoes. It occurs in all States where sweetpotatoes are grown commercially and in all varieties that have been examined. In some cases it has infected every plant in a field during the growing season.

When only the chlorotic leafspot virus is present in sweetpotato plants, it causes a mild chlorosis on older leaves with occasional spots along veins having a "feathered" outline.

Chlorotic leafspot and internal cork symptoms in foliage are so much alike that ordinarily they cannot be clearly differentiated by observation alone.

Use of virus-free stocks is the recommended method of control for both chlorotic leafspot and internal cork viruses. In experimental trials new vine growth free of both viruses has been obtained by growing plants continuously at 100° F. for 6 months.

Yellow Dwarf

Yellow dwarf virus causes a stunting of both plants and roots (fig. 39). In the field it is

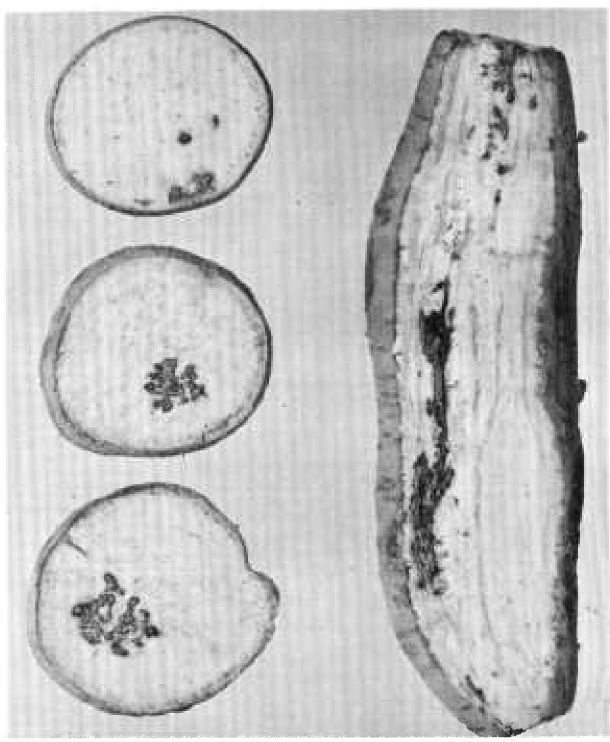

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FIGURE 38.—Cross and long sections through sweetpotato roots infected with internal cork, showing appearance of lesions.

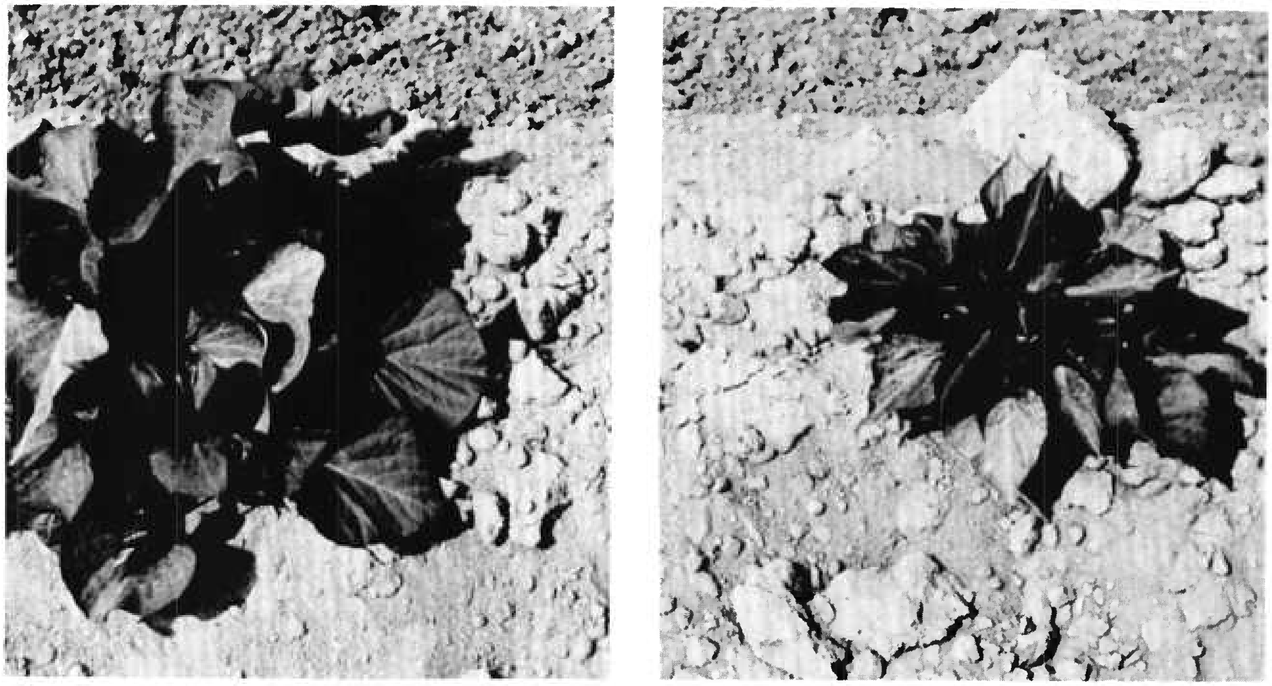

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FIGURE 39.—*Left,* Healthy sweetpotato plant; *right,* sweetpotato plant infected with yellow dwarf virus. Note the lighter color and smaller size of the infected plant.

always found in mixture with the internal cork and chlorotic leafspot viruses. Dwarfed plants produce roots that are few, dwarfed, misshapen, and practically worthless for food or for propagation. The virus lives from one season to the next in roots of diseased plants. It apparently is not seedborne (in true seed). Under controlled conditions in the greenhouse, plants infected with yellow dwarf virus show systemic vein clearing and nonchlorotic leaf-dwarfing symptoms.

Yellow dwarf is spread in the field by the banded-wing whitefly (*Trialeurodes abutilonea*), an insect that feeds and reproduces on weeds commonly found in sweetpotato-growing areas, and by the sweetpotato whitefly (*Bemisia tabaci*). Yellow dwarf-free planting stock should be used to avoid introduction of this disease into an area.

Feathery Mottle

When the internal cork, chlorotic leafspot, and yellow dwarf viruses are acting together, the disease complex is called feathery mottle. Leaves of infected young plants are commonly mottled with green and yellow. There may be a feathery yellowing of older leaves. In some sweetpotato varieties the leaves may become distorted and sometimes fan shaped. In later stages of the disease, growth is dwarfed (from yellow dwarf virus) and leaves are yellowed and spotted (from the internal cork and chlorotic leafspot viruses). Roots produced by plants diseased by this complex are few, small, and worthless.

Russet Crack

The first observations of russet crack were reported from Maryland and New Jersey about 1960. Since then, it has been found in other sweetpotato-producing States. The virus that is the primary cause of this disease is spread rather rapidly in the field by the green peach aphid (*Myzus persicae*), which appears to be the principal insect vector. Losses from russet crack can be heavy because the disfiguring lesions on the surface of the roots render the sweetpotatoes unfit for sale. All sweet potato varieties tested to date appear to be susceptible to the root-lesion phase of the disease.

The most conspicuous symptoms of russet crack occur on the enlarged fleshy roots. The characteristic symptoms, as they occur on roots in the field, appear to result from secondary infections by rhizoctonia and other fungi. These infections discolor the tissues around less conspicuous primary lesions caused by the russet crack virus. Less readily observable symptoms can be found on leaves, stems, and feeder roots of infected plants. Where the fleshy roots are

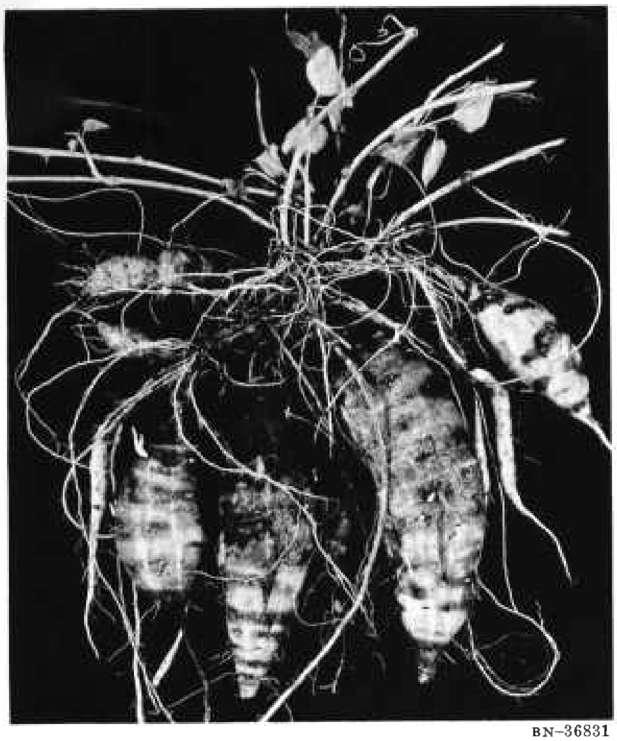
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FIGURE 40.—Hill of Yellow Jersey sweetpotatoes severely infected with russet crack disease.

only mildly affected, symptoms appear as small to moderate-size, dark-brown to grayish spots, or transverse bands with fine longitudinal cracks in the skin and cortical layers of the roots. In moderately infected roots, lesions are darker, with deeper, more extensive cracking. These lesions usually extend in transverse bands of varying width, sometimes incompletely but often entirely circling the roots. Sometimes the encircling lesions may cause constrictions in the roots. In very severely infected roots, the damaging lesions cover the entire surface of the roots (fig. 40). Cracking and discoloration also occur in the smaller feeder roots of infected plants or of sprout plants grown from infected bedding stock. Grayish-black spots or streaks sometimes occur on vines and leaf petioles of infected plants. The disease causes a characteristic necrotic spotting of older leaves in some varieties, such as those of the Jersey types.

Until completely effective control of insect vectors is devised, it will probably be impossible to prevent spread of russet crack (as well as other virus diseases discussed above) in field plantings if infection sources are present. Clean plants for propagation can be obtained only if bedding stock is entirely free of the disease because any sprouts produced from infected bedded roots will also be infected.

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APPENDIX

TABLE 22.—*Some synonyms for the sweetpotato, used in writings concerning this plant*[1]

Ahe (Choctaw Indian)	Lohita
Amotes	Maby (Antilles)
Apichu (Peru)	Mankutu
Artichaut des Indes (France)	Mawandres
Batala	Mita-alu (Hindustan)
Batatas (Malaya)	Myonk-ni (Burma)
Bataten-Winde (German)	Obi-djawa (Java)
Batates douces	Pappas
Battades	Pararo
Battatas	Patales
Boga	Patata
Cacamotic	Patatas
Camote	Patate Jaune (France)
Canange	Patates
Chillagada	Pendaloo (Hindustan)
Convolvulus (several species names)	Potades
Cumala	Potates
Cumar	Potato, Virginian (or Carolina)
Dankali	Potato, sweet
Doukali	Potatoes (Spain)
Fiasi (Wanika-land)	Potatos
Gajar lahori	Potatus
Getica (Brazil)	Ranga
Grasugada	Ratalu
Gumalla	Rukta-kunda
Gumara	Ruktaloo
Hantsoa	Ruktupindaloo
Hetich	Sakaria
Hoanxy (Cochinchina)	Schumbalino
Igname	Shakarkand (Punjab)
Ino (Japan)	Shukar-kandu (India)
Ipomoea batatas	Sisarum Peruvianorum
Ipomoea tuberosa	Skirrets (Peru)
Jetica (Brazil)	Sukkarag-vullie
Kan-chu	Truffe douce (France)
Kara-imo (Japan)	Ubi (Java)
Kiasi	Ubitora (Malaya)
Kimhella	Umara (South Sea Islands)
Kindolo	Vallikilangu
Kitaiti	Veeazee (Central Africa)
Kumana (New Zealand)	Ycam (Peru)
Kumara (New Zealand)	Yeti
Lardak-lahori (Persia)	Zardak-lahori (Persia)

[1] Partial list, adapted from The Sweet Potato (*7*).

TABLE 23.—*Estimated average annual world production and yields of sweetpotatoes and yams from 1960 through 1965* [1]

Continent and country	Production area	Yield per acre	Production
	1,000 acres	*Cwt.*	*1,000 Cwt.*
EUROPE:			
Italy	5	146	669
Portugal (Azores)	[2](7)	[2](121)	[2](880)
Spain	20	111	2,191
NORTH and CENTRAL AMERICA:			
Antigua	[3](5)	[3](50)	[3](242)
Barbados	5	89	475
Cuba	[2]151	[2]33	[2]4,972
Dominican Republic	[4](101)	[4](18)	[4]1,723
Guadeloupe	6	110	704
Haiti	[2](49)	[2](45)	[4](2,178)
Hawaii	—	[5]130	[5]22
Honduras	2	24	66
Jamaica	85	49	4,167
Martinique	9	[4]99	[4]1,100
Mexico	48	60	2,292
Panama	[3]5	[3](161)	[3](814)
Puerto Rico	18	32	581
St. Lucia	[2]2	[5]35	[4]51
St. Vincent	[5]6	[5]21	[5]110
Trinidad and Tobago	—	—	[5](418)
United States	200	81	16,192
SOUTH AMERICA:			
Argentina	89	89	7,960
Bolivia	[3](10)	[3](69)	[2]44
Brazil	361	96	34,632
British Guiana	[2](7)	—	[3]110
Columbia	—	—	[4](2,904)
Ecuador	13	38	524
French Guiana	[4]2	[4]107	[4]161
Paraguay	21	86	1,769
Peru	[4]39	[4]79	[4]3,080
Uruguay	[3]37	[3]50	[2]1,826
Venezuela	30	67	1,923
ASIA:			
Brunei	—	55	22
Cambodia	6	77	502
Ceylon	32	37	1,162
China (Taiwan)	582	112	65,072
Hong Kong	7	85	638
India	385	59	22,735
Indonesia	[5]1,080	[5]60	[5]51,955
Japan	785	176	142,402
Korea, Republic of	208	79	17,103
Laos	[4]5	[4]56	[4]205
Lebanon	—	138	22
Malaysia:			
Malaya	21	[2](93)	[2](4,356)
Philippines	364	45	16,249
Ryukyu Islands	17	146	2,561
Sabah	2	(74)	(264)

See footnotes at end of table.

TABLE 23.—*Estimated average annual world production and yields of sweetpotatoes and yams from 1960 through 1965* [1]—Continued

Continent and country	Production area	Yield per acre	Production
	1,000 acres	*Cwt.*	*1,000 Cwt.*
ASIA—Continued			
Malaysia—Continued			
Singapore	2	76	101
Thailand	[5]56	[5]69	[5]7,711
Viet-Nam, North	[2]457	[2]40	[2]18,381
Viet-Nam, Republic of	111	53	5,861
AFRICA:			
Algeria	[2](2)	[2](89)	[2](242)
Cameroon:			
East Cameroon	[5]132	[5]29	[5]3,432
West Cameroon	[3](7)	[3](73)	[3](572)
Central African Republic	40	33	1,320
Chad	[2]23	[2]46	[2]1,078
Congo (Brazzaville)	[4]25	[4]48	[4]1,100
Congo (Democratic Republic)	(141)	(104)	[3](6,952)
Dahomey	[5]177	[5]72	[5]12,683
Ethiopia	[4]55	[4]27	1,122
Gabon	[3]2	[3]18	[3]44
Ghana	[5](158)	[5](67)	[4]10,604
Guinea	[3]10	[3]124	[5]1,716
Ivory Coast	[5]612	[5]67	[5]40,766
Madagascar	[4]148	[4]38	[5]5,753
Malawi	[2]49	[2]18	[2]902
Mali	[2]12	[2]124	[2]1,540
Mauritius	—	[5]79	[5]22
Niger	5	111	537
Nigeria	[3](3,223)	[3](68)	[2]335,500
Reunion	—	107	66
Ruanda-Urundi (former)	[2]353	[2]64	[2]22,660
Rwanda	[2]183	[2]71	[2]11,858
Senegal	[4]7	[4]62	[4]693
Sierra Leone	7	23	198
South Africa	[3](25)	[3](36)	[4]1,419
Southern Rhodesia [6]	—	[4]38	[3]22
Tanzania:			
Tanganyika	[5](193)	[5](27)	[2]5,225
Zanzibar	[5]5	[4]37	[4]169
Togo	[3]210	[3]85	[3]17,776
Uganda	641	[4](92)	[4](46,882)
United Arab Republic	11	171	1,870
Upper Volta	60	23	1,373
Zambia	[2](5)	[2](44)	[2](220)
OCEANIA:			
Australia [7]	—	[5]75	[5]33
British Solomon Islands	[5](12)	[4](93)	[4](1,056)
Fiji Islands	5	—	[5](330)
New Caledonia	[2]5	[3]13	[3]44
New Guinea (Australia Administration)	[5]5	[5]61	[5]242
Pacific Islands (U.S. Administration)	[5]2	44	88
Papua	[2]2	[5]52	[5]44
Tonga	[2]11	[2]119	[2]1,353
WORLD TOTAL	39,322	66	2,604,800

[1] Calculated from data in Production Yearbook 1963 (*4*) and Production Yearbook 1965 (*5*). Figures shown in parentheses are for period from 1948 through 1953.
[2] Average 2 years. [3] One year only. [4] Average 3 years. [5] Average 4 years.
[6] For farms and estates only. [7] Excluding New South Wales.

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