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HONOLULU, HAWAII

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THE SWEET POTATO IN HAWAII

BY

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By H. L. CHUNG, *Specialist in Tropical Agronomy.*

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INTRODUCTION.[1]

It can not be definitely determined when the sweet potato (*Ipomœa batatas*) was first cultivated in Hawaii, but it is thought that the crop has been under cultivation on the island since about 500 A. D.,[2] because the taro, which is a companion crop of the sweet potato, has, from the earliest days, constituted the staple food crop of the natives. Captain Cook records the finding in 1778 of specimens of taro of large size, and sweet potatoes, weighing 12 to 14 pounds, in the Hawaiian Islands, then known as the Sandwich Islands.

The sweet potato first became of commercial importance to the Islands in about 1849. It ranked tenth in value of the agricultural crops in 1919, having been reintroduced as an emergency crop. The World War was an efficient factor in emphasizing the need of producing locally grown food crops to make the island independent of imported foodstuffs; and during this period the sweet potato was used in place of potatoes, occasionally instead of barley and oats for farm animals and for wheat and corn for poultry, and as a partial substitute for wheat flour in the making of bread and pastries. The crop is no longer exported, owing to rigorous quarantine regulations.

Today the sweet potato is found growing in back yards and school gardens and on areas covering upward of 50 acres on large ranches throughout the islands. Fully 350 acres, located principally on the islands of Hawaii and Maui, are now under cultivation. This crop will undoubtedly play an important rôle in the further development of the diversified agricultural industries of the islands, more especially since it affords large returns in money from small areas.

[1] The writer desires to express his appreciation to those in charge of the Bishop Museum, Honolulu, for their courtesy in placing at his disposal information relative to ancient methods of cultivating the sweet potato in Hawaii, and also to F. G. Krauss, former superintendent of the Haiku substation, who very kindly contributed data obtained at that substation.

[2] Alexander, W. D. A Brief History of the Hawaiian People, p. 19.

BOTANICAL RELATIONSHIP.

The sweet potato belongs to the morning-glory family (Convolvulaceæ) and is known botanically as *Ipomœa batatas*. It is probably indigenous to the West Indies or Central America. In the Tropics this plant is a perennial and produces long trailing stems. Except in case of a few varieties, the sweet potato blooms profusely in Hawaii from November to April. The shape of the leaves and the color of the skin and flesh differ with the variety. The skin ranges from white to dark brown in color, and the flesh varies from white to pumpkin and dark purple.

CULTIVATION IN ANCIENT TIMES.

The sweet potato was grown with care by the ancient Hawaiians. The vines for planting were not gathered at random, but with a discrimination which showed that the native agriculturists appreciated the importance of selection. Vines of individual plants bearing roots in large quantities were selected for further planting.

PLACE IN THE HAWAIIAN CROPPING SYSTEM.

From ancient times the native Hawaiian farmer has realized the advisability of alternating his sweet potatoes with other cultivated crops to improve the physical condition of the soil. Observation taught him that land which was allowed to rest for a year or so after having produced a sweet-potato crop yielded a better and heavier crop than did ground which was kept continuously in one crop. Weeds and native grasses were therefore allowed to grow for a reasonable length of time before the land was replanted to sweet potatoes.

The rice planters of to-day use the sweet potato and other cultivated crops in their system of rotation. As soon as the last annual grain crop has been harvested, the coarse straw is burned and the stubble is turned under and harrowed. The land is then given a heavy application of manure and is immediately used for some quick-growing vegetable, such as lettuce, spinach, beets, radish, or mustard cabbage, followed by sweet potatoes.

The following cropping systems are recommended for use in connection with sweet-potato cultivation in Hawaii:

Two-year rotation.—Corn, cowpeas, sweet potatoes, peanuts; or sweet potatoes, beans, buckwheat, cowpeas, and corn.

Three-year rotation.—Corn, peanuts, grass or sorghums, cowpeas, and sweet potatoes.

Four-year rotation.—Corn, mungo beans, sorghum, alfalfa, and sweet potatoes.

Five-year rotation.—Corn, peanuts, sorghum, pigeon peas, sweet potatoes; or cassava, cowpeas, peanuts, sweet potatoes, and alfalfa.

ADAPTATION TO HAWAII.

Hawaii, being situated well within the Tropics, is naturally adapted to the growing of sweet potatoes. The situation is so favorable, in fact, that the plant produces immense roots, even when it is grown in the pockets of volcanic rocks where there is little soil. The sweet potato can be grown on all the areas of Hawaii except in rocky

regions where there is no soil, in locations where there is an insufficient amount of rainfall, or on high elevations which are exposed to the wind.

The plant thrives from sea level to an elevation of 2,000 feet. Growth can be maintained at a still higher altitude, provided the location is sheltered from strong winds, which are decidedly harmful to the plants. When grown at an altitude higher than 1,500 feet, the period of maturity of a given variety varies with the altitude; that is, the higher the elevation, the longer will be the period required to mature the crop, owing to lower temperatures.

To make its best development, the crop needs moderate rainfall, an abundance of sunshine, and warm nights from the time of planting until the vines produce vigorous axillary buds.

SOIL.

To produce its maximum yield, the sweet-potato crop should be grown in a well-drained, moderately fertile, loose sandy soil. The following hints may be of value to planters living in regions where there is no soil of this kind.

Heavy clay soil.—When the sweet potato is grown in heavy clay soil, such as local taro soil, it develops a dwarfed and sickly vine growth and coarse roots which are likely to be unmarketable, owing to their irregular shape. (Pl. I.) Clayey soil renders aeration impossible, since it is extremely sticky during wet periods and closely compacted during the hot summer months, when it dries out in hard lumps.

To improve the physical condition of such soil, leguminous crops, such as cowpeas and velvet beans, should be grown and plowed under as green manure. The plowing under of leguminous crops adds large quantities of nitrogen to the soil. Preparatory to the planting of a second leguminous crop, and before harrowing is done, other organic matter, such as rotted stable manure, rice hulls, or chaff, should be broadcasted on the plowed field. Rice hulls can be obtained from any rice-milling establishment in Hawaii for the asking and cartage. The incorporation of organic matter in the clayey soil loosens and mellows the soil and enables it to retain sufficient moisture for plant growth.

Soils rich in humus.—The vines make luxuriant growth at the expense of the roots when the crop is grown on land containing very large quantities of humus. Such land should not be planted to sweet potatoes for six months following the successive planting of crops having edible foliage, such as green mustard, white mustard, and Chinese cabbage.

Soils in seashore areas.—The sweet potato can be grown very successfully on areas not far from the seashore and on soil containing a large quantity of sand. Flat cultivation rather than ridge planting should be practiced on such land, and organic matter and commercial fertilizers should be incorporated with the soil from time to time to render it productive. Only those varieties of sweet potatoes which have already been acclimated and are adapted to seashore conditions should be planted on sandy soil, otherwise the roots will contain a high percentage of salt. Experiments conducted at the experiment station on land near the seashore showed that the roots

of four varieties of sweet potatoes contained from four to seven times as much salt as did those grown at the central station.

SOIL MOISTURE.

In Hawaii, where there is an uneven distribution of rainfall as well as great diversity of soil types, the moisture content of the different soils varies considerably. Some of the soils are so porous that the water filters through the surface instead of being absorbed, and washes away much vegetable matter. Such soils may be improved in water-holding capacity by green manuring. Other soils are too retentive of moisture and for this reason are detrimental to the crop. The sweet-potato crop should not be planted until it is known what the soil and rainfall conditions are.[3]

Virgin lands, or fields that have lain fallow for some time, should be plowed and all volunteer growth turned under to insure excellent soil conditions for the development of the roots of the new crop. If the soil contains a suitable amount of moisture the roots will develop near the surface, but if it is dry they will grow downward before enlarging. Roots growing in a dry soil are difficult to harvest.

In localities where the fields are flooded after a heavy rain and the water remains standing in the furrows for several days, not only are the fertilizers leached out of the ridges, but the growth of vines is stimulated at the expense of the roots. All the furrows should therefore lead into a channel at the lowest part of the field. After the standing water has been removed from the furrows, the ridges should be examined. On those which are saturated with water the vines should be thrown to one side, so that the wind and sun will hasten evaporation. After about four days, when these ridges have returned to normal conditions, the vines should be thrown to the opposite side, so that the newly exposed part will dry out. (Pl. II, fig. 1.)

METHODS OF CULTURE.

PROPAGATING MATERIAL.

Sweet potatoes are propagated either from vine cuttings or from slips resulting from the sprouting of shoots from the root. In Hawaii terminal cuttings are used almost exclusively, because they have the ability to make quick growth and the advantage of being practically free from insect pests. Old stem cuttings are likely to carry the eggs or larvæ of the stem borer and are often the means of infesting new fields with the pest. So far as resulting yield is concerned, no appreciable difference has been found between the terminal and old stem cuttings.

In Hawaii, where propagating material can be readily taken from the vine at any time of the year, the roots of the sweet potato are not usually bedded in the greenhouse in spring for slips. It is only when a variety shows signs of degeneracy, in the form of unproductiveness, that the sweet-potato roots are sprouted. The terminal cuttings are removed in lengths of from 12 to 16 inches, and the large leaves and their petioles are stripped from them. The cuttings should be moistened and protected from drying when they are not to be planted immediately after their removal from the vine. Fresh-

[3] Planters may obtain a report on their soils by consulting the experiment station.

cut vines which are planted in beds without irrigation make quicker growth than do partly shriveled cuttings which are several days old. Slips that are not to be planted immediately should be covered with burlap bags saturated with water.

PREPARATION OF THE LAND.

The sweet-potato crop, like most other vegetable crops, gives best results when it is planted on well-prepared land, especially on land that has been planted with some leguminous crop the year preceding. The area should first be thoroughly cleared of all coarse material and then plowed fairly deep, the sod and débris being turned under. The depth of plowing is an important factor in the preparation of land and exerts considerable influence upon the character of the roots. The depth used for corn will do for sweet potatoes. The fertilizer, if any is to be applied, should then be spread broadcast, and the field harrowed three or four times to make the soil sufficiently mellow. Later a plank drag may be used to smooth the surface.

A spading fork is recommended for use in small areas. This implement is very efficient for soils that are not compact and hard, as the prongs strike well into the ground. Small areas which are covered with low-growing weeds and other vegetation may be turned under with it. Fertilizers should then be applied and a rake used to level the area and to mix the fertilizer with the soil. Planting, either by the level or ridge method, may begin a week later, when the soil has had ample time to settle.

PLANTING.

Three methods of planting are practiced in Hawaii, namely, (1) ridge planting, (2) flat planting, and (3) individual mound or hill planting.

Ridge planting.—This method is commonly practiced by the sweet-potato growers of the islands, and is of advantage in that it provides drainage, insures aeration, and puts the soil in good physical condition for the best development of the roots. The ridges are constructed of loose earth and vegetable matter and stand from 12 to 16 inches high. They are spaced about 3 or 4 feet apart and are planted with 1 or 2 cuttings set 1½ and 2 feet apart in the row. (Pl. II, fig. 2.)

Soils which are located near the seashore should not be ridged, because ridging tends to increase the surface area and to hasten evaporation of soil moisture.

Flat planting.—This method of planting is also extensively practiced, but more especially on very sandy loam or sandy soil. In flat planting the surface of the soil is made flat or level before planting is done.

Mound or hill planting.—The method of setting plants in hills or elevations of earth (Pl. III, fig. 1) has been handed down from primitive times and has an advantage over the other two methods, so far as the native Hawaiians are concerned, in that it permits of the mound's being broken down and the roots exposed at once without great effort. The natives make it a rule to harvest only enough roots to cover the needs of the day. The mounds are from 9 to 12 inches high and are spaced about 24 inches apart each way.

The number of sweet-potato cuttings required per acre is indicated in the following table:

Number of sweet-potato cuttings required per acre when planted at different distances.

Distance apart of rows.	Distance apart in rows.	Number of sweet-potato cuttings per acre.	Distance apart of rows.	Distance apart in rows.	Number of sweet-potato cuttings per acre.
Feet.	*Feet.*		*Feet.*	*Feet.*	
2	2	10,890	3	3	4,840
2½	2½	6,008	3½	1½	8,297
3	1½	9,680	4	2	5,445
3	2	7,260			

CULTIVATION.

The sweet potato requires careful cultivation when it is grown in soil other than sand or sandy loam. The shape and size of the roots are materially affected by the physical condition of the soil. Cultivation loosens and aerates the soil, and puts the plant food in such condition that it can readily be assimilated by the crop. It also keeps down weed growth and helps to conserve soil moisture.

The first cultivation should be given when the vines are about 8 inches long, or sooner, if the field is weedy. Cultivation consists in turning under the weeds and throwing the soil from the furrow to the ridge with a small one-horse plow, supplemented with hoeings to bring the soil up around the plant. When the vines are grown under level cultivation, a harrow should be used on the soil. Usually three or four cultivations are sufficient to keep the soil in good tilth until the field is overrun with vines. Weed growth is promoted during the rainy season, and the ground then requires frequent cultivation. Sweet potatoes can best be cultivated with a hoe when they are grown on small areas.

FERTILIZERS.

The sweet potato readily responds to applications of fertilizer. At the experiment station an increase of 42 per cent in yield resulted from the application of a mixture of sodium nitrate, potassium sulphate, and acid phosphate, in the proportions of 75, 150, and 400 pounds, respectively, per acre. At the substation at Haiku, Maui, sodium nitrate, potassium sulphate, and equal parts of reverted phosphate and acid phosphate, in the proportions of 100,150, and 250 pounds, respectively, per acre gave the best results.

It is suggested that the potassium sulphate be increased in the first formula to 200 pounds for very sandy soil, half of the fertilizer being applied when the plants have been set for about five weeks, and the rest five weeks later. The fertilizer should be uniformly applied. The Haiku formula is recommended for use on areas where the soil is adapted to the production of sweet potatoes, but on elevated regions maturity is delayed by reason of the altitude, the reverted phosphate being gradually made available to the plants during the protracted period of growth.

SWEET POTATOES PRODUCED IN HEAVY CLAY SOIL. IRREGULAR IN SHAPE AND UNMARKETABLE.

FIG. 1.—VINES TURNED TO ONE SIDE TO PROMOTE EVAPORATION FROM SOIL OF EXCESSIVE MOISTURE CAUSED BY STANDING WATER.

FIG. 2.—SWEET POTATOES GROWN BY RIDGE METHOD.

IRRIGATION.

Irrigation is not an important consideration in connection with sweet-potato growing in Hawaii owing to seasonal conditions and the drought-resistant character of the plant. It thrives and produces a crop of roots with very little moisture. The type of soil and the amount of rainfall largely determine where and when the crop can be grown to the best advantage. When rainfall is the only source of moisture, the crop should be frequently cultivated to conserve moisture as the dry season approaches.

The plants should be watered sparingly when they are grown on small areas or in localities where irrigation is possible. It is impossible to establish a definite rule for time of irrigation, because some soils retain moisture longer than do others, but it is good practice to water the plants when the soil, to a depth of 3 or more inches, is comparatively dry to the touch.

A very effective way of irrigating the sweet-potato crop is by turning the water into alternate furrows. This practice permits thorough saturation of the soil immediately surrounding the plant and precludes the possibility of its packing later. In flat culture light irrigation, rather than heavy, should be practiced.

PRUNING.

Some of the local growers cut the sweet-potato tops from the cultivated field for feeding hogs. To determine the effect of such a practice upon yield of roots the experiment station, in 1917, carried on a test, covering eight months, with the Yellow Yam variety of sweet potato. The plants were set in 12 rows, each 100 feet long, and the vines were cut once a week after they had attained a length of 18 inches. The following table gives the result of the test:

Effect on yield of cutting back sweet-potato vines.

Rows.	Length to which vines were cut.	Calculated acre yield.
	Inches.	*Pounds.*
1, 2, 3, 4	12	6,859.4
5, 6, 7, 8	(1)	21,857.6
9, 10, 11, 12	18	10,779.1

[1] Not pruned.

The above table shows that the yield of sweet potatoes is greatly decreased when the vines are cut back. The rows, the vines of which were kept within 12 to 18 inches long, produced a yield of roots approximating 31 and 49 per cent, respectively, of a crop as compared with the unpruned vines. The test showed that many pruned vines were devoid of enlarged marketable roots. Apparently the shorter the vine is cut, the greater will be the reduction in yield.

HARVESTING.

The period of maturity of the sweet potato differs with the variety and the locality in which it is grown. Some varieties mature a crop much earlier than do others. In all varieties the period required for

maturity is lengthened when the crop is grown at the higher elevations. Sweet potatoes are classified in three groups, those maturing in three months, or early varieties; those maturing between four and five months, or medium early varieties; and those maturing between six and seven months, or late-maturing varieties. Some suppose that the crop is mature and ready for harvesting in about four or five months after planting if the leaves turn yellow. Yellowing of the leaves is not always an indication of ripening and may be caused by drought or the disease known as stem rot. Excessive rainfall, on the other hand, stimulates the growth of the vines and causes the foliage to remain green for months after the roots have matured. Again, it is supposed that the crop has matured if the roots remain white upon being broken, and that, vice versa, immaturity is shown by discoloration of the broken surface. In experiments with sweet potatoes which were known to be immature, the experiment station found no discoloration to occur after breaking except that due to the milky substance, latex, which is also present in the mature root.

On account of its excellent keeping qualities the sweet potato in Hawaii may be left unharvested in the field for months without likelihood of its decaying, even when the period of maturity has passed. If the roots are kept in the ground after maturity, not only will the quality be improved materially, but the yield will be considerably increased. The question of when to harvest, then, is not an important one, so far as maturity is concerned. Under no circumstances, however, should the crop be harvested after a rain when the ground is very moist, if the roots are intended for market and a large area is to be harvested. When the soil is wet, sweet potatoes are difficult to harvest and the earth sticks to them.

A gardener whose sweet-potato area is small may harvest his crop before it matures fully. To harvest the required quantity of roots without disturbing every hill, the vine should be carefully lifted and the ground examined for large cracks or crevices around the plant. These cracks are found when the soil surface is dry and occur where extra-sized roots are growing.

In small areas, and where the crop is grown primarily for home consumption, harvesting may be facilitated by means of a four-pronged spading fork. After the vines are removed the fork should be inserted in the soil at a distance of 8 or 10 inches from the plant and the roots lifted and brought to the surface.

When the crop is grown on a large scale in Hawaii, a turnplow is used for harvesting after the vines have been removed by hand. The sweet potatoes are brought to the surface by plowing, thrown to one side by men, and later are graded for market. The roots should be left in the field and exposed to the sun for a few hours to dry

YIELD.

The yield of sweet potatoes depends largely upon the locality and soil in which the crop is grown, the kind and amount of fertilizer used, the culture given, and finally upon the variety itself. A yield of 10 tons per acre can be secured from a crop that is grown under favorable conditions. As high a yield as 17½ tons of roots and 21½ tons of vines per acre has been produced at the Haiku sub-

station. If the yield is estimated on a small basis, 100 plants, spaced 4 by 2 feet apart, should produce at least 150 pounds of merchantable and 50 pounds of cull roots.

In varietal tests covering a period of five years at the central station at Honolulu an average yield of 4 tons per acre was obtained from all the varieties tested. In these tests the early maturing varieties were less productive than either the medium or late varieties. The following table gives the comparative yield of a number of these varieties:

Comparative yield of sweet potatoes tested at the central station.

Variety.	Yield per acre.	Variety.	Yield per acre.
	Tons.		*Tons.*
Delicious	3.7	Native Red	6.0
Huamoa	4.1	"Yellow Yam"	6.6
Pikonui	3.2	New Era	6.7
No. 111-A	3.1	Tantalus	6.2
Madeira	5.4		

The yield of sweet potatoes may be increased by proper culture and the application of fertilizers, or by the selection through several generations of individual hills producing heavy crops of desirable and well-shaped roots. The most opportune time to select for improvement is when the crop is being harvested. Hills are then dug individually, showing numbers of roots of varying shape and size. Vine cuttings should be taken from the hills which contain the largest number of roots of good size and uniform shape (Pl. III, fig. 2). These should be carefully labeled and notes made concerning their individual parents.

Many hills should be selected for foundation work, because some of them will fail to transmit their prolific characteristics. Improvement should then be continued by eliminating the unproductive vines and retaining those bearing heavy crops of roots. (Pl. IV, fig. 1.) Within a period of five or six years, representing 10 or more generations, the grower will be able to establish a prolific strain of fine quality which he is entitled to call his own and to give a special name if its characters are sufficiently distinct.

GRADING.

Although sweet-potato grading has been advocated in Hawaii for many years, wholesalers continue to purchase solely on the basis of exchange of so much money for so much weight, regardless of kind of material weighed. The local farmers raising diversified crops recognize the importance of standardizing agricultural produce as a means of building up their business, but the local growers, who supply the markets with sweet potatoes for culinary purposes, are indifferent to suggestions regarding grading, either because the planting of this crop is incidental to their specialized crops and the area is so small that it does not justify the extra labor expended in grading, or they have learned that quotations are the same for graded and ungraded sweet potatoes. Standardization of the crop will not become a reality until uniformity of size, shape, and color enters into

the transaction and sweet potatoes are marketed practically free from cuts, bruises, decay, scars, cracks, and other defects resulting from careless handling, as well as from diseases and insect pests.

SELECTION OF SWEET POTATOES FOR HOME USE.

Fully 15 to 25 per cent of the total weight, depending upon the shape of the roots, is lost in the paring of sweet potatoes which are intended for culinary use. In other words, there is removed in the form of paring from 1½ to 2½ pounds by weight for every 10 pounds of sweet potatoes pared. For this reason there should be selected for home use regular-shaped, uniform, smooth, firm, and fresh-looking roots rather than shriveled or irregular-shaped specimens.

STORING.

In Hawaii the sweet potato is not stored for future use for any great length of time, because the crop can be harvested during any month of the year. After sunning for a few hours in the field the roots are taken to a shed and spread out in shallow piles to cure thoroughly. A number of sweet-potato growers on Oahu make it a practice to harvest just enough to supply the current needs of the wholesaler, and the native Hawaiians never harvest more than the actual quantity of roots needed to supply the household for the day. In this they show an appreciation of the quality of the freshly dug root and a knowledge of how to eliminate the problem of storage. The small gardener would do well to adopt their practice.

SHRINKAGE IN STORAGE.

Data obtained at the experiment station on shrinkage occurring in sweet potatoes, which are sacked and left in a cool but dry room, show that a loss of 12 per cent of the original total weight takes place in 21 days, approximately 6 per cent of which is lost during the seven days immediately following harvesting and 6 per cent during the next 14 days. It is evident, therefore, that sweet potatoes should be carefully stored to reduce the loss by shrinkage to a minimum. Storage houses intended for sweet potatoes should have wooden roofing, which does not have the same heat-retaining properties as does galvanized-iron roofing, and the storage rooms should be kept cool and dark.

COST OF PRODUCTION.

The cost of producing a crop of sweet potatoes depends largely upon the locality where it is grown and the method of growing. On level land, where labor-saving devices can be used to do considerable of the work, the cost per acre is less than is the case on hilly lands where the greater part of the work has to be done by manual labor. In Hawaii, where labor is rated as an expensive item, the cost of producing an acre of sweet potatoes ranges between $80 and $100, exclusive of the charge for rental of land, fertilizers, and cost of sacks. The following table gives the comparative cost of producing sweet potatoes at the central station, the substation at Haiku, and on the mainland:

FIG. 1.—SWEET POTATOES GROWN BY MOUND OR HILL METHOD.

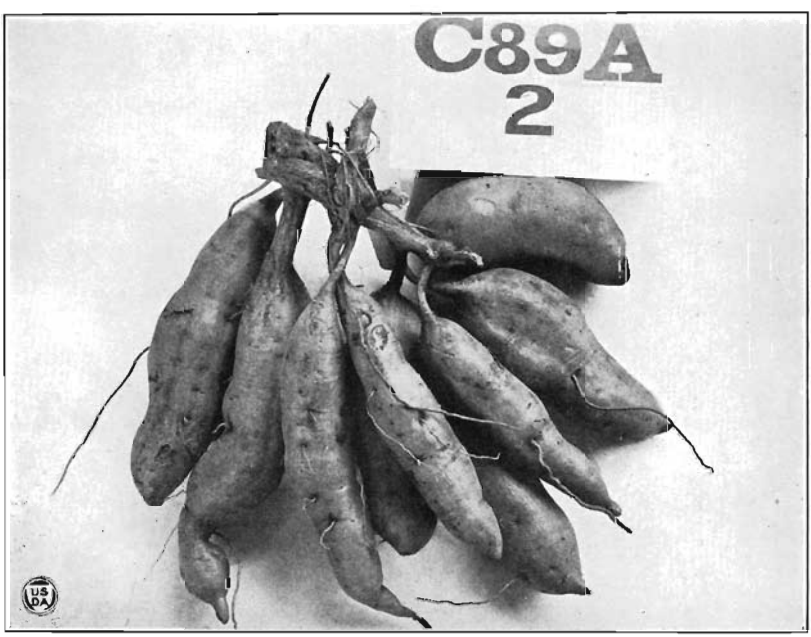

FIG. 2.—CLUSTER OF SWEET POTATOES OF UNIFORM SIZE AND SHAPE.

FIG. 1.—HILLS BEARING SWEET POTATOES IN GOOD CLUSTERS. CUTTINGS SHOULD BE MADE FROM PLANTS OF THIS TYPE.

FIG. 2.—SWEET POTATOES BADLY DAMAGED BY STEM BORERS.

Comparison of the cost of producing sweet potatoes in Hawaii and on the mainland.[1]

Expenditures.	Location.		
	Central station.	Haiku substation.	Mainland.
Plowing (3 times)	$18.00	$18.00	$15.00
Disking	6.00	9.00	.....
Harrowing	3.00	.....	.....
Plank dragging	.....	1.00	.....
Ridging	6.00	5.00	4.00
Plants	15.00	15.00	10.00
Planting	8.00	6.50	5.00
Cultivation	6.00	4.50	5.00
Removing vines	11.00	[2] 9.00	.....
Harvesting	16.00	15.00	25.00
Extra cost, due to experimental data obtained	10.00	.....	.....
Hauling	5.00	7.50	.....
	104.00	90.50	64.00

[1] See Farmers' Bul. 324, Sweet Potatoes, p. 38.
[2] The item of cost in removing the vines is recovered by disposing of the vines as a soiling crop. They were delivered to the piggery of the Haiku substation for $5 a ton.

The above table shows that the cost of production at the experiment station was considerably more than was the case at either the Haiku substation or on the mainland. This difference was largely due to the great care which was exercised in the planting, cultivation, and weighing of the roots and vines, grown as they were under experimental conditions rather than under ordinary field conditions.

The figures of the Haiku substation serve as representative items in the cost of production when the crop is grown on a commercial basis in Hawaii. At this substation the cost per cultivation was $1.50, or three cultivations for $4.50; the cost of removing the vines and loading them on to the wagon was at the rate of $1.50 per ton, or 6 tons for $9. An item of 15 cents represents the actual cost of preparing, harvesting, cleaning, grading, and sacking a 100-pound sack of sweet potatoes for delivery from the field. On the basis of 100 sacks per acre the cost would be $15, as indicated. The hauling charge was $1.50 per ton.

The mainland cost for producing an acre of sweet potatoes is decidedly low, as shown by the table. The use of labor-saving devices and the growing of the crop in extensive areas make the low figures possible. The item of $15 for three plowings also includes the cost of disking and leveling the surface prior to ridging, and the item of $25 for harvesting includes cost of cleaning, grading, sacking, and hauling.

INSECT ENEMIES AND METHODS OF CONTROL.

The sweet potato in Hawaii is attacked by a number of insects which feed upon the leaves, stems, and roots. Leaf-eating insects cause little permanent injury to the plant, owing to its vigorous growth, and they can be brought under control with proper measures. Practically all of the insects attacking the crop have been described in Bulletin 22 of this station, and only those which are especially injurious are mentioned here.

INSECTS INJURING THE FOLIAGE.

JAPANESE BEETLE (*Adoretus tenuimaculatus*).

The Japanese beetle perforates the foliage of the sweet-potato plant. The pest can be brought under control by spraying the under side of the foliage with a mixture containing 1 pound of lead arsenate in 20 gallons of water.

SWEET-POTATO LEAF-MINER (*Bedellia orchilella*).

The leaf-miner, after the stem borer, is perhaps the most destructive insect enemy of the sweet-potato vine. Its injuries are confined to the foliage, which as a result presents a notched and withered appearance and bears traces of excrement. The newly hatched larvæ penetrate the leaves and feed upon the green coloring matter. The leaves gradually lose their color and wither, and the leafstalks drop.

The leaf-miner can best be controlled by the removal and burning of severely infested foliage and by the practice of clean cultivation.

SWEET-POTATO SPHINX (*Herse convolvuli*).

During the rainy season the sphinx caterpillar periodically appears on sweet-potato vines. The eggs are usually laid on the under side of the leaves of the wild morning-glory *Ipomœa digitata*, and occasionally on those of the sweet potato. The caterpillar is from 2 to 6 inches long, ranges from light green to dark brown in color, and is characterized by a single black horn.

As a means of control, all host plants, such as morning-glory and pigweed (*Portulaca oleracea*), should be destroyed. On vacant lots in the Waialae district of Oahu wild morning-glory vines should be destroyed to protect the surrounding fields of sweet potatoes from attack by the sphinx caterpillar.

Spraying the under side of the leaves with arsenate of lead solution (1 pound of the arsenate to 20 gallons of water) will materially reduce the number of caterpillars. This pest may also be kept in check by picking the larvæ from the vines growing on small areas.

SWEET-POTATO LEAF-ROLLER (*Phlyctænia despecta*).

This leaf-roller is one of the minor insect pests attacking the foliage of the sweet-potato crop. In extreme cases it skeletonizes the leaves and envelopes the remaining structure in a filmy web. The young caterpillar, although colorless, usually appears green, owing to the green contents of the alimentary tract, which can be seen through the body. Its hiding place is on the under side of the leaves.

An application of lead arsenate to the leaves is recommended as a control measure. Clean cultivation should also be practiced.

INSECTS INJURING THE STEM.

CUTWORM (*Agrotis ypsilon*).

Cutworms attack the sweet-potato vine at night during the early growing period, eating the terminal and axillary buds and sometimes completely cutting off the growing vine at the base.

As a control measure the use of poison bait, composed of 1 pound of molasses, ½ pound of lead arsenate, and 10 pounds of bran, thoroughly mixed and spread near the base of the vines, is recom-

mended. If the soil around the base of the plant is stirred with a small stick, the worms will leave their hiding places and can then be easily destroyed.

INSECTS INJURING THE ROOTS.

SWEET-POTATO WEEVILS (*Cryptorhynchus batatæ* and *Cylas formicarius*).

Sweet-potato weevils are quite destructive at times, thoroughly channeling the roots with larval burrows and causing the vines to shrivel and decay.

As a control measure, all infested potatoes and trash above ground should be burned and clean cultivation should be practiced.

INSECTS INJURING BOTH STEM AND ROOT.

STEM BORER (*Omphisa anastomosalis*).

The stem borer is perhaps the most destructive of all the insects attacking the sweet potato in Hawaii. It not only burrows large and distinct tunnels in the stems of the plant, but also damages the root crop. (Pl. IV, fig. 2.) In a severely infested field the vines die and the yield of roots is greatly reduced.

Stomach poisons are of little avail in connection with the stem borer, as most of its life is passed within the stem or the roots. Probably the most effective way of combating it is by the practice of clean cultivation. All infected vines and roots should be gathered and burned. In severely infested small areas the borers can be crushed within the stem by the pressure of the fingers up and down the tunneled vines.

FUNGUS DISEASES AND MEANS OF CONTROLLING THEM.

The sweet-potato plant is attacked by a number of diseases which are divided into two classes: (1) Those attacking the crop in the field, and (2) those attacking the crop in storage.

DISEASES ATTACKING THE CROP IN THE FIELD.

BLACK ROT (*Sphæronema fimbriatum*).

Black rot, due to the fungus *S. fimbriatum*, is not confined to the field, but also attacks the crop in storage. Infected roots, when taken from the field, show discoloration in small patches which enlarge and finally affect the whole root. Cooked sweet potatoes which are affected with black rot have a bitter taste.

STEM ROT (*Fusarium batatatis*).

Stem rot, caused by an organism (*F. batatatis*), commonly attacks the plant and its roots. As the name indicates, the stem is affected, usually becoming blackened in the advanced stage, and the foliage turns a dull yellow and drops. As a rule the vine wilts, and in the instances where it does survive the roots are discolored.

SCURF (*Monilochætes infuscans*).

Scurf, also known as soil stain, is due to a fungus (*M. infuscans*) which adheres in such a way to the roots as to be mistaken for soil particles. It is not a serious disease and damages the potato only by

discoloring the skin. A white-skinned variety when attacked presents a dark-gray appearance, while a red-skinned variety turns black.

FOOT ROT (*Plenodomus destruens*).

Foot rot is indicated by rotting of the stem near the surface of the soil. The infected plant presents a rather wilted appearance.

BLIGHT OR WILT (*Sclerotium rolfsii*).

Blight or wilt is indicated by decay of the plant at the base and by moldy white growth.

TEXAS ROOT ROT (*Ozonium omnivorum*).

Texas root rot is indicated by a spotting of the roots and a wilting of the vine.

PIT OR POX (*Cytospora batatas*).

Pit or pox, also known as soil rot, is indicated by malformation and girdling of the roots of the plants, accompanied by low yield.

DISEASES ATTACKING THE CROP IN STORAGE.

SOFT ROT AND RING ROT (*Rhizopus nigricans*).

Soft rot is indicated by decay of the root at one end, the diseased part becoming very soft.

Ring rot is indicated by a softening of the roots between the ends.

DRY ROT (*Diaporthe batatatis*).

Dry rot is indicated by shriveling of the roots, unaccompanied by softness.

JAVA ROOT ROT (*Diplodia tubericola*).

Java root rot is indicated by blackened flesh.

LEAF DISEASES.

Three minor diseases which affect the foliage of the plant are leaf-blight, giving the plant a withered appearance; leaf-spot, identified by minute white specks on the leaves; and white-rust, indicated by small white spots. Being only minor diseases, they require no treatment when occurring on a large area. Infected leaves should be removed from small areas, however, and burned.

CONTROL.

It is only by the most careful management that sweet-potato diseases can be eliminated from the field. The selection of propagating materials from absolutely sound plants, the careful examination of the root crops and vines before moving from one field to another, and the practice of crop rotation are the only effective measures.

Cuttings which are intended for propagation should be selected with care if they are taken from infected areas. They should be treated with a solution of bichlorid of mercury (1 ounce of bichlorid of mercury to 8 gallons of water), being submerged in the solution for five minutes. Vines or roots showing signs of disease should be removed from the field and burned. If a locality continues to be

infected, notwithstanding its receiving every precaution to make it disease free, it should be allowed to lie fallow for a year or two and then be planted with about 20 varieties of sweet potatoes. Selection should then be made for future planting from the varieties appearing healthy and producing luxuriant foliage and good crops of sound roots.

VARIETIES OF SWEET POTATOES IN HAWAII.

Approximately 70 distinct varieties of sweet potatoes having Hawaiian names are known to the native growers, and fully 200 others are either unnamed or bear English names.[4] Many of these varieties are undoubtedly cultivated elsewhere under different names. For practical and commercial purposes the following listed varieties are recommended for table use and for feeding to live stock:

Varieties of sweet potatoes which are adapted for both human consumption and for live-stock feeding.[1]

Varieties.	Color of skin.	Color of flesh.
Early maturing:		
Delicious Yellow	Purplish pink	Pumpkin.
Huamoa	Straw	Orange.
Pikonui	do	Light yellow.
Medium early maturing:		
No. 111–A	White	White.
Madeira	do	Light yellow.
Native Red	Red	White.
"Yellow Yam"	Straw	Pumpkin.
Late maturing:		
New Era	Dark buff	Light cream.
Tantalus	Light brown	Cream.
Madeira	White	Light yellow.

[1] The late-maturing varieties are especially recommended for live-stock feeding because they are prolific bearers, and good keepers, and contain a high percentage of starch.

A great variety of potatoes is needed in Hawaii to meet the demands of the cosmopolitan population. The occidental population in Hawaii prefers sweet potatoes having orange or pumpkin-colored flesh, while the oriental population prefers a red-skinned variety having flesh varying from white to canary in color.

COMPOSITION OF THE SWEET POTATO.

Sweet potatoes vary considerably in chemical composition according to the variety and the place where they are grown. The following table gives a comparison of the sweet potato with other starchy crops:

Relative value of the sweet potato and other starchy root crops.[a]

Crop.	Water.	Ash.	Crude protein.	Carbohydrates.	Fat.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sweet potato (whole)	68.89	0.90	2.12	27.83	0.26
Sweet potato (peeled)	68.50	.94	2.18	28.18	.20
Sweet potato (peeling)	74.35	.31	1.29	21.96	1.09
Cassava (whole)	64.17	.86	.77	32.61	1.59
Taro (whole)	60.55	.73	1.10	37.49	.13
Potato (whole) [b]	78.30	1.00	2.20	18.50	.10

[a] Practically compiled from Hawaii Sta. Press Bul. 53.
[b] Unpublished analysis made by the Hawaii Experiment Station.
[4] Sweet-potato breeding has been carried on by the experiment station since 1917, since which time more than 700 seedlings have been produced.

From the above table it will be seen that the sweet-potato root compares favorably in chemical composition with the three other root crops. The whole sweet potato shows a higher ash and crude protein content and a lower carbohydrate content than does either the cassava or the taro. In fat content it is lower than the cassava, but higher than the taro. A comparison of the sweet potato with the potato brings out the significant fact that the former is about as high in crude protein content as is the latter and that it is much higher in carbohydrates and fat. Notwithstanding these facts, the potato commands the higher price of the two on the local markets throughout the year.

RECIPES.

Sweet potatoes are prepared for table use by practically all of the many nationalities in Hawaii, in the occidental homes and hotels being baked, boiled, or braised, and in the oriental homes, boiled whole, or pared, sliced, and then boiled. Starch is extracted from the raw potato for the preparation of a paste-forming meal which can be fed to infants and also to adults. Some of the methods of using the sweet potato are given below.

SWEET-POTATO BREAD.

(1 loaf.)

1 cupful of mashed sweet potatoes.
1 teaspoonful of salt.
1 tablespoonful of sirup, if desired
4 tablespoonfuls of lukewarm water.
2½ cupfuls or more of sifted flour.
⅛ to ½ cake of yeast (dry or compressed), or from 2 to 4 tablespoonfuls of liquid yeast.[5]

Use left-over boiled or baked sweet potatoes or boil sweet potatoes in their jackets until tender. Pare and mash the sweet potatoes or put them through a colander or ricer to free them from lumps.

Short process.—To 1 cupful of the cool mashed sweet potatoes add 1 teaspoonful of salt, 1 tablespoonful of sirup, and ½ cake of compressed yeast mixed with 4 tablespoonfuls of lukewarm water, or 4 tablespoonfuls of liquid yeast. It may be necessary to add more water if the sweet potatoes are rather dry or mealy. Add to this ½ to 1 cupful of sifted flour and stir until the whole is thoroughly mixed. Cover and allow the mixture to rise for about two hours until it becomes soft and light. Knead in another quantity of flour sufficient to make a dough somewhat stiffer than for white bread. Knead the mixture until it is smooth and elastic, then cover and let it rise again until it becomes very light. Knead, mold, and finish as usual. Allow the mass to rise in the pan until it reaches 2½ or 3 times its original bulk. Bake slowly in a moderately hot oven for at least 50 minutes.

Long process.—To 1 cupful of the cool mashed sweet potatoes add 1 teaspoonful of salt and either ⅛ cake of yeast, dry or compressed, mixed with 4 tablespoonfuls of lukewarm water, or 2 tablespoonfuls of liquid yeast. Add to this ½ to 1 cupful of sifted flour. Cover and set to rise where the temperature ranges from 60° to 70° F. When the mixture is light and soft add the sirup and knead in another quantity of flour sufficient to form a smooth, elastic, and rather stiff dough. Cover and let rise a second time until it becomes very light. Then knead, mold, and finish as directed for the short process.

Cooked or baked squash, pumpkin, peas, beans, or dasheen may be substituted for sweet potatoes. When larger quantities of sweet potatoes are to be used, less water will be required; that is, for every 1⅔ cupfuls of mashed sweet potatoes only 2 tablespoonfuls of water per loaf are needed. In this case less flour will be required.

SWEET-POTATO BISCUIT.

2 cupfuls of sifted flour.
1 tablespoonful of salt.
3 teaspoonfuls of baking powder.
1 cupful of mashed sweet potatoes.
3 tablespoonfuls of shortening.
Sufficient water or milk to mix.

[5] Liquid yeast, when used, should be included in the total liquid.

Sift the flour, salt, and baking powder together. Cut or rub the cold shortening into this mixture. In the same way rub into this flour mixture the mashed potatoes. Finally, add just enough cold liquid to make the mass cling together. Do not knead. Place mass on floured board, roll until ⅛ inch thick, and cut with a biscuit cutter. Place in lightly floured biscuit tins and bake for 15 or 20 minutes in a moderately hot oven. Bake potato breads more slowly than all-flour breads.

SWEET-POTATO GREENS.

The tops of the sweet potato vine make excellent greens for the table, comparing in this respect with spinach. Remove the tips to a length of 3 inches, wash, and place in saucepan containing water and salt. Boil, drain, and season with salt and pepper before serving.

SWEET-POTATO PORRIDGE.

(Oriental method.)

1 tablespoonful of sweet-potato starch.
½ cupful of cold water.
About 1 cupful of boiling water.
Sugar to sweeten.

Place the sweet-potato starch in a quart container, add water, and mix thoroughly. Gradually add boiling water and stir until a thick, paste-like porridge is formed. Add sugar to sweeten and serve.

SWEET-POTATO SOUP.

(Oriental method.)

Pare sweet potato, cut into slices about one-fourth inch thick, and place in a saucepan containing barely enough water to cover. Cook over a moderate fire for 1½ hours. A little sugar may be added if desired.

HAM SMOTHERED IN SWEET POTATOES.[6]

1 slice of smoked ham cut into sizes for serving.
3 cups of raw sliced sweet potatoes.
2 tablespoonfuls of sugar.
1 tablespoonful of butter or ham fryings.
1 cupful of hot water.

Broil the pieces of ham lightly on both sides and arrange them to cover the bottom of the baking dish. Spread the slices of sweet potato over them, sprinkle with sugar. Add the hot water and extra fat. Cover the dish and bake slowly until the ham is tender, basting the potatoes occasionally with the gravy. Brown the top well.

SWEET POTATOES AND PEANUTS.

1 quart of mashed sweet potatoes.
2 tablespoonfuls of butter or other fat.
1 cupful of roasted peanuts chopped fine.
¼ teaspoonful of cinnamon.
1 teaspoonful of salt.

Mix the ingredients well; form into a mound upon a shallow baking dish; press a tablespoonful of butter into the top. Heat in a moderate oven until brown.

SWEET-POTATO NUTS.[7]

To 1 pint of boiled and mashed potatoes add 1 pint of toasted bread crumbs rolled fine, 1 pint mixed nut meats chopped fine (peanuts are excellent); season with salt, a little pepper, also sage and mace, if desired; to the yolks of 2 eggs add 2 teaspoons of baking powder and whip until light; pour the egg mixture into the first-mentioned mixture and stir well; form into small cakes; dip each into the whites of the eggs, then into shredded coconut, and brown in a frying pan containing a little pork fat (not deep fat); turn; brown on both sides.

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[6] This and the following recipe were obtained from miscellaneous sources through the courtesy of the Bureau of Home Economics of the United States Department of Agriculture.

[7] This and the following recipes were obtained from the Tuskegee Normal and Industrial Institute, Tuskegee Institute, Ala., through the courtesy of Dr. G. W. Carver. (Bul. 38, How the Farmer Can Save His Sweet Potatoes.)

SWEET POTATOES WITH ROAST PORK.

Parboil the desired number of potatoes with the skin on until nearly done; remove and skin; put in the baking dish with the nearly done roast; cook until done, and serve with the pork.

CHIPS.

Cut in thin slices, steam until nearly done, allow the surplus water to drain off, or dry between napkins, fry in deep fat to a light brown. A little salt adds to its flavor.

SWEET POTATOES BAKED WITH APPLES.

Wash, pare, and cut 4 medium-sized sweet potatoes into slices about ¼ inch thick, pare and slice 4 apples in the same way; put in baking dish in alternate layers; sprinkle 1½ cups of sugar over the top, scatter ½ cup of butter in lumps over the top; add ¾ pint of hot water; bake slowly for 1 hour; serve steaming hot.

SWEET-POTATO PUFFERS.

Whip 2 eggs until quite light; 2 cupfuls of cold mashed potatoes; 1 cupful of flour into which 1 teaspoonful of baking powder has been sifted. The potatoes and eggs should be worked together, then the flour and baking powder; roll lightly; cut quickly, and fry in deep fat like doughnuts. Some think a little spice improves the flavor.

SWEET-POTATO PIE.[8]

Boil in skins; when tender remove skins, mash and beat until light; to each pint add a pint of milk and 4 eggs. Season and bake as pumpkin pie.

SWEET-POTATO GLACÉ.

Cut in slices ½ inch thick, wash, and place in deep saucepan spread with butter, season with a little grated nutmeg and salt; moisten with broth or water, cover and let simmer over slow fire for ¾ hour, turning the slices so that they may glaze on both sides. Serve with drawn butter or other sauce.

SWEET POTATOES STUFFED.

Bake; then cut off one end and scoop out the inside; season with butter, pepper, and salt; beat until light; replace in the skin; close with the piece cut off and put into the oven to heat through. Serve in napkins. Suitable for luncheon.

A SOUTHERN DISH.

Cut cold baked sweet potatoes into slices and put into an earthern dish; add sugar and butter to each layer and bake until slightly browned.

SWEET-POTATO CROQUETTES.

Take 2 cupfuls of mashed, boiled, steamed, or baked sweet potatoes; add the beaten yolks of 2 eggs and season to taste; stir over the fire until the mass parts from the sides of the pan. When cold form into small croquettes, roll in egg and bread crumbs, and fry in hot lard to an amber color. Serve on napkins. The croquette mixture may be made into balls inclosing minced meat. When used in this way, serve with sauce.

SWEET-POTATO PUREE.

Mash boiled, steamed, or baked sweet potatoes, season, and add enough hot milk to moisten; serve like mashed white potato; or put in pudding dish, dress the top with egg, and brown in the oven. Serve with sauce.

SWEET POTATOES BAKED.

Bake like potatoes, without breaking the skin. When done, break the skin in one place in the form of a cross, forcing the meat partly out, cap with butter, and serve.

[8] This and the following recipes have been taken from United States Department of Agriculture Farmers' Bul. 129, Sweet Potatoes.

SWEET POTATOES AS FEED FOR FARM ANIMALS.

When the sweet potato is grown on a large scale in rotation with other crops and it is desired to economize on labor in harvesting the roots, cattle and sheep may be pastured on the area to consume the vines, and later hogs may be turned in to harvest the roots for themselves. If the area in sweet potatoes is exceptionally large, and the above system of harvesting is practiced, the grazing area should be inclosed with a portable fence to prevent waste when the hogs are turned in to root. Potatoes which are brought to the surface but not eaten should be daily gathered from the paddocked area and fed to other hogs.

Sweet potatoes can be fed to horses and mules as a supplement to the regular carbohydrate feed. The roots should be cut into pieces with a vegetable cutter and then mixed with a small quantity of molasses, so that the animals will become accustomed to them. The work mules at the experiment station are given rolled barley in the morning, corn at noon, and chopped sweet potatoes in the evening, when corn and sweet potatoes are available, This ration keeps them in excellent condition.

Sweet potato tops.—In the hog-raising and dairy enterprises in Hawaii large quantities of the succulent garden pigweed or purslane (*Portulaca oleracea*) and honohono (*Commelina nudiflora*) are fed to hogs and cows. The following table gives the chemical composition of sweet-potato vines, pigweed, and honohono:

Composition of sweet-potato vines, pigweed, and honohono.

Crop.	Water.	Ash.	Crude protein.	Carbohydrates.	Fat.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sweet potato vines	87.67	1.27	2.93	7.77	0.36
Pigweed	95.20	.96	1.04	2.71	.09
Honohono	89.43	1.40	1.27	7.58	.32

SUMMARY.

The sweet potato belongs to the morning-glory family, and many varieties bloom profusely in Hawaii from November to April.

In ancient times the crop was cultivated, the native agriculturists evidently appreciating the importance of selection and the value of alternating the crop with other crops to improve the physical condition of the soil.

The crop needs moderate rainfall, an abundance of sunshine, and warm nights for best development. It should be grown in a well-drained, moderately fertile, loose sandy soil. It responds to favorable treatment, making good growth and producing roots of fine quality on well-prepared land that has been planted with legumes the year preceding. The depth of plowing usually practiced for corn is satisfactory for sweet potatoes.

Cultivation should begin when the vines are about 8 inches long. Usually from three to four cultivations are sufficient to keep the soil in good tilth until the field is overrun with vines.

The plant is drought-resistant and produces a crop of roots with very little moisture.

In a test made to determine the effect of pruning on yield, it was found that production was considerably decreased when the vines were cut back. Apparently the shorter the vine is cut, the greater will be the reduction in yield of roots. Yield is largely influenced by the locality and the soil where the crop is grown, the kind and amount of fertilizer used, the cultivation given, and finally by the variety itself. It may be increased by proper cultivation and the application of fertilizers, or by the selection through several generations of individual hills producing heavy crops of well-shaped roots.

The period of harvesting differs with the different varieties. Yellowing of the leaves is not always an indication of ripening and may be due to the disease known as stem-end rot.

Unfortunately the sweet potato is not graded in Hawaii. Standardization will hardly become a reality until uniformity of size, shape, and color is taken into consideration, and the roots are marketed free from defects resulting from careless handling, diseases, and insect pests. Regular-shaped, uniform, smooth, firm, and fresh-looking potatoes should be selected for home use.

The problem of storage can be eliminated by harvesting just enough potatoes to meet the needs of the wholesaler or the householder. When they are to be held for some time, sweet potatoes should be carefully stored to reduce to a minimum the loss by shrinkage.

The sweet-potato plant is attacked by a number of insect pests and fungus diseases which can be brought under control by the use of proper measures.

In chemical composition the sweet potato compares very favorably with taro, cassava, and potato.

On account of their high feeding value, sweet-potato vines should be used as feed for farm animals. They are greatly relished by hogs and dairy cattle, and when it is desired to practice economy of labor in harvesting, the former may be turned in to harvest the roots, after the latter have been allowed to pasture the vines.

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