seeds a rubber plantation could be developed which would surpass anything theretofore conceived of. In fact, small scale operations on this plan proved in 1914 that the labor cost of harvesting rubber latex could be brought down to 6 cents per pound, with 17 pounds of rubber gathered per man-day. Of course, there are other cost items which have to be added to this, as the maintenance of the plantations, the manufacture of crude rubber from the latex, etc. These, it was estimated, would amount to 20 to 30 cents per pound, to which the 6 cents cost of gathering the latex would have to be added.

Any crop which cannot be handled largely by mechanical means has little chance of becoming the basis of a large industry in a high wage country, as Hawaii.[7] In considering possible ways of diversifying our present agricultural industry this basic fact must be kept in mind.

See also *"Euphorbia lorifolia."*

Ref.—Haw. Agr. Exp. Sta. Press Buls. 13 (1905), 44 (1913); Bul. 16 (1908), 19 (1910); Annual Rep. 1905:22; 1906:12; 1907:19; 1908:11; 1909:15; 1910:17; 1912:88; 1914:51; Haw. For. Agr. 1904:287-294 (Kidwell); 1905:255-260 (R. H. Anderson, on possibilities of industry in Hawaii).

RUSHES See "Matting Sedges and Rushes."

RUTABAGA The rutabaga *(Brassica campestris napo-Brassica)* is very similar to the turnip and in the market here usually passes as a turnip. It may be distinguished by the purplish color of the exterior.

See "Turnip," also "Truck Crops."

RYEGRASS Italian ryegrass *(Lolium multiflorum)* is considered very valuable on the Parker and Shipman Ranches.

Ref.—Haw. Exp. Sta. Bul. 65:26, 1933.

SABUCAIA See "Sapucaia Nut."

SALSIFY Salsify *(Tragopogon porrifolius)* is only sparingly grown in Hawaii, not because of any unfavorable climatic conditions but because the demand here is very small. The edible portion of the plant is its long,

[7]An exception to this is any crop which commands a very high unit price in the winter months when our freedom from frost makes it possible to produce. Even with high labor and overhead costs such production may pay well during a limited season.

tapering, fleshy tap-root, which on being cooked has a flavor remotely suggestive of oysters.

See "Truck Crops"; also, "Burdock."

SALT Although not an agricultural industry, salt production may be mentioned as an art developed by the ancient Hawaiians. Sea water was evaporated in earth basins and the resulting crystallized salt, of a reddish color, was used to season food and preserve fish.

In spite of large imports there is still a considerable demand for this locally made salt.

Ref.—Thrum's Annual 1924, pp. 112-117.

SALTBUSH Saltbush is the name applied to several species of plants of the genus *Atriplex,* which grow habitually in low flats along sea margins. The foliage is somewhat succulent and makes acceptable feed for livestock in areas where better forage plants would not grow.

In the 1890's an Australian species of saltbush, *Atriplex semibaccata,* was introduced by Tom Gay and established at Mokuleia (Oahu). A few years later it was taken to Molokai by G. C. Munro[1] and has become well distributed over that Island. F. R. Fosberg[2] reports this species as being of general occurrence in the Territory, disseminated probably by birds.

Several other species have been introduced and two have become established: *Atriplex rosea, Atriplex lentiformis* (the Arizona saltbush).[3] Three species introduced from Australia by the Hawaii Experiment Station[4] about 1907 *(A. nummularia, A. leptocarpa* and *A. halimoides)* seem not to have established themselves here, as they are not reported by botanists.

SANDALWOOD Sandalwood *(Santalum freycinetianum),* now a rare and high-priced forest product, was once the basis of a lucrative industry in Hawaii. From about 1790 to 1840 varying quantities of this valuable and fragrant wood were shipped to China, the total in some years amounting in value to over $100,000, while in one

[1]See Haw. For. Agr. Vol IV, p. 248 (1907).
[2]Univ. Haw. Occ. Papers. (As yet unpublished).
[3]This was introduced from Arizona by G. C. Munro in 1900 or 1901. [See Haw. Agr. For. IV, 248 (1907).]
[4]Haw. Exp. Sta. Annual Report 1914:39.

period of 18 months it yielded $400,000. The forests in time became stripped of this species of tree, however, and in the 1830's the industry declined, exports in 1836 being about $26,000, in 1837, $12,000, in 1838, $6000, and nothing after 1840.

Thereafter, until the beginning of the present century, sandalwood in Hawaii was merely a memory, for it was almost extinct throughout all the islands. In 1904, however, the Territorial Board of Agriculture and Forestry began giving some attention to the replanting of this valuable tree in the mountain forests. Although no great amount of effective planting resulted for a number of years, in the 1930's many thousands of young trees were planted which in due time may become the means of reviving a long dead industry. It is safe to predict, however, that when that time comes the exploitation of this resource will not be as wastefully managed as once was the case.

Ref.—Thrum's Annual 1905, pp. 43-74 (an excellent account of "The Sandalwood Trade of Early Hawaii," by Thos. G. Thrum); 1933:81-88 (C. S. Judd). Haw. For. Agr. 1927:42-43 (C. S. Judd); also, Botanical Bul. 3, by J. F. Rock, 1917.

SANSEVIERIA Bowstring hemp is the fiber of the leaves of *Sansevieria,* a tropical plant which grows very readily and successfully in Hawaii, resembling somewhat the pineapple plant in general appearance. Its leaves can be harvested periodically for ten years or more without the necessity of replanting the fields. The fiber is of good quality and readily marketable.

An effort was made in 1893 by the Bureau of Agriculture of Hawaii to establish an industry on this plant, as it was then receiving attention in Florida. No results of commercial importance followed, however, and the plant has remained to the present an interesting feature in many gardens but not exploited industrially.

SAPODILLA See "Sapota."

SAPOTA The sapota *(Achras sapota)* is a relative of the custard apple. It is a tropical tree, introduced here from Central America many years ago, and grown occasionally as an ornamental. The fruit is about the size of a small apple, somewhat rusty in color; its outer skin is rough and leathery, and its pulp inside divided into a

number of compartments, like the custard apple, each with a black seed. The flavor is pleasant, suggestive of the apricot. Chewing gum may be made from the hardened latex. There is no commercial exploitation of this fruit in Hawaii.

Another species of tree *(Casimiroa edulis)* produces a fruit somewhat similar to the foregoing and is known in tropical countries as the white sapota. It is uncommon in Hawaii, and is used only as an ornamental.

Ref.—Kuck and Tongg, "The Tropical Garden," p. 145; Bryan, Nat. Hist. Hawaii, p. 266.

SAPUCAIA NUT The sapucaia nut *(Lecythis zabucajo)* is related to the common brazil nut and is produced on a large tree indigenous in the Amazon Valley of South America. This nut is believed to be superior to the brazil nut, but is not much known in the American market.

A few trees are growing on Kauai, and a few on the Kona lands of the Hawaii Experiment Station. As yet, no commercial importance has been attached to them in Hawaii.

SATSUMA ORANGE See "Tangerine."

SEDGE See "Matting Sedges."

SHADDOCK See "Grapefruit."

SHEEP[5] The first sheep in Hawaii were brought here by Vancouver in 1793, and a second lot a year later by the same sea captain. They were allowed to run wild and multiply, but there was no great commercial exploitation of these animals until about a half century later. In 1845 some Merino rams were brought in to improve the flocks and with that the sheep growing industry in Hawaii may be said to have begun. Other importations followed in the succeeding ten years, the new stock coming from various parts of the world.

Until 1852 the entire interest in sheep here had been as a source of meat, but in the 1850's the Royal Hawaiian Agricultural Society turned the attention of sheep raisers to the great possibilities in the production of wool.

Sheep ranches were established in various parts of the

[5]In the preparation of this statement Prof. L. A. Henke has collaborated.

Islands, one on the Waimea plains about 1856 by Frederick Low, and others on Molokai, Lanai and Niihau. By 1875 wool production had reached a relatively high point of development here, the clip having been 565,469 pounds that year, from which there was a return of about $70,000. In subsequent years this industry has had its ups and downs; in 1878, for example, the clip was only 243,740 pounds, but in other years it amounted to 400,000 and 500,000 pounds.

The sheep industry of Hawaii apparently reached its high point about 1884, and there has been a decline since that time as is shown below:

Year	*No. of Sheep*
1879	101,726
1884	121,683
1895	93,312
1900	102,098
1910	76,710
1920	44,042
1930	32,256

Sheep were important on Molokai Ranch thirty years ago, as many as 17,000 being reported for the year 1907, but at present only a few hundred are found on Molokai.

The sheep industry at the present is concentrated at the Humuula sheep station of the Parker Ranch located on the saddle between Mauna Kea and Mauna Loa, where about 12,000 Merinos are kept, and on the Island of Niihau. Three thousand sheep were carried from Molokai to Niihau in 1864, according to Interior Department letters in the Archives of Hawaii.

Sheep in Hawaii are at present kept largely for wool production and not much lamb is locally produced. The demand for the mutton that is produced is small, usually at an unprofitable price.

Imports of fresh mutton and lamb during recent years follow:

Year	*Pounds*	*Value*	*Per cent from Foreign sources*
1920	290,772	$ 26,607	100.0
1923	462,270	65,660	96.5
1926	401,719	58,513	92.3
1929	692,871	103,438	92.5
1932	789,670	91,799	3.7
1935	891,773	140,006	.0

The following tabulation of wool exports during the past 30 years shows rather wide fluctuations, which are quite as much due to price as to the size of the clip:

Year	*Value*	*Year*	*Value*
1905	$ 53,558	1921	$101,756
1907	54,548	1922	15,726
1908	58,133	1923	117,818
1909	52,448	1924	42,835
1910	56,425	1925	73,772
1911	53,140	1926	63,210
1912	61,780	1927	70,486
1913	71,113	1928	45,735
1914	77,214	1930	16,112
1915	70,971	1931	44,302
1916	31,152	1932	28,620
1917	27,395	1933	57,448
1918	81,805	1934	50,000
1919	96,842	1935	42,121
1920	138,673		

Ref.—U. H. Research Publ. No. 5, pp. 16-18 (Henke, "Survey of Livestock in Hawaii" 1929). Thrum's Annual 1903:54; 1906:45, and subsequent issues for tabulation of exports.

SHELL BEANS See "Beans."

SILK Contrary to general belief, rayon has not pushed silk out of the market. It caused the price of silk to decline very greatly, and probably is responsible for a small drop in American imports, but silk is still much in demand. American imports of silk in 1909 were 23 million pounds and were increasing steadily until 1929, when they reached the peak of 90 million pounds. By 1934 imports were down to 70 million pounds, but that was a large amount considering that rayon production in our country had jumped from 40 million pounds in 1924 to 210 millions in 1934. While rayon has not caused any great decrease in our silk imports, it (with other factors) brought the price of raw silk tumbling down from $6.00 per pound in 1924 to $1.20 in 1934; current prices fluctuate around $1.90 to $2.00 per pound.

Silk worm culture is carried on in many countries both in Asia and Europe, but not much in America. Some sporadic efforts have been put forth during the past hundred years to make Hawaii a silk producing country, but thus far with no success.

The first commercial venture in silk in Hawaii was in 1836 at Koloa, Kauai. Two partners, Peck and Titcomb,

leased a tract of 400 acres for experiments in producing cotton, coffee and silk. On adjoining land, the firm of Ladd and Company was developing the Territory's first successful sugar plantation. Here, then, were four potential industries struggling to be born, of which two were more or less successful: sugar and coffee.

The mulberry, planted to furnish feed for the silk worms, did exceedingly well at Koloa and the partners soon had a large area under cultivation. To this day the hill on which those mulberries grew, nearly a century ago, bears the name of Mauna Kilika, which is Hawaiian for Mt. Silk.

Commenting on this early attempt to found an industry, Ethel Damon says in her "Koamalu"[6] (p. 181) that, "it was thought that the care of cocoons might well employ Hawaiian women and children." Again (p. 331), she observes that as silk culture began to get under way "Hawaiians had now some means of profitable labor by which they could free themselves from the restrictions of the Konohiki, or overlord."

But troubles beset the new industry, first in the extreme irregularity of the hatching of the silkworm eggs. As young worms must be fed and treated differently from older worms, this irregularity of hatching made the handling of the worms very difficult and expensive. Occasional droughts, also, handicapped the pioneers by causing a shortage of mulberry foliage.[7] By 1840 the silk part of the Koloa venture was declared a failure, and one of the partners (Titcomb) transferred his efforts to the other side of Kauai, at Hanalei, where for several years a small industry was maintained. The first export of silk was in 1844, and was rated as being of fairly good quality. The industry did not persist long, however, for "the profits were too slow to warrant the necessary outlay of capital" (Damon, in "Koamalu," p. 332), and by the middle of the century the culture of silk worms on a commercial basis was abandoned.

A revival came after a half century, however, for in

[6]Privately printed in Honolulu in 1931.

[7]Another obstacle sometimes cited was the fact that the worms had to be fed on Sundays and Sunday labor was supposed to be tabu by the newly adopted Christian teachings. This probably had little or nothing to do with the failure of the industry.

1905 the Hawaii Experiment Station began some trials which ran for three years, then faded out of the picture. Eggs were brought in from Europe (through Washington, D. C.), Japan and China, and several trial lots of cocoons were produced and sent to the U. S. Department of Agriculture for testing. The reports were good; the silk was of very good quality. The general results of three years of investigations led the Station entomologist, D. L. Van Dine, to declare in 1907 that "silk of good quality can be produced with as little effort in Hawaii as in any other silk-producing country." He might have added, however, that the same effort in Hawaii demands a considerably higher wage rate than in the other silk producing countries.

An important factor influencing the Hawaii Experiment Station to undertake these studies was the presence here of large numbers of Oriental plantation laborers and their families who, it was believed, would welcome an opportunity to increase their incomes by rearing silkworms outside of plantation hours. "If Hawaii is to succeed in holding the laboring class to the soil, the industry of silk culture is worthy of receiving serious consideration," says the 1907 Annual Report (p. 42) of the Station.

The mulberry, necessary as feed for silkworms, grows very successfully in Hawaii. In most respects the climate here is favorable to silkworm culture. The evenness of our climate makes it possible to raise worms throughout the entire year, whereas in most other producing countries the industry is seasonal. There are some disadvantages, as the humidity of our atmosphere, but these are offset by certain advantages.

There is no doubt that good quality silk can be produced here, for it has been done on several occasions and the results checked by competent experts.

The principal obstacle to developing a silkworm industry here has been the cost of labor. So long as the usual methods are employed in the rearing of the worms and handling of the cocoons there is a large amount of expert labor required. Even though a large part of this work were done by women and children, still the cost would be much higher than in Japan or China because of the very large differential in wage rates and living costs.

Hawaii could not possibly compete with the Orient in any industry requiring much hand labor.

This does not mean, however, that there is no hope for a silk industry in Hawaii. Such an industry might be developed here very successfully if a large part of the expensive hand labor could be eliminated by the substitution of machinery. That the culture of silkworms can be handled in this way is not merely a hypothetical idea but a reality, for it is being done in a small way in California. One man has mechanized most of the processes, from growing and harvesting mulberry foliage to the feeding of the worms and keeping their trays clean and preparing the cocoons for reeling.

If Hawaii ever develops a silk industry it will be on some such basis as this. It would seem that a good trial should be made, for we have excellent conditions in our natural environment, and our people are accustomed to doing things by the use of machinery and scientific research. If, by this method, silk could be made profitably at present low market prices, the future would seem to be comparatively safe and attractive, for probably the price will never be any lower than at present.

Ref.—Haw. Exp. Sta. Annual Report 1905:41; 1906:19; 1907:41. "Koamalu" by Ethel Damon (1931), Vol. I, pp. 181-2, 331-2. Thrum's Annual 1911:67-71. Planters Monthly III, 664 (1885); XV, 52 (1896).

SILVER BEARDGRASS Silver beardgrass *(Andropogon saccharoides)* is of very minor importance as a range grass, except in dry localities, where it may be valuable.

Ref.—Haw. Exp. Sta. Bul. 65:6, 1933.

SISAL Sisal, or sisal hemp, is the fiber of the long, tough, spear-pointed leaves of a century plant *(Agave sisalana)*, which has for many years been cultivated very extensively in Mexico. In the middle of the nineteenth century sisal production was urged by some as an especially promising industry for Hawaii[8] but the sugar industry was claiming major attention just then and, moreover, Mexico was trying to maintain a monopoly on sisal by preventing the exportation of any live planting material.

[8]Trans. Royal Haw'n Agr. Soc. 1851, p. 27.

Although this was an obstacle to the introduction of the sisal plant into these Islands, interest in it as a potential crop grew stronger. The slump in the sugar market in the 1880's and the rising tide of beet sugar production in California accentuated the need of diversifying agriculture here, and sisal was frequently mentioned as being particularly promising for this purpose. Even the official organ of the Hawaiian sugar industry, the Planters Monthly, joined this chorus, declaring editorially[9] that "it will not do for us to sit down with our hands folded and wait till the California beet sugar scheme effectually cuts our throats"; sisal was recommended as a crop that ought to be established to support Hawaii if sugar should fail.

The strength of this movement was sufficient to bring about the successful introduction of this Mexican plant in 1893. At once thereafter there began to develop a small industry, at first on an experimental scale and later of commercial dimensions. The prospects seemed excellent because of the fact that this plant was well suited to land areas where rainfall was insufficient for sugar cane, and of this type of land there were many thousands of acres. Added to the impulse that came from fear of the beet sugar industry in California, there suddenly appeared a new impetus in the early 1900's when the leafhopper began to threaten the existence of the sugar cane industry. The possibility of substituting sisal for sugar cane in some of the drier areas was especially appealing at that time because of the high price of sisal fiber. This fiber was being imported in very large quantities from Mexico for use as binder twine in the large wheat areas of the United States. In 1900, for example, these imports amounted to 80,000 tons, worth nearly $12,000,000, and Hawaiian agriculturists believed they could capture a good part, if not all, of that business. The price of 10 cents per pound, then prevailing, left a comfortable margin of profit above costs of production, and experience showed that a good quality of fiber could be grown and extracted here.

The first large plantation, the Hawaiian Fibre Co., with about 1000 acres, was established on Oahu in 1900 and 1901 by Wm. Weinrich, and several others later on other islands: 450 acres at Pahala, Hawaii, in 1902; 500

[9]Vol. VI, p. 390 (1887).

acres at Kailua, Hawaii; smaller plantings on Maui and Molokai.

Thus begun, commercial production of sisal fiber made good progress for several years and the new industry seemed to have excellent prospects for the future. The following table of figures shows the extent of this development as reflected in the value of annual shipments to the mainland:

Year	*Value*	*Year*	*Value*
1903	$ 8,096	1918	$127,987
1905	10,631	1919	233,211
1910	11,790	1920	97,010
1911	15,161	1921	16,620
1912	34,735	1922	3,197
1913	44,221	1923	1,800
1914	59,915	1924	1,637
1915	52,608	1925	5,513
1916	68,764	1926	4,526
1917	89,543		

This interest in sisal was short-lived, however, because of several factors: (1) The sugar cane leafhopper was brought under control and when its threat to the industry was thus removed the necessity of finding a substitute for sugar was less urgent; (2) the new pineapple industry was growing and expanding rapidly and could use the lands occupied by sisal and, furthermore, could afford to pay a higher rental for them; (3) the world-wide boom in sisal which began in 1900 came to an end in 1910, when so much fiber was coming into the market that the price fell considerably below the average cost of production. Only in Yucatan (Mexico) and German East Africa has the industry persisted to the present, for in both those places the wage scale is so low that it is not much of a factor.

Writing in the Advertiser (July 23, 1925), Jared Smith said that the demand had fallen off greatly in recent years because of the advent of new grain harvesting methods and also because of the use of steel cables by modern ships instead of ropes. "About the only remaining market for sisal," said Smith, "is for hula skirts, and now even that is gone, for they are being made of cellophane."

Ref.—Haw. Exp. Sta. Bul. 4 (1903); Annual Reports 1902:314; 1903:403; 1912:58; Thrum's Annual 1904:29; 1908:138-141. Haw. For. Agr. 1904:226-242 (Comprehensive article by L. G. Blackman); 1918:42-48 (McCaughey).

SORGHUM Sorghum, known also by many other names, including milo maize, kafir corn, Egyptian corn and feterita, is not grown in Hawaii as extensively as in temperate zone regions, although moderately good results have been obtained here. It is usually grown for use as green fodder and is cut before full maturity is reached, to avoid coarseness of stems. The yield is not as good as sudan or elephant grass.

Ref.—Haw. Expt. Sta. Annual Report 1913:38; 1914:37; 1915:41; 1916:29; U. H. Agr. Dept. Annual Report 1918:10; 1919:10; 1920:14; 1922:11; 1923:11; 1927:32. Planters Monthly XI, 98, 105; XIII, 238; XV, 27.

SOUR SOP The sour sop *(Annona muricata)* is a tropical fruit closely related to the cherimoya and not infrequently encountered in home gardens. The juice of its fruit is sometimes pressed out of the very fibrous pulp and used in blending with other juices in punch or ice cream.

There is no considerable commercial planting of this fruit.

See also "Cherimoya."

Ref.—Haw. Exp. Sta. Bul. 77:77-78 (recipes, uses, etc.).

SOYBEAN The soybean *(Glycine hispida)* is indigenous in Asia, where it is cultivated very extensively and used in many ways: the beans are cooked and eaten; also sprouted, and eaten as greens; oil is extracted, also soyo sauce; bean cake, bean curds, soybean meal and other products are manufactured from the beans; in the United States this bean is the basis of several new industrial products, as automobile steering wheels and other parts. Altogether, the soybean is probably the most useful member of the large leguminous family.

Most varieties of the soybean are adapted to temperate zone conditions and do not thrive well in Hawaii. A few varieties, however, have been grown successfully here on a small scale and are believed by Krauss[10] and others to offer exceptionally good promise of becoming a crop of major importance for this Territory. According to Dr. Krauss, "The crop is adaptable over a wide range of soil types and locations, for intercropping and for rotation

[10]F. G. Krauss in "Extension Letter," a mimeographed serial of the University of Hawaii, Vol. XV, No. 11, pp. 2-3, Nov. 1935.

with other crops, notably to follow the early potato crops immediately after harvest. Soybeans require the minimum of tillage and fertilization when following potatoes, etc., and produce a maximum yield under favorable season for harvest. They contain high food value for man and beast with a low cost of production.

"Among the outstanding varieties thus far tested by the Experiment Station and by the Agricultural Extension Service as well as in general field culture is the Biloxi, introduced to Hawaii from Mississippi in 1918. It has been demonstrated that the spring plantings almost invariably give the best results in yield and quality of product. Yields of seed have ranged from 800 pounds to 2000 pounds per acre for the average 100 to 120 day varieties. Cured forage yields have ranged from 1 to 4 tons per acre. There seems to be no good reason why one ton of prime seed per acre should not be produced when suitable varieties are planted on good land, on land which has produced 100 sacks of potatoes in an early spring harvest. One or two double disc harrowings of such potato land should put it into good shape for planting the soybean crop which is to follow. Little or no fertilizer other than the residue from the potato crop should be required. Under such conditions the crop should readily be produced at a cost not to exceed $50.00 per acre. Of course, mechanical planting, harvesting, and threshing would need to be resorted to and the planting carried on on a large scale.

"Crops grown thus economically should prove fairly profitable, netting in the neighborhood of $50.00 profit per acre. If carried on extensively, on a scale of not less than 2500 acres, an oil-expressing plant might be justified.

"Two methods for extracting oil are employed by American mills, termed the hydraulic and expeller processes. An average of 32 gallons (about 7.5 lbs. per gallon) of oil and 1600 pounds of oil cake is recovered from a ton of beans by the latter process. The 130 pounds unaccounted for represents loss due to natural waste and the evaporation of moisture. The cost of producing oil and cake is less with soybeans than with cotton seed. Cotton oil mills can readily be adjusted to handle soybeans, peanuts, and other oil-bearing seeds. The cost of equip-

ment to handle 2500 tons of beans would not exceed $18,000 and should pay for itself in two or three seasons under good management.

"The soybean oil cake meal ranges from $35.00 upwards per ton, while the price of the oil, which is competitive with and can be substituted wholly or in part for cotton seed, coconut and linseed oils, ranges from 5 to 10 cents per pound. In other words, a ton of soybeans when manufactured into oil and cake will bring around $50.00 per ton. This would make a very low acre income for the beans, but would provide an outlet for surplus production.

"The composition of soybean oil cake meal will run around 44.0 per cent protein, 8.7 per cent fat, 27.0 per cent nitrogen free extract, and 6.0 per cent fiber. On this basis of high feeding value, especially in nitrogenous matter, the price quoted is very low and would enable its extensive feeding, especially when supplemented with large quantities of molasses and roughage or pasturage when fed to dairy cows, beef cattle, swine, and even poultry, including turkeys. Whole and ground soybeans are too rich in oil to be fed to livestock in large quantities, especially swine, in which case it produces soft pork.

"Soybeans are likewise a valuable food for man. They may be used in the same manner as dried kidney or navy beans, or as manufactured products such as tofu, miso, and soy sauce so extensively used by Orientals. The Journal of the American Medical Association recently stated editorially: 'The studies of Chang and Tso at Peiping University have stimulated interest in the soybean for infant feeding. So-called soybean milk gave results comparable to that of cow's milk and breast feeding. Chemists have learned how to turn soybeans into printer's ink, glycerin, celluloid, waterproof glue, soap and rubber substitutes and have listed 65 other products. The list grows larger every year.' "

Although the soybean was practically unknown in American agriculture twenty-five years ago, it is now one of the major crops of the country. In 1924 the acreage of soybeans raised in the United States was about 2,000,000 and in 1935 it had increased to 5,000,000 acres.

This crop offers attractive possibilities for Hawaii, to

occupy some lands not suitable for sugar cane or pineapples, and should be carefully considered in any plan for diversification. For data on yields in Hawaii see Haw. Expt. Sta. Annual Report 1936, p. 20.

SPANISH CHERRY See "Brazilian Plum."

SPINACH Common spinach *(Spinacia oleracea)*, although consumed in large quantities in Hawaii, is not produced extensively here. It is a cool weather plant and can be grown successfully in the truck gardens near Honolulu only in the winter and spring months. A recent crop survey (1936) showed only about 10 acres of spinach planted. Import records indicate that some 15,000 to 20,000 pounds per year are brought in from the mainland in the fresh state, but larger quantities come in canned. It is probable that total consumption here is between 100,000 and 200,000 pounds per year, with perhaps one-fourth of it supplied by local producers.

Krauss[11] calls attention to a New Zealand variety of spinach which thrives in our lowland areas at all times of the year, producing an excellent quality of foliage which should be capable of supplying all local consumption needs.

See also "Truck Crops."

SQUASH The squash and pumpkin are related to the melons and cucumber and have been cultivated in Hawaii for a great many years. During the gold rush days in California there were shipments of considerable size from these Islands; in 1851, for instance, some 51,769 squashes were sent.

The accidental introduction of the melon fly early in the present century proved to be a serious handicap to the production of squashes and pumpkins, for they seemed particularly susceptible to its attacks. In recent years, however, as this pest has been brought under partial control by parasites, this crop has begun to come back into more prominence, with about 200 acres devoted to various kinds of pumpkins and squashes.

The summer squash is still very difficult to produce

[11]Agr. Ext. Bul. 16, pp. 123-125, 1932.

here because of the ravages of the melon fly and most of the consumption demand is filled by importations from California, which run to about 100,000 pounds per year.

There are several related plants which produce fruits quite the equal of summer squash for succulence and flavor and could be used here in place of the imported article, such as the chayote and the Chinese melon.

Ref.—U. H. Agr. Ext. Bul. 16:79, 1932.

STAR APPLE The star apple *(Chrysophyllum cainito)* is a tropical fruit common in the West Indies and Mexico. The fruit derives its name from the fact that the core in transverse section is somewhat star-like in shape. When thoroughly ripe the star apple is edible, but until then it is as astringent as an immature persimmon.

Introduced into Hawaii many years ago the star apple has become moderately common in gardens as an ornamental, but is seldom cultivated for its fruits which are eaten by very few people in these Islands. As a source of juice for blending with other kinds of fruit juices for punch or ice cream it may have some value worth exploiting.

STARCH Starch is extracted from many different kinds of plants, the world over, each kind yielding starch with certain more or less distinct characteristics. In chemical constituents starch is essentially the same, regardless of its source. In physical characteristics there are marked differences as to size and shape of the starch granule, in viscosity and other characteristics; some kinds seem to be more easily digestible than others in the human body, and some have physical qualities that make them particularly valuable for certain industrial uses, such as the manufacture of adhesives and the sizing of cloth and paper.

The three chief commercial sources of starch are corn, the Irish potato and cassava. Several millions of tons are manufactured every year in various countries from these three sources, and the product finds its way into consumption in many different ways, partly as food but much of it is used in the textile industries and other manufacturing enterprises. Neither corn starch nor potato starch, how-

ever, is suitable for certain purposes and other starch sources have been sought out to supply the need. For instance, for the making of the adhesive material for the back of postage stamps, envelope flaps, binding tape and so forth a type of starch is necessary from which dextrin of the proper consistency can be made. American manufacturers of this special adhesive have always depended upon imported cassava starch as their raw material, but recent experiments by the U.S. Department of Agriculture indicate that the sweet potato yields a starch which is just as good for this special purpose as cassava starch. "Sweet potato-starch dextrin," says the 1935 yearbook of the U. S. Department of Agriculture (p. 308), "is the first domestic product which has met the requirements of the Bureau of Engraving and Printing for this purpose." It is said, also, that this starch has been found to be satisfactory for the sizing of warp yarn and finishing, in cotton mills.

Another specialized demand for starch of a particular texture is in the making of foods for convalescents and infants. Arrowroot starch is considered satisfactory for this, as are, also, several others, including taro starch.

The following statistical figures compiled by J. C. Ripperton[12] indicate the relative degrees of importance of certain starches in American consumption.

(a) *Production, Importation, and Prices in the United States*[13]

(Data are the Average of the Six-Year Period, 1929 to 1934, incl.)

Source of Starch	Total Production Tons	Total Imports Tons	Price (duty paid) per ton
Corn	464,670	None	$ 68.00
Potato (White)	6,570	8,348	85.00
Cassava (Tapioca)	None	73,763	40.00
Arrowroot	None	992	124.00
Sago	None	4,448	29.00
Rice	None	517	76.00
Wheat	20,050	15	74.00

[12]Of the Hawaii Agricultural Experiment Station.

[13]From data furnished by Bur. Agr. Economics, U. S. D. A. and U. S. Dept. of Commerce.

(b) *Starch Imports Into United States, Six Years*[14]

	(Casava)		(Potato)		(Arrowroot)	
	Imports Tons	Value per ton	Imports Tons	Value per ton (duty paid)	Imports Tons	Value per ton
1929	79,784	$52.00	14,141	$84.00	489	$140.00
1930	50,468	60.00	7,970	86.00	494	126.00
1931	70,477	42.00	9,152	87.00	987	120.00
1932	61,744	30.00	5,371	84.00	954	120.00
1933	94,150	30.00	6,640	86.00	1,288	122.00
1934	85,950	34.00	6,810	.....	1,742	126.00

(c) *Chief Starch-Producing Nations of the World*

Corn starch: United States—Exports 75,000 to 200,000 tons per year.
Potato starch: Germany—Exports 110,000 tons per year.
Cassava starch: Dutch East Indies—Exports 105,000 tons per year.

(d) *Chief Uses of Starch*

Corn starch:

Grocers (Package starch for retail trade)	23%
Textiles (Cotton mills and textile finishers)	18%
Dextrins, pastes, gums	16%
Bakers, confectioners	8%
Baking powder	7%
Brewers	5%
All others	23%

Potato starch: Largely textile finishing, pastes, gums.

Cassava starch: Better grades for food (tapioca) and dextrins. Cheap grades for wood glues.

(e) *Present Tariff on Starches (Tariff Act of 1930)*

Potato	2.5¢ per lb.
Corn, *Wheat*, *Rice*	1.5¢ per lb.
Cassava, *Sago*, *Arrowroot*	No duty.[15]

Hawaii has been so busy producing sugar that her latent potentialities in the manufacture of starch have gone undeveloped. Small beginnings, however, have been made along several lines which are of some importance in our present study of diversification possibilities for this Territory.

[14]From data furnished by Bur. Agr. Economics, U. S. D. A. and U. S. Dept. of Commerce.

[15]These starches come into the United States as "flour," and thus escape the duty levied on foreign starches.

Tree Fern Starch—The first of these, in point of time, was the discovery several centuries ago by the early Hawaiians that a good food starch could be extracted from the trunks of tree ferns. This, however, was never exploited to any great extent until recent years. In 1920 the Hawaii Experiment Station undertook to study the nature of this starch and to investigate the commercial possibilities in its manufacture, for there are great forests of tree ferns in various parts of the Territory. The conclusion finally reached was that as a commercial source of starch the tree fern does not seem very promising, because of the slow rate of growth of the trees; accordingly, the investigations were dropped after a few years.

Taro—Taro, for many centuries the staff of life for the Hawaiian people, has been used on a small commercial scale as the source of a starch or flour which is said to be especially valuable as a food for convalescents and infants. This starch or flour has made its appearance in the market under two different names, "taroina" and "taromano," representing two distinct attempts to commercialize the idea of making taro starch. Neither of them made much of a success and this source of starch remains largely undeveloped, unless one considers poi as a starch development.

A portion of the AAA sugar processing tax fund is being devoted to a study of taro production; and one feature of this study is an experimental effort to transform taro into a dry powder or flour. This is different in some respects from both taroina and taromano, and its commercial possibilities seem attractive. As a source of pure starch, taro would not be able to compete successfully with certain other crops, because of the greater expense of production. The chance of commercial success for a taro product outside of Hawaii depends upon the possibility of establishing for itself a reputation as a food of special value.

Cassava—Cassava starch, sometimes called "tapioca," is well known in the world markets, both for its value as a food and for certain industrial uses, also. The American market consumes about 80,000 tons per year, imported from various tropical regions, chiefly the Dutch East

Indies. The cassava plant grows well in Hawaii and yields heavily, five tons of roots per acre being obtained in more or less typical cases, with 10 to even 18 tons not unknown. Grove Farm, on Kauai, has experimented in the extraction of the starch with satisfactory results so far as quality of the product is concerned. W. H. Rice, also, operated a cassava starch mill at Kipu, Kauai. The cost of manufacture, however, is considerably more than the prevailing market price. It would appear that in competition with other tropical countries Hawaii would experience much difficulty in making a commercial success of cassava starch production, because of higher wages and high land rentals here. For it must be kept in mind that, although there is a duty on foreign cassava starch, it comes into the United States under the name of cassava "flour" and thereby eludes the tariff. But for this, there might be developed at least a small industry in the production of this starch.

Canna—Edible canna, the source of so-called "Queensland Arrowroot" starch, was introduced into Hawaii about 1898. In 1916 the Hawaii Experiment Station began some investigations of the possibilities of establishing a canna starch industry here, for the plant flourishes well under Hawaiian conditions and characteristically yields heavy crops of tuberous roots, the source of the starch. These investigations led to the establishment of an incipient industry in 1922 in the Waimea section of Hawaii. A corporation was formed and a small factory was built which turned out several tons of good starch. Mechanical difficulties in connection with the extraction machinery were encountered. This and some financial troubles caused the cessation of their efforts and the dissolution of the company.

In 1930 the Honolulu Chamber of Commerce made a study of the situation, with cooperation from the Los Angeles Chamber of Commerce. Stein-Hall and Co., of New York, one of the largest starch importers in the United States, after giving careful attention to the possibilities of producing canna starch here, declared that the local product was "the finest they had ever seen."[16] The

[16]Quoting from a report by John A. Hamilton, Secretary of the Honolulu Chamber of Commerce, April 14, 1930.

New York firm offered to contribute generously to the capitalization of a new company to develop this industry, but local capital was unwilling to take up the offer, for the recent failure at Waimea was too strong a deterrent.

Later, when the sugar industry was put on a quota basis by the federal AAA, some consideration was given to the possibility of developing canna starch production on idle sugar lands. A new study of market possibilities was not very encouraging, however, for it indicated that the demand for this type of starch was not very great: about 10,000 tons per year, at 5 cents per pound; at lower prices it might displace some potato starch and have a larger market, but it was doubtful if production costs could be reduced below the 4 cents per pound level. This was not considered a large enough market to meet the readjustment needs of the dislocated sugar industry, and attention turned to other crops.

Sweet Potato—While the market demand may not be large enough to warrant the sugar plantations developing the canna starch industry, it is sufficient to provide a good outlet for a minor industry independent of sugar plantations. Probably better, however, would be the idea of producing sweet potato starch, for recent investigations by the federal government indicate that this starch is excellent for the same uses for which canna starch would be used, and in addition the sweet potato crop would be more widely useful than canna roots for livestock feed, human food, etc.

With excellent yields of sweet potatoes here, this crop might offer some possibilities worth investigation. A combination of a canning industry, with starch manufacture to utilize the culls and surpluses, might be sufficiently profitable to use certain marginal or submarginal sugar lands to good advantage. As a form of insurance against possible emergencies in food shortage, this crop would be very useful for feeding our population.

Arrowroot—The old Hawaiian arrowroot (pia), made from *Tacca pinnatifida,* offers some interesting possibilities for commercial development. See "Arrowroot."

Ref.—Several bulletins published by the Hawaii Experiment Station are of special value: No. 53, "Hawaiian Tree Fern Starch," 1924; No.

54, "Edible Canna in Hawaii," 1924; No. 57, "Edible Canna in Waimea," 1928; 63, "Physico-chemical Properties of Edible Canna and Potato Starches," 1931; 70, "The Manufacture of Poi from Taro in Hawaii," 1933. Also, the following references in Haw. Exp. Sta. Annual Reports: 1902:322; 1905:23; 1916:24, 25; 1917:51; 1918:48; 1919:41, 45; 1920:27; 1921:26, 38; 1922:8, 17; 1923:9; 1924:11, 12, 14; 1925:11; 1926:12, 15; 1927:13, 15; 1928:14, 19; 1930:13; U. S. D. A. Yearbook 1935:308-9.

STARFRUIT See "Carambola."

ST. JOHN'S BREAD See "Carob."

STRAWBERRY Strawberry *(Fragaria chiloensis)* culture is a small industry in Hawaii, with perhaps a total of thirty acres devoted to it, chiefly on Oahu. The cooler lands of the Wahiawa district seem to offer the best conditions for this crop. The Hawaiian product is smaller than that of the mainland states and less attractive.

It is not known when the strawberry was first introduced into Hawaii, but it was probably during the nineteenth century. The Hawaii Experiment Station gave it some attention in 1920 for the first time.

Ref.—Haw. Exp. Sta. Bul. 77:79 (recipes); Annual Report 1920:21; 1922:6.

STRING BEAN The pods of several species[17] of beans are used for food in the immature stage after being cooked, either whole or cut into short pieces. The more common of these are known to the trade as "string beans," but by gardeners are sometimes known by special names such as "wax beans," "snap beans," etc. Taken collectively, these are cultivated more extensively in Hawaii than any other type of bean, the present acreage being between 100 and 150 acres for all the islands combined; the largest part of this is, of course, on Oahu, in the truck gardens which supply Honolulu.

There are some possibilities of developing a seasonal (winter) trade in the shipment of string beans to the mainland, provided a means can be found of treating the product so that the danger of disseminating the melon fly will be removed. At present the string bean is on the quarantine list.

[17]See also "Goa Bean," "Chinese Pea" and "Yard-long Bean."

See also "Beans" and "Truck Crops."

Ref.—U. H. Agr. Ext. Bul. 16:61, 1932.

STRYCHNINE The well-known poisonous drug, strychnine, is obtained from the seeds of a tree *(Strychnos nux-vomica)* which grows well in Hawaii. No effort has been made, however, to exploit the plant here, commercially.

SUDAN GRASS Sudan grass *(Holcus sorghum sudanensis)* is cultivated very extensively in Hawaii, especially for use as fodder in dairies, but not infrequently for pasturage, as well. It thrives best at the lower elevations but will grow at relatively high altitudes. It is a tall grass, 3 to 7 feet high, and is relished by cattle and horses. When cut for fodder, the new growth springs up very quickly, making it possible to take several cuttings in a year. After about a year, it becomes necessary to replant to obtain maximum yields. When pastured, the field must be rested at frequent intervals to protect it against being trampled out.

Sudan grass is probably the best of all green fodder crops in Hawaii, yielding 40 to 50 tons per year, and being valuable for mixing with other feeds. Its only drawback is the necessity of replanting every year.

Ref.—Haw. Exp. Sta. Bul. 65:47, 1933. Also, U. H. Agr. Dept. Annual Reports 1918:11; 1919:11; 1920:13; 1921:18; 1922:10; 1925:8, 45; 1928:35.

SUGAR CANE[18] Sugar cane *(Saccharum officinarum)*, while not indigenous in Hawaii, has been here for many centuries, having been brought in probably by the early Polynesian immigrants. Its original discovery by man as a source of sugar was thousands of years ago, probably in India; from there the knowledge of it spread both east and west. Chinese writings dating back nearly 3000 years mention sugar cane as having been imported from India. Doubtless, in those early centuries, it was carried to the islands of the South Pacific and thence to Hawaii. At any rate, it was here when Captain Cook first visited this group of islands in 1778, for he noticed it

[18]This statement concerning sugar cane is largely a condensation from "The Story of Sugar in Hawaii," revised edition 1929, published by the Hawaiian Sugar Planters' Association.

growing in some of the gardens. It was not used by the Hawaiians as a source of sugar, however, for the art of sugar extraction seems not to have come with the plant when it was brought here.

The first effort to make practical use of the sugar cane plant here was in 1802. A Chinese who came to the Islands in 1802 on a vessel trading for sandalwood brought a stone mill and a boiler with him. He set up this apparatus on the island of Lanai, but after grinding one small crop he left the Islands. Don Francisco de Paula Marin, a Spaniard who came to Hawaii in 1791, succeded in making sugar in 1819.

In 1823 an Italian named Lavinia made sugar in Honolulu by pounding the sugar cane with stone beaters, on poi boards, and boiling the juice in a small copper kettle.

In 1825 an Englishman, John Wilkinson, first began the cultivation of sugar on a large scale by planting 100 acres in Manoa Valley, Oahu; but after his death in 1827, the cultivation was discontinued.

In 1835 the sugar industry received its first permanent impulse from an American firm, Ladd & Company, which obtained a grant of land from the king and established a small plantation at Koloa, Kauai. With the gold rush to California in 1849 and the opening of the Civil War in 1861 the demand for Hawaiian sugar was stimulated and the industry first commenced to thrive, although maximum progress did not occur until a number of years later.

In 1875, a reciprocity treaty was negotiated between the United States and the Hawaiian Kingdom, allowing Hawaiian sugar into America free of duty. This treaty marks the real beginning of development. Twelve years after the signing of the treaty, the Islands exported over 100,000 tons of sugar. Since the annexation of Hawaii to the United States in 1898, continuous progress has been made in the development of the industry.

An evidence of this progress is the increase of sugar production from 277 tons in 1856 to over a millon tons in 1932; the land area under sugar cane expanded from a few hundred acres in the 1850's to about 250,000 acres in the 1930's; capital investments, also, had increased very greatly in the same period from a few hundred thousand

to about $175,000,000; similarly, wages paid by the industry amounted to nearly $25,000,000 per year in the 1930's instead of the few thousands in the earliest years.

Eminent authorities who have made a study of the sugar industry throughout the world have declared that the scientific culture and manufacture of sugar is further advanced in the Territory of Hawaii than in any other part of the world.

It takes about eighteen months for a crop to mature in Hawaii. The plantation area is about double that used for any one crop. While one crop is being harvested another is growing. During certain periods each year, usually in June and July, a visitor on an Hawaiian plantation can see one crop growing, one being harvested and one being planted. Harvesting begins in November and usually ends in July or August, and planting begins from March to June and usually ends in September, according to plantation conditions.

The production of sugar per acre varies according to conditions and the type of cane. The amount of sugar obtained per acre of cane varies greatly, the poorest yields producing as low as two and one-half tons while some large individual fields produce as much as sixteen tons per acre;[19] the average, however, is six and one-half tons.

Hawaii's sugar lands are among the most intensely cultivated lands in the world. Year after year the sugar-growing lands of Hawaii have been made more productive through the study and use of scientific methods. Over forty years ago it was predicted that the soils of Hawaii would be rapidly exhausted. Science came to the front with methods that have given the sugar industry of Hawaii an unexampled record in agricultural history. Lands have produced constantly a yearly harvest without rest or fallow, and are now more productive than they were a generation ago.

These results are mainly due to the scientific use of fertilizer. The fertilizer bill of Hawaii's sugar industry for

[19]It should be noted that this is not the *annual* production rate, for the crop requires from 16 to 22 months to mature.

1928 was close to $5,600,000. This is double the amount used in 1914. Over 95,000 tons, or an average of over 1650 pounds of fertilizer per crop were applied to every acre of sugar cane, the largest amount used on any staple crop in the world. Sugar production in Hawaii has shown an average increase of two and three-quarters tons to the acre since 1905.

The Experiment Station of the Hawaiian Sugar Planters' Association has made an exhaustive study of Hawaiian soils. Extreme care is taken to protect the fertility of these soils and the highest quality of the proper elements are brought here from various parts of the world to be used in fertilization.

H.S.P.A. Experiment Station—Although it is usual for an agricultural industry to look to the government for scientific protection and development, the sugar industry in Hawaii has developed its own research station, staffing, equipping and maintaining it wholly at the expense of the producers. This station was established in 1895, with an initial staff of three scientists which subsequently has grown to over forty; the first year's expense was $7000, but within thirty years it had increased to about $500,000 per year.

One of the most notable of the achievements of this Station was the "creation" in 1905 of a new variety of sugar cane, H 109, which replaced the older Lahaina variety and saved the industry from the fate of virtual extinction which seemed in prospect because of the rapid failing of that variety. After several years of experimental plantings to test the new variety, it was generally adopted as the best producer of sugar and the acreage rapidly increased to nearly 100,000 within a decade or two. Meanwhile the search is being continued for even better varieties.

The work of the Station in overcoming several insect scourges was so remarkable as to be almost dramatic in its interest. There was, for example, the campaign against

the leafhopper, which was finally vanquished by parasites sought out in various parts of the world and brought here, in some cases with great difficulty. Later, there were other pests: the cane borer, the Anomala beetle, and others. Likewise, devastating diseases have had to be combated by the Station scientists.

Irrigation—For each ton of sugar produced, 2085 tons of irrigation water are used, or over 500,000 gallons.[20] At the average acreage production of six and one-half tons of sugar this means that each acre of land receives enough water to cover it to a depth of nineteen feet during one crop.

The irrigation systems on Hawaii's sugar plantations rank among the finest in the world. They are unequalled in any other sugar-growing country.

Mountains have been tunneled, hundreds of miles of canals and ditches have been built, siphons, flumes, reservoirs, as well as hundreds of artesian wells and scores of electric and steam-operated pumping stations are in use. Around $40,000,000 has been spent by the plantations in irrigation equipment alone. The men back of these projects have been called the "most daring and successful pioneers of irrigation in the world."

The first large irrigation project in the Islands was undertaken on Maui by Samuel T. Alexander and Henry P. Baldwin. From the forest-covered slope of East Maui, cut by deep gorges and valleys, water was brought seventeen miles through ditches and siphons to the potentially fertile but dry leeward slopes. In spite of difficulties in construction and financing the project was completed in 1878 at a cost of $80,000, a cost that would be ridiculously low today.

[20]In laboratory experiments conducted by Prof. H. A. Wadsworth in which sugar cane plants were grown in tanks, with all water losses eliminated except transpiration through the leaves, sugar was produced at a cost of 493 tons of water per ton of sugar. This situation is never duplicated in the field, however, and the water cost is much higher. In some instances the ratio is about 1000 tons of water per ton of sugar, but the average is said by Prof. Wadsworth to be about 2000 tons of water per ton of sugar. In earlier years, with less efficiency in irrigation, the ratio was said to be about 4000 tons (about 1,000,000 gallons) of water per ton of sugar.

This was immediately followed by a larger ditch constructed by Claus Spreckels, to irrigate the land on the central Maui plain. Since that date a very extensive water system has been developed, paralleling and extending the lines of the original system, at a cost of over $4,000,000. The latest addition to this great Maui project is the "Waialoa Ditch," which cost over $1,500,000 and is capable of delivering 170 million gallons of water daily.

On Oahu, the great Waiahole Aqueduct, built by the Oahu Sugar Company at a cost of over $2,500,000, brings water from the opposite side of the Koolau mountains through a tunnel nearly three miles long.

The Olokele ditch, supplying the Hawaiian Sugar Company's plantation on Kauai with water from the Olokele Canyon, is fourteen miles long and its upper portion includes a continuous tunnel for six miles, within a cliff. There are a number of other spectacular engineering achievements on the plantations, which have enabled thousands of acres of land to be placed under intensive cultivation, and have greatly increased the Territory's productiveness. Development of water is still going on, and a number of plantations now have large projects under construction.

Some plantations have developed pumping systems to draw from artesian water supplies instead of bringing in surface waters through long ditches and tunnels. One plantation, for example, has a pumping capacity of 120,000,000 gallons of water per day in addition to the amount it gets from its mountain supply. This one plantation pumps and uses daily nearly three times the water consumed by all the population and industries of the city of San Francisco, and one and one-half times the amount used by the city of Boston. There are a number of other plantations having from sixty to one hundred and ten million gallons pumping capacity per day.

Many of the plantations have from six to twelve or more pumping stations which tap the water supplies. Water is pumped from these stations to varying elevations, some-

times as high as seven hundred feet or more. These stations are equipped with large steam or Diesel or centrifugal pumps electrically driven. The plantations are watchful in keeping their pumping equipment up to date.

At some locations on the plantations pumps have been placed in shafts between 200 and 400 feet below the surface of the ground in order to reach the water level. Several of the large pumping stations are built in pits, giving the observer a thrill when he looks down upon their glistening array of machinery. Each pumping station taps a number of wells and a single unit may pump as much as 22,000,000 gallons of water per day.

At Ewa Plantation on Oahu, the irrigation water supply depends entirely upon sixty-one artesian wells and the pumping capacity is over 100,000,000 gallons per day.

The pumps are usually kept working day and night and the night water is deposited in a series of reservoirs built throughout the fields. The steep slope of the land and the nature of the soils on the Islands make the storage of surface water from streams in extensive reservoirs an extremely difficult, and in many cases, an impractical undertaking. The largest reservoir in the Territory is the Wahiawa Reservoir near Schofield Barracks. Here the whole valley was dammed up, creating a reservoir capacity of 2,544,000,000 gallons. The Koloa Reservoir on the island of Kauai covers a square mile of land and has a capacity of 2,225,000,000 gallons. The Alexander Dam on Kauai, also is worthy of note.

Extensive tests in irrigation have been made by the plantations and by their Experiment Station. The most effective and economical methods of applying the water to the sugar crop have been adopted. Experts in this work are constantly striving for the maximum results in this branch of the sugar industry.

Cane Transport—Sugar cane is carried from the fields to the mill in a variety of ways: by railroad trains, by flumes, or by overhead cable lines. Thirty-two plantations have extensive railway systems, with a total of about 900

miles of main-line track and 300 miles more of portable track; some 140 locomotives and other rolling stock worth $5,000,000 run on these tracks to transport millions of tons of cane to the central mills.

Several plantations are so situated that they can flume their cane to the mill, using small streams diverted from their natural courses into many miles of wooden flumes. Others use overhead cable lines, with gravity to carry bundles of cane down from the fields.

Builders of the Industry—Many people have had a part in the building of this great industry. Thousands from Europe, mainland America, China, Japan, the Philippine Islands, and elsewhere have made their various contributions of physical strength, intellect and money to develop the extensive plantations, great mills and refineries and the transportation facilities which are essential parts of the industry.

The pioneers included men who brought capital to invest, and many others who came here poor, but worked their way up through sheer pluck and industry. Fortunes were lost as well as made. Many succeeded and many failed, but all contributed their share to development. There were energetic Americans, and many native Hawaiians high in the councils of their kingdom; Englishmen, Scotchmen, Irishmen, Norwegians, Germans, Portuguese, Spaniards—men of various nationalities, but men who possessed in common the pioneer spirit and energy. Many of them have contributed inventions which not only advanced the sugar industry here, but had a far-reaching effect on the sugar industry throughout the world.

Noteworthy among the pioneers were James Campbell from Ireland, Robert W. Wood from America, Valdemar Knudsen from Norway, H. P. Baldwin and S. T. Alexander, both born in Hawaii, Claus Spreckels and John M. Horner from California, Captain James Makee from Massachusetts, Paul Isenberg from Germany, W. H.

Rice, a son of Hawaii, Charles R. Bishop, B. F. Dillingham, and many others.

The Hawaiian Sugar Planters' Association, known popularly as the H. S. P. A., is perhaps one of the most unique business associations in the world. It is an unincorporated, voluntary association of thirty-seven plantation companies which have for years combined in working for the common good of the sugar industry of Hawaii, and indeed of the world.

The first attempt at cooperation by the plantations occurred in the early 1850's with the organization of the Royal Hawaiian Agricultural Society. This association went out of existence, however, in a business depression about 1857, and no further attempt was made until 1882. At a convention held in the rooms of the Chamber of Commerce in Honolulu in March, 1882, The Planters' Labor & Supply Company was formed, with leading plantations throughout the Islands as members. In 1895 this company was reorganized under its present name of the Hawaiian Sugar Planters' Association.

The purpose of the H. S. P. A. is to work for the benefit and development of the sugar industry of Hawaii. One of the most outstanding achievements of the Association is its Experiment Station, where scientific study and control of the industry have made possible great advancements and have accomplished and promoted work which has been of far-reaching benefit to the Territory in general.

The H. S. P. A. studies and compiles accurate records about the sugar industry, and constantly supplies valuable information and data to all its members. The securing of labor for all plantations that are members is also a very important service of the Association.

Hawaii's record in sugar production is set forth in the following table of figures. At present the sugar made in this Territory constitutes about 3.25 per cent of the total world production, including both cane and beet sugar.

HAWAIIAN SUGAR PRODUCTION

(From Early Records Down to Date, in Tons of 2000 Pounds)

Year	No. of Tons	Year	No. of Tons
1837	[21]2	1887	106,362
1838	44	1888	117,944
1839	50	1889	121,083
1840	180	1890	129,899
1841	30	1891	137,492
1842–1843	572	1892	131,308
1844	257	1893	165,411
1845	151	1894	153,342
1846	150	1895	147,627
1847	297	1896	221,828
1848	250	1897	251,126
1849	327	1898	229,414
1850	375	1899	282,807
1851	11	1900	289,544
1852	350	1901	360,038
1853	321	1902	355,611
1854	288	1903	457,991
1855	145	1904	367,475
1856	277	1905	426,428
1857	350	1906	429,213
1858	602	1907	440,017
1859	913	1908	521,123
1860	572	1909	535,156
1861	1,281	1910	518,127
1862	1,503	1911	566,821
1863	2,646	1912	595,258
1864	5,207	1913	546,798
1865	7,659	1914	617,038
1866	8,865	1915	646,445
1867	8,564	1916	593,483
1868	9,106	1917	644,574
1869	9,151	1918	576,842
1870	9,392	1919	603,583
1871	10,880	1920	556,871
1872	8,498	1921	539,196
1873	11,565	1922	609,077
1874	12,283	1923	545,606
1875	12,540	1924	701,433
1876	13,036	1925	776,072
1877	12,788	1926	787,246
1878	19,215	1927	811,333
1879	24,510	1928	904,040
1880	31,792	1929	913,670
1881	46,895	1930	924,463
1882	57,088	1931	999,787
1883	57,053	1932	1,025,354
1884	71,327	1933	1,035,548
1885	85,695	1934	936,318
1886	108,112	1935	963,316

[21]First Record of Exportation.

By-Products—Several by-products of the sugar industry in Hawaii are of considerable importance, notably stock feeds, alcohol, paper, wall board, cellulose, fertilizer, and other articles; others have been sought, as wax. For details, see "Alcohol," "Bagasse," "Molasses," "Wax," etc.

The cane tops are to some extent used as fodder for plantation animals and dairy cows.

See also "Feeds for Livestock."

SUMACH See "Tan Bark."

SUNFLOWER A giant type of sunflower *(Helianthus)* is cultivated in some countries for the seeds which are used as feed for poultry and other livestock. Several trial plantings in Hawaii have not given encouraging results and it is doubtful if this plant offers any attractive possibilities for extensive production here. Birds do a great deal of damage to the crop. The yields obtained were about 2500 pounds of dry seeds per acre.

See also "Jerusalem Artichoke."

Ref.—U. H. Agr. Dept. Annual Report 1920:14; 1927:33.

SUNN HEMP Sunn hemp *(Crotalaria juncea),* a leguminous plant, is a good source of fiber.[22] Although no thorough test of it has been made in Hawaii, Dr. Krauss considers it one of the most promising for fiber purposes and is responsible for the following statement concerning it.

Sunn hemp in India is sown annually at the beginning of the rainy season in early spring and harvested at the end of September or the beginning of October. This is also the most favorable season for planting in Hawaii, although the crop can be grown through the winter months and harvested or turned under in the spring so that the land may be utilized for other crops, such as sweet potatoes, corn, field beans, etc., during the summer months. Sunn hemp would probably rotate very satisfactorily with the early export potato crop. A double disc harrowing of a newly harvested potato field would be all the tillage needed, while the residual fertilizer remaining from the

[22]It is also valuable as a green manure crop, for in sixty days it makes a lush growth which may be plowed under to improve tilth. See Haw. Exp. Sta. Annual Report 1924:12; also, an article by O. C. Magistad et al in Journ. American Soc. Agronomy, Vol. 26, No. 5, pp. 372-380, May, 1934.

potato crop would, in most cases, supply all the fertility needed by the succeeding sunn hemp crop. Almost any crop following the sunn hemp would be benefited, because of its ability to extract large amounts of free nitrogen from the air, and at least part of this would be returned to the soil in turning under the plant stubble. The crop grows well on a great variety of soils, from sea level to an altitude of at least 3,000 feet. Lighter and not too rich soils would probably be found most suitable for the best fiber. When grown as a catch crop for green manuring[23] and for suppressing weeds, it is best to sow the seed thickly broadcast up to 80 pounds per acre. The seed for fiber might best be drilled in rows with a grain drill, spacing the drills 12, 18, or 24 inches apart, depending on circumstances. Twenty to forty pounds of seed will be required per acre when drilled as indicated. The closer the plants stand, the straighter they will grow, and if used for fiber they will be freer from detrimental lateral branches. The plant grows from four to eight feet in height, depending on spacing, soil fertility, and moisture supply. The yields in a green crop range from 10 to 20 tons per acre. The growing season ranges from about 120 to 160 days, dependent on location, season, and cultural practice.

In Hawaii the crop has been singularly free from disease and attack from insect pests. Like most legumes, this crop responds to phosphatic fertilizers, especially in the higher lands, which are often deficient in this element.

The fiber of sunn hemp is prepared by doubling up the bundles of dried stems and placing them, weighted down, in pools of water, completely submerging the mass as is done in retting jute and like material. Retting requires four to five days during the warmer seasons of the year and possibly twice as long in the cooler seasons of the year. Fresh, moving water is said to be preferable to stagnant water for retting, because the color and luster of the fiber are influenced thereby; on the other hand, stagnant water is conducive to hastening the retting process.

[23]The H.S.P.A. Experiment Station has used this plant, as well as other legumes, for green manuring purposes. See Planters Record V, pp. 210, 345 and VII, p. 363.

The process of stripping and washing the fiber consists of beating the stems to separate the various tissue layers. The resulting hank of cleaned fiber is then wrung out to remove the excess water, and is twisted and hung for drying and bleaching. It is then plaited threefold into a "tail" and in that form it is sold for manufacture into burlap.

Ref.—Planters Monthly Vol. VI, pp. 454-457 (1887).

SURINAM CHERRY The Surinam cherry *(Eugenia uniflora),* also called French cherry, or Cayenne berry, is an attractive shrub used in moderate abundance as an ornamental throughout Hawaii, notwithstanding the fact that it is only a recent introduction. Its bright-colored oddly ribbed fruits make it a striking feature in any garden. The fruit is very tart and has an agreeable bitterness which makes it popular for use in jelly and jam. This, however, is not developed on a commercial basis and there is practically no production of this fruit outside of household gardens and estates. It would seem to offer some possibilities for large scale cultivation.

Ref.—Haw. Exp. Sta. Bul. 77:80-82 (recipes, uses, etc.).

SWAMP CABBAGE Swamp cabbage *(Ipomoea reptans)* is not in any way related to the head cabbage, as it belongs to the sweet potato family. It is a creeping vine which grows in swampy areas and produces foliage which is somewhat succulent and good to eat when cooked as greens. It is an Asiatic plant, believed to have been introduced here by early Chinese immigrants.[24] Its consumption is very limited.

SWEET CLOVER Sweet clover *(Melilotus alba)* is a temperate zone perennial plant very useful for pasturage. It does not thrive well in Hawaii, judging from trials at the University Farm.

Ref.—U. H. Agr. Dept. Annual Report 1919:12; 1920:14.

SWEET POTATO The sweet potato *(Ipomoea batatas)* has been under cultivation in Hawaii for many centuries. It is believed to have been brought here about 500 A. D. by the first Polynesian immigrants, the pro-

[24]Haw. Exp. Sta. Bul. 60, p. 24, 1929.

genitors of the present Hawaiians, for the sweet potato and taro have been the two chief staple foods of this people for a very long time. Captain Cook on his discovery voyage reported finding very large sweet potatoes produced here. Other reports of those ancient times indicate that the Hawaiians had developed considerable skill in the cultivation of this crop, apparently having discovered that the propagation of only the most productive plants gives the best results at harvest time.

Cultivation of this crop continued extensively after the coming of the white people, but gradually diminished as the Hawaiian population decreased in numbers. A temporary upward turn came during the years when many whaling ships were calling here for food supplies; in the gold rush days some shipments of sweet potatoes were sent to California, which still further influenced the revival of interest in this crop in the middle of last century. In the latter part, however, production declined again to a relatively low point and remained there until the World War stirred up a new interest in this food commodity. Meanwhile, however, the Hawaii Experiment Station, in the same year it was established (1901), began to direct attention to the possibilities of making sweet potato production an industry of at least minor importance, pointing out that imports of California sweet potatoes were larger in volume than the local production and commanded a higher price because of better grading, in spite of the fact that it is a sub-tropical plant and should thrive better in Hawaii. In 1910 a further effort was made by the Station to arouse interest in this crop, this time by making some trial shipments to California to test the possibilities of developing a winter and spring trade with the mainland when production there was impossible. Nothing of commercial importance came of it, however, and the situation continued about as it had been. A few years later another obstacle arose in the form of a federal quarantine against sweet potato shipments to the mainland, imposed because of certain insect pests attacking the tuber and stem of the plant.

When the World War began to affect Hawaii in 1917 by threatening to cut off normal food shipments, the sweet potato loomed into importance as a possible substitute

for certain imported articles. It was planted in many home and school gardens, and some 350 acres of agricultural lands were devoted to this crop. Overproduction resulted, causing some unfavorable reactions, but in spite of this a considerable interest has continued, to the present.

The Hawaii Experiment Station began in 1917 to develop superior types by cross-breeding and selection, and at times had a very large number of varieties growing under test. Interestingly enough, they found the old varieties formerly grown by the ancient Hawaiians quite equal and in some instances superior to the newer varieties introduced from the mainland. By 1924 the Station had succeeded in developing several particularly good strains, one, for instance, yielding at the rate of 23 tons of potatoes per acre,[25] while the usual harvest was 7 to 10 tons; Krauss had obtained yields on his Maui farm as high as 17 tons.

The sweet potato offers some interesting possibilities for greater exploitation in Hawaii, not, however, as an export crop in the fresh state, because of quarantine restrictions against it. These possibilities are three: (1) As a feed for livestock it has certain values which could be capitalized for a partial replacement of imported concentrates, thus reducing a little the cost of dairy products and pork; feeding tests show that 3 pounds of sweet potato roots have a feed value about equal to one pound of beet pulp; in addition to using the roots as feed, the tops make excellent forage. (2) Sweet potato starch has certain qualities which make it peculiarly valuable in some manufacturing and industrial lines (see "Starch"), and the U. S. Department of Agriculture is undertaking to stimulate its production in the southern states, where much cotton land is idle. Conditions are more favorable here and it would seem that Hawaii could succeed in this line even better than the cotton states. (3) As a canned food the sweet potato is in good demand. Since the quarantine would not affect the canned product, it might be possible to develop a large industry on this basis, for the Hawaiian sweet potato is of good quality and by further selection and

[25]These yields were on small experimental plots, probably not capable of duplication on a large scale, commercially.

breeding a type suitable for canning could be developed.

Present production occupies about 250 acres, including small garden plantings. This is barely enough to meet the local market demands. It grows well at any elevation from sea level to 2000 feet, and is adapted to a wider range of soil types than many other crop plants.

See also "Starch."

Ref.—U. H. Agr. Ext. Bul. 16:115-123, 1932 (an excellent and practical guide for production and harvesting); Haw. Exp. Sta. Bul. 50 (The Sweet Potato in Hawaii), 1923; Bul. 22 (Sweet Potato Insects), 1911; Annual Reports 1901:375; 1910:36; 1918:49; 1919:46; 1921:27; 1923:6; 1924:12; 1925:10; 1926:11; 1927:13; 1928:14; 1936:23; U. H. Agr. Dept. Annual Reports 1919:24-26; 1920:15, 21-24. U. S. Dept. Agr. Yearbook 1935, pp. 308-9.

SWEET SOP The sweet sop *(Annona squamosa)* is a tropical rarity seldom found in gardens in Hawaii and not at all planted commercially. It resembles the cherimoya, which see.

SWEET VERNAL GRASS Sweet vernal grass *(Anthoxanthum odoratum)* is widely distributed in the higher elevations of all islands. Cattle do not eat it readily and it may become a pest.

Ref.—Haw. Exp. Sta. Bul. 65:8, 1933.

SWINE[26] Swine were found in Hawaii when Captain Cook made his discovery voyage. Records show that he left a pair of English breed pigs in 1778 but little definite information seems available as to other sources of breeding stock until the beginning of the present century.

During the whaling era there was a steady demand for pigs to replenish the food supplies on the vessels which put into port. Also, in the 1850's a brisk business developed in the exporting of swine to California. President W. L. Lee of the Royal Hawaiian Agricultural Society noted in 1853 that "the demand for live hogs for exportation to California exceeds the production and hardly a vessel leaves for San Francisco that does not carry a deck load of grunters. They are worth 4 to 6 cents per pound on foot and the business of raising them is within the scope of the natives and pays well." In the transactions of the

[26]This statement was prepared by Prof. L. A. Henke.

same society for 1855 a record appears that a Berkshire imported boar was awarded the first prize. Other breeds have been introduced since then, but Berkshires are still one of the most popular breeds, along with Duroc-Jerseys and Tamworths. Some Chester Whites and Poland-Chinas have been introduced, but they occupy a secondary position to the first named breeds and crosses of these breeds.

Since 1900 rather definite records are available and they show that there has been a gradual increase in the number of pigs in the Territory, although there have been times during this period when interest in swine raising was at a low point due to the large numbers of live pigs shipped to Hawaii from California for immediate slaughter. Swine raising in this Territory is largely concentrated around the larger cities and towns, and garbage from homes, hotels, and army posts is one of the major feeds used. However, for satisfactory gains it is necessary to supplement garbage with some concentrates which cost far more in Hawaii than in the corn belt. Experiments[27] at the University of Hawaii have demonstrated that cane molasses can be advantageously used as part of the ration fed to swine and increasing quantities of molasses are being used in this way, resulting in a material reduction in the cost of pork production (see "Molasses").

Garbage from homes is secured at no cost by hog raisers, other than collection costs, which may be considerable in some cases; restaurants, hospitals and hotels receive some pay for their garbage, and garbage from army posts is sold on competitive bid, which ranges around 20 to 35 cents per man month.

The number of hogs in Hawaii during recent years as shown by the U. S. Census follows:

Year	*Number of swine*
1900	8,057
1910	20,484
1920	38,940
1930	42,841

[27]For a report on recent feeding experiments see Haw. Exp. Sta. Annual Report 1936: 70-72.

Practically all pork produced in Hawaii is consumed as fresh pork, and cured meats are almost entirely imported. The extent of these imports during recent years follows:

IMPORTS OF HOG PRODUCTS TO HAWAII

Year	*Pounds*	*Value*
Hams, Shoulders, and Bacon		
1920	1,437,626	$526,439
1923	1,584,057	459,874
1926	1,221,242	480,387
1929	2,118,917	714,924
1932	2,857,754	459,909
1935	2,604,740	715,339
Fresh and Pickled Pork		
1920	146,270	34,299
1923	540,519	94,879
1926	874,178	217,318
1929	1,420,381	306,014
1932	2,350,267	245,131
1935	2,220,076	420,978
Lard		
1920	40,850	9,944
1923	265,532	36,984
1926	130,836	22,396
1929	184,352	24,590
1932	159,052	10,490
1935	170,353	25,374
Sausages[28]		
1920	201,788	79,566
1923	551,360	125,485
1926	825,491	223,169
1929	1,115,135	285,838
1932	2,028,811	304,586
1935	2,605,873	500,132

In general it appears that pork products imported to Hawaii have increased somewhat during the years shown with a grand total of 7,601,042 pounds for 1935 valued at $1,666,823. To produce these amounts locally would require that approximately 50,000 additional hogs be produced and marketed annually.

Exact data on local production are hard to secure because many pigs are killed in various small slaughter houses. Based on available data, it is estimated that approximately 40,000 pigs are slaughtered annually in Hawaii, having a total weight of about 6,000,000 pounds and valued at about $800,000.

[28]May include some other meats.

Based on available data, per capita pork consumption in Hawaii averages about 35 pounds per year, which is about half of the per capita consumption on the mainland.

In addition to the pork products reported above, the following numbers of live hogs have been imported to Hawaii in recent years:

Year	*Live hogs shipped to Hawaii*
1929	6740
1930	5178
1931	3100
1932	4259
1933	3080
1934	1728
1935	15

Hog cholera is found in the Territory and some of the hog raisers regularly immunize their pigs. Many others, however, resort to vaccination only when outbreaks occur and heavy losses occasionally result.

Round, intestinal worms are prevalent in many piggeries and occasion some losses by causing the death or stunting of small pigs. These losses can be largely avoided by proper sanitation and treatment with worm remedies; the Agricultural Extension Service of the University is doing valuable work along these lines.

Many hog raisers have a very limited area of land and many pigs are born and go to market without ever having had access to pasture areas. Some hog men may have as many as 500 pigs on an area of one acre or less.

Data compiled by the Board of Health show the following number of pigs and pig raisers on Oahu in 1936:

	Hog raisers	*Number of pigs*
City of Honolulu	195	19,460
Rural Oahu	214	7,241
	409	26,701

Unfortunately, similar data for the other islands do not seem to be available.

SWISS CHARD Swiss chard *(Beta vulgaris cicla)* is a relative of the beet. Its leaves have thick, fleshy midribs and are excellent when cooked as greens, or the midribs

may be separated from the leafy portion and used as a substitute for asparagus.

The plant grows to perfection in Hawaii[29] and should be cultivated extensively. Unfortunately, it is not well known and the market demand for it is limited, which causes gardeners to plant it but sparingly.

See also "Truck Crops."

TALL OATGRASS Tall oatgrass *(Arrhenatherum elatius)* is of moderate importance on Lanai as a pasture grass.

Ref.—Haw. Exp. Sta. Bul. 65:9, 1933.

TAMARIND The tamarind *(Tamarindus indica)*, one of the most beautiful of ornamental trees, grows exceedingly well in Hawaii and may be found in many yards and gardens. Although it has been recommended from time to time as having commercial possibilities as a source of fuel wood and timber, it is considered throughout the Islands as nothing more than an ornamental.

The fruit of the tamarind tree is a somewhat fleshy pod, from which may be extracted a juice of an agreeably acid flavor. In Mexico this juice is much prized as a refreshing drink when greatly diluted with water and sweetened. In Hawaii, however, this use of the fruit seems not to have developed,[1] and the pods simply waste away on the ground or are eaten by swine. In India the seeds are cooked and ground into meal, but the flavor is sometimes bitter.

Ref.—Trans. Royal Haw'n Agr. Soc. Vol. I, No. 2, p. 83 (1851); Haw. Exp. Sta. Annual Report 1921:20; Bul. 77:83-85 (uses, recipes, etc.); Haw. For. Agr. 1908:124.

TAN-BARK The bark of several kinds of trees has been used in Hawaii for securing the tannin necessary in curing and tanning leather. The three kinds used most commonly are koa, ohia and kukui (candle nut tree). Koa *(Acacia koa)* contains a good amount of tannin and has been used for over a century; it makes a rather dark colored leather. Ohia *(Metrosideros)* makes a relatively

[29]Krauss—Agr. Ext. Bul. 16, p. 70, 1932.

[1]The Planters Monthly Vol. XII, p. 531 (1893) gives directions for the "preserving" of tamarind pods, but there is no indication that it was a common use of this product.