Extension Bulletin No. 15 September, 1931

COMMERCIAL POTATO PRODUCTION IN HAWAII

U. S. Fancy No. 1 Potatoes
Hawaii's goal: "100,000 sacks by 1935"
In 1853 Hawaii Exported 51,957 Barrels of Potatoes

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A bushel of "one pounder" potatoes, sixty potatoes to the bushel. Hawaii's goal for 1935 is a crop of 250 such bushels to the acre.

SLOGANS FOR THE HAWAII POTATO-GROWER

Quality. Fancy potatoes: better than U. S. No. 1 grade.

Yield. One hundred and fifty sacks to the acre.

Price. $2.00 per hundred pounds for our main crops, and $5.00 per hundred pounds for early "export" potatoes.

Market. Supply the home market first, then develop an export trade for early potatoes, for mainland and steamship requirements. Our home market, including Army and Navy requirements, absorbed 181,354 sacks in 1930.

Returns. $100.00 net, or better, per acre per annum, and the consciousness of a job well done!

Caution. Do not overproduce! Consult freely with your County Agent.

HOW THESE ENDS MAY BE ACCOMPLISHED

They can be accomplished by intelligent and persistent cooperation of all the interests concerned, including the farmer, banker, jobber, merchant, consumer and agricultural extension worker, to the end that all may prosper in a common cause to which each has contributed his share. In this and all similar agricultural enterprises the Agricultural Extension Service of the University of Hawaii pledges its heartiest support.

COMMERCIAL POTATO PRODUCTION IN HAWAII

By F. G. Krauss

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INTRODUCTION

The so-called "Irish" or "White" potato is one of the most important food crops grown, and is second only to rice and wheat as a world crop. Europe produces about four-fifths and the United States less than one-fifth of the total production. The average European yield is 200 bushels per acre, that of the United States only about 100 bushels. Hawaii's average potato yields are better than those of the continental United States but not equal to those of Europe. That they can be made not only equal but better is the thesis of this bulletin. The per capita consumption of potatoes in the United States is around 140 pounds, that of Europe almost three times as great.

Hawaii consumed 302,258 bushels of potatoes in 1930, equivalent to 18,135,480 pounds, costing $382,094. This gives an average per capita consumption of only about 50 pounds costing $1.05.[1] This small per capita consumption is probably due to the ex-

[1] The average wholesale price of potatoes consumed in Hawaii in 1930 was $2.10 per cwt.

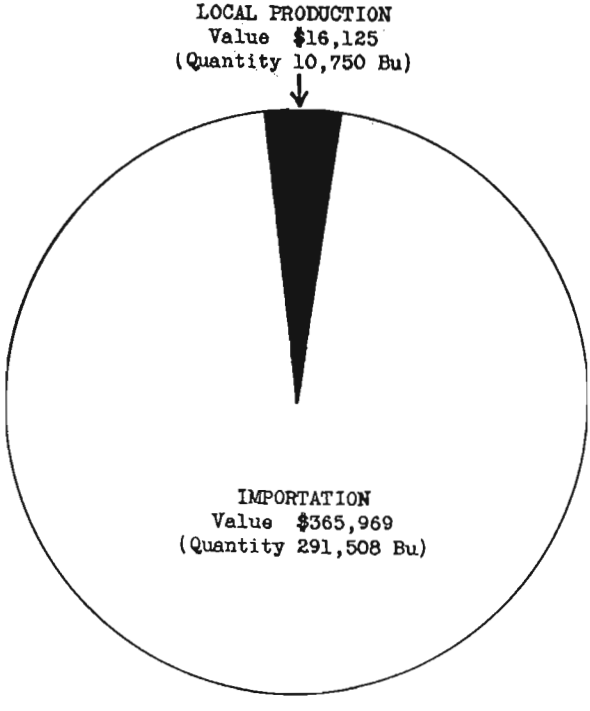

Fig. 1.—Diagram showing the importation of potatoes into Hawaii, compared with local production, 1930.

tensive use of such substitutes as rice, poi, taro and sweet potatoes, all of which are produced in Hawaii somewhat more cheaply than potatoes are.

While Hawaii's consumption of potatoes is comparatively low, it is interesting to note that her imports in 1930 totaled 291,508 bushels, valued at $365,969, while the local production was only 10,750 bushels valued at $16,125. Insignificant as was the home production, the home-grown potatoes were in general of superior quality and brought a higher price in the retail markets than the imported article did.

The following tabulations give the annual imports of potatoes in Hawaii for the 20-year period from 1911 to 1930:

Importation of Irish potatoes to Hawaii
1911-1930

(for the fiscal year, ending June 30)

Year	Bushels	Value
1911	111,921	$118,758.00
1912	158,872	158,109.00
1913	208,525	95,265.00
1914	216,360	142,248.00
1915	222,121	159,798.00
1916	223,981	179,675.00
1917	167,275	283,537.00
1918	210,865	236,359.00
1919	189,706	240.814.00
1920	152,409	327,039.00
1921	253,293	310,532.00
1922	283,137	291,504.00
1923	283,564	254,041.00
1924	283,149	324,838.00
1925	292,968	335,889.00
1926	261,638	449,492.00
1927	267,368	311,154.00
1928	314,206	289,063.00
1929	296,843	220,417.00
1930	307,592	321,687.00

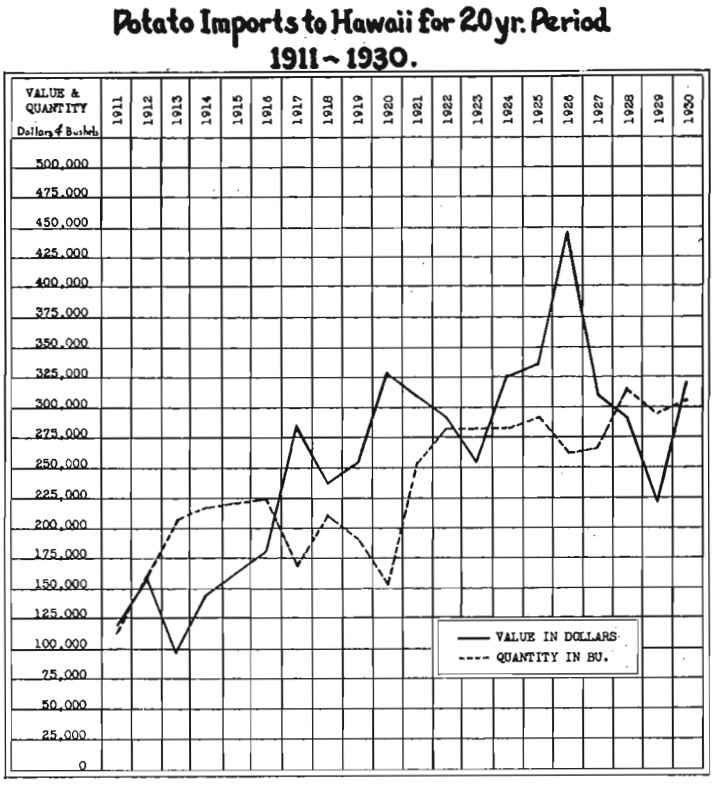

Fig. 2.—Graph showing potato importations into Hawaii, 1911-1930.

The total import of potatoes through a period of 57 years (1873-1930)[2] amounting to 6,024,468 bushels, valued at $6,104,155 might well in large part, have been produced on a thousand acres of Maui's fertile Kula uplands had only we had the foresight and been equal to the opportunities there and then existing. The past year's importation likewise, valued at $365,969, might well have been produced on 2000 acres of Haleakala's broad slopes, which are now covered with gorse[3] and pamakani[4] a curse becoming more costly and threatening with each succeeding year.

It is such minor but sound agricutural industries, with a ready market at our front door, which will fill in the inter-spaces be-

[2] For tabulated records giving annual imports of potatoes for the 57-year period 1873-1930, and the monthly imports for 1930, see appendix.

[3] Ulex europaeus

[4] Eupatorium adenophorum

tween our major industries, and thus still further stabilize our sturdy ship of state.

Lest our practical men of affairs question the soundness of our thesis we would here contrast the conditions of today with those of yesterday. We have found from reliable authority that Hawaii at one time (1849-60) exported Maui-grown potatoes to California in large quantities.

According to Sedgwick[5] *"Formerly potato growing was an important industry, potatoes standing at the head of the list of exports. In 1849 the number of barrels exported was 51,957, but at the present time (1899-1900) the local demand is almost wholly supplied by importations, which amount to 1,500,000 to 2,000,000 pounds per annum*[6]*. The retail price varies from 1½ to 4 cents per pound."* By 1853 the exports, together with the numerous whalers which frequented Hawaiian waters in those days, absorbed 56,000 barrels of Hawaiian potatoes, equivalent to 6,720,000 pounds, the highest record of exports of potatoes from Hawaii in any one year is said to have been 71,000 barrels, equivalent to 10,080,000 pounds an amount almost half the size of our present large importation.

Sedgwick goes on to state: *"It is estimated that there are at least 6000 acres of land well adapted to the growing of potatoes. The best potato land is in the Kula district, Island of Maui, on the slopes of Haleakala, the yield varying from 1½ to 4 tons per acre. The soil is fine, almost a powder, quite deep and does not crack. The tubers are smooth and free from pimples and present a good appearance in the market. The size of the potato is inferior, but this is due to poor selection and bad cultivation, as there are records of specimens 16 inches long and 11 inches in circumference. The quality is excellent, and when properly shipped brings a good price in the market."*

The present writer, who was intimately associated with potato investigations on the Island of Maui during the period from 1914 to 1921, would corroborate Mr. Sedgwick's statement and would add that better varieties, selection of seed stocks, better cultivation, fertilization, spraying and marketing *did* materially improve the conditions which he cites.

Quoting from the Report of the Hawaii Agricultural Experi-

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[5] Sedgwick, I. F., Potatoes, Hawaii Agricultural Experiment Station, Report, 1909, p. 374.

[6] Customs records show that in 1899 and 1900, 1,166,220 and 2,728,620 pounds respectively were imported.

ment Station for 1919[7]. "This year marks the close of a four-year field experiment with potatoes. This experiment included comparative tests of numerous varieties, together with fertilizer and cultural experiments . . . . The highest yielding varieties gave yields, for the four-year period, equivalent to 300 bushels per acre. Numerous hills yielded as high as 5 pounds, (or at the rate of 968 bushels, 580 bags per acre!)[8]. The variety known as the New Era Earliest of All, yielded after three years of hill selection at the rate of 300 bushels (18,000 pounds) per acre on a field scale. The cost of producing this crop was approximately $150.00 per acre. The price realized for the tubers was $2.25 per hundred pounds on the farm (some lots brought $2.50 to $3.50 per hundred pounds). The net profit per acre was close to $250.00 for this four-month crop.

During the experimental period at the New Era Homestead Farms from 1914 to 1920, one acre to four acres of potatoes being grown annually, the average yield for all varieties tested was 102 bags per acre and the average price received $1.75 per hundred pounds. The average cost of production was slightly less than $1.50 per hundred pounds. The net profit per annum per acre for the entire period of six years was $25.50. This comparatively low acre profit paid however for the experimenting and experience. Every grower must pay for experimentation at least in part. Furthermore New Era Homestead Farms were originally not well adapted to potato culture. The soils needed a lot of upbuilding. We knew little at that time about suitable potato varieties and fertilizers. Then, the experiment encountered at least two very unfavorable years. After these obstacles were overcome, it was not difficult to net $100.00 per acre and to improve the productivity of the soil at the same time through rational crop rotation and green manuring practices.

The best of the old potato lands of the Territory, including the Makawao and Kula regions on Maui, the Waimea and Waiki districts of Hawaii, many of the untried fertile uplands on each of the islands, and some of our most favorably situated abandoned rice areas, should give better returns than did our lands at Haiku.

It is because of this conviction, the result of intimate personal experience plus a comprehensive survey covering the past two years, that the Agricultural Extension Service of the University of Hawaii is this year launching a carefully planned potato pro-

[7] Experiments with potatoes p. 64-67.

[8] See appendix for additional experimental data gleaned from Hawaii Agricultural Experiment Station Reports.

duction project. We hope this fall 1931 to enroll in the enterprise a nucleus of good farmers who are favorably situated for making a success at potato raising.

To do this job well will necessitate the cooperation of all concerned. This means that the grower, the consumer and the merchant must work together intelligently and persistently over a long period of time. It means that probably we shall do well to organize within another year a potato growers' association to set up standards of a high order and enforce them upon its members. Quality of product and stabilization of the "industry" must become the watchwords of the organization once it is formed, and these principles must ever be kept in mind.

Fig. 3.—Imported potatoes stored in a warehouse. These are part of a shipment of 1,300 sacks of "quality" tubers per S. S. Maui, August 18, 1931.

For these potatoes the California grower gets about $1.00 per 100 pounds, the jobber gets about $2.00 after paying for transportation, and the retailer charges about $3.00. Hawaiian grown potatoes of the same quality ought to bring $1.50 to $2.00 to the grower, selling to the consumer for $2.50 to $3.00.

One of the greatest obstacles formerly encountered has fortunately been surmounted. The principal commission merchants and importers are now giving us their support and counsel, as if they had confidence in the undertaking.

We shall look forward to a worthwhile get-together concourse

of potato growers at least once annually. Here every phase of the potato growing industry should be discussed openly and freely. Our wholesale merchants and retail dealers, our bankers, our managers of cooperatives, and transportation, our fertilizer and seed dealers, not less than our agricultural extension workers, and lastly, our always cooperating local press, must work together for the common good.

In justification of this plea, unusual perhaps in a publication such as this, let us briefly summarize the measures most urgently needed to make this potato venture a very striking success.

We need (1) intelligent leadership and full cooperation on the part of the growers; (2) advance market information for price and acreage stabilization; (3) supplementary credit; (4) close market coordination and improved marketing practices; (5) higher standards and better grading; (6) a conviction that all of us working for a common end, and holding together, will accomplish infinitely more than when each goes blindly on his independent way. The sum total of all our efforts will be better than the best efforts of any individual.

In other regions such cooperation has resulted in stabilization. Cooperation has encouraged planting year after year on a proper acreage scale and has demonstrated the unwisdom of excessive planting in normal years, it has caused the merchant, the banker,

Fig. 4.—A fine potato field, in full bloom. As grown in the famous potato region of Aroostook County, Maine.

Fig. 5.—The same crop as shown in Fig. 4 harvested after a 110-day growing season. This type of cultivation produces 350 bushels or more per acre per annum on the best farms.

and the producer to agree together in the matter of acreage to be planted to potatoes. It has brought about a conviction that co-operation betwen all parties concerned can be controlled to a nicety in normal seasons. It has convinced everybody that adverse conditions, which might demoralize an industry where there is a lack of understanding, can be in large part overcome.

The Agricultural Extension Service of the University of Hawaii through its divisions of marketing, farm management and agronomy, with the United States Department of Agriculture and Hawaii Agricultural Experiment Station cooperating, extends its helping hand.

POTATO CULTURE

CLIMATE AND SOIL REQUIREMENTS

In general, the potato demands a relatively cool and moderately moist season for its best development. The optimum air temperature is placed at around 65° F. However good crops, especially of early varieties, are grown under considerably higher temperatures, say, up to 75 and even 85°. Moderately low soil temperature is likewise advantageous. For summer culture the chief advantage of peat and muck soils, as well as others rich in humus, is probably due in large part to the relatively lower temperature of these types of soils. It may be for this reason that some of Hawaii's old rice lands have produced such large crops and such excellent tubers. It is interesting to note in this connection that potato rows protected by a straw mulch, whereby the soil temperature has been lowered several degrees, have frequently yielded markedly better crops than those plants grown in unmulched soil. This is a hint which the Hawaii potato grower might well take cognizance of.

Moisture is another very important factor in the production of good crops of potatoes. Possibly most of the potato crop failures in Hawaii are due to severe and protracted droughts, especially when the soil is in poor physical condition. Too great stress cannot be placed on the importance of utilizing soils in the best possible tilth, and reasonably high in their humus content, especially wherever the moisture factor is low. On the other hand, excessive rainfall and high humidity have their drawbacks. If the soil is porous and well drained and the crop is grown in ridge culture, the potato will tolerate a large amount of moisture, especially if the weather gets drier toward the period of maturity. High humidity is primarily detrimental in that it is often accompanied by epidemics of late blight and other fungus diseases, to which late-maturing Hawaiian grown potatoes are especially subject. Soil types, especially their physical make-up, influence greatly the shape, size, and smoothness of the tubers. Heavy clay and stony soils are conducive to malformed and rough-skinned tubers. Well aerated free-working loam, sandy soils and silty soils, on the other hand, yield smooth, well shaped tubers of large size. In Hawaii the fine, deep, silty soils typical of the Kula region on Maui and the more tractable of the peaty and muck rice-areas of the lowlands, when well drained are doubtless the best all-around potato soils we have. Heavier soils, if well sup-

plied with organic matter and well drained and tilled, have given excellent results in the hands of skilled Oriental gardeners. Even the medium-coarse, granular, reddish soils of Wahiawa and other plateau regions are capable of yielding excellent crops of potatoes under good management.

SHELTER AGAINST WIND[9]

Heavy winds are very detrimental to the growing potato crop. It is therefore important that this factor be given adequate consideration in locating the potato fields or in choosing the season for growing the main crop.

While naturally protected areas, such as some of our sheltered valleys or the lee of a hill or a cliff, are much to be preferred, much protection may be obtained by planting permanent belts of trees and hedges. When more immediate protection is demanded, two or three rows of the stiff erect growing Uba cane, Merkier, Napier (Elephant grass), or pigeon peas, will give excellent temporary protection. However, since all plant windbreaks sap much fertility and moisture from the ground, it is well to leave field headlands, or locate roadways, say, twelve feet in width, bordering the windbreak. Beyond such a strip the soil is ordinarily not sapped by protecting windbreaks. Windbreaks, even if ten feet high, unfortunately will not protect crops for more than fifty feet and it therefore becomes necessary to plant these temporary hedges every fifty feet. Planting them every twenty-five feet would be better.

The practice of planting permanent belts or groves of tall and hardy trees to the windward, often affords the most practical protection to the more tender field crops planted leeward. Crop-plants as they develop and are massed into compact rows usually afford themselves considerable protection independent of other shelter. Young plants grown in deep furrow culture get considerable protection from the adjacent ridges when these are run at right angles to the prevailing winds.

Whatever the method adopted, the success of the potato crop in windy locations may be primarily dependent upon the control of this one factor.

SOILS, TILLAGE AND SOIL MANAGEMENT

Soil fertility and productiveness depends primarily upon the

[9] Consult Zschokke, "A Manual for Tree Planters in the Hawaiian Islands," Extension Bulletin No. 5, January 1930. Agricultural Extension Service, University of Hawaii.

soil types and how the soils are tilled and managed. Obviously extreme differences in soil types necessitates different methods of management. The end objective in any case is to bring about good soil tilth and make available the inherent fertility, and withal to conserve both the soil and its fertility. To bring this about to the highest degree possible may necessitate much more than merely good tillage. Our low-lying, heavy, clay-like soils typified by many of our rice land areas now becoming available for new cultures, never can be made to produce good crops of potatoes and certain other classes of vegetables unless they are well drained and aerated. On the other hand, our sloping land, often well drained naturally through surface runoff, may possibly need measures to prevent wasteful and destructive erosion.[10]

The first requisite to overcome excessive soil moisture with frequent accompanying stagnation, is to provide adequate drainage. Ordinarily, open drainage ditches are best suited for carrying off excess ground-water as well as surface water under most Hawaiian conditions. Open ditches are therefore recommended for general drainage, notwithstanding certain disadvantages.

The drainage layout should be well planned beforehand, not only to make it as effective as possible but likewise to interfere as little as possible with tillage and cropping.

Having provided against the accumulation of excessive ground-water and surface run-off, it becomes of great importance to plow the land at the right time and in the right way. This is especially true of heavy, compact soils such as abound in our rice growing areas. Such soils are easily injured by tilling when too wet. On the other hand, if worked while too dry the clods are hard to break up. Heavy soils are in the best condition to work when they crumble apart if squeezed in the hand. If the particles stick together and knead, the soil is too wet. Heavy, claylike soils should therefore never be tilled when in a wet state. Fine, silty soils should likewise be handled with care. On the other hand, sandy soils can be properly plowed and tilled notwithstanding a wide range of moisture content. So any soils, to maintain the ideal physical structure, should be handled with utmost care in tillage lest their texture for the season be seriously injured.

There are three extreme physical soil types in Hawaii which may in time be utilized by the potato farmer. One is the heavy,

[10] See Agricultural Extension, University of Hawaii Bulletin No. 11, 1931, "The Problem of Soil Saving in the Hawaiian Islands."

Fig. 6.—Third plowing of heavily manured land with 28-inch reversible disc-plow. No disc harrowing is necessary but colti-packing is beneficial for firming the soil. Cost, $5.00 per acre. New Era Farm.

adobe type, characterized by some of our rice lands, which becomes sticky and smeary when wet. A similar type is represented by the raw, red upland found in the Wahiawa, Haiku and Waimea areas, which while less sticky and more granular, nevertheless become compact and as hard as an impervious subsoil upon drying. These two types of soil can be greatly improved in texture and tilth by incorporating large quantities of coarse, rank vegetable matter to a depth of at least a foot in the surface layer. The coarse-growing pigeon pea makes an excellent crop to supply the necessary humus for such soils. The beneficial effects of this

Fig. 7.—Colti-packing excessively mellow soils.

crop's deep rooting habit will be greatly enhanced by subsoiling and the application of liberal amounts of raw phosphate rock.

The second extreme type of soil is represented by those that are excessively sandy. These especially need humus to give them life and supply binding material. Rank-growing, succulent vegetation such as cowpeas and velvet beans, make excellent green manuring crops for this class of soils. It usually pays to fertilize green-manuring crops liberally with mineral fertilizers such as phosphoric acid and potash, in addition to nitrogen, to stimulate maximum growth. In turning the vegetable matter under, the commercial fertilizer which they have absorbed becomes a revolving fund in being returned to the soil for the benefit of the succeeding potato crop, thus serving a double purpose.

The third type of soils we have in mind are the peculiar, fine, deep, silty, ash-like soils which prevail in the Kula uplands on Maui and at Waiki on Hawaii. These are undoubtedly our very best potato lands, both by virtue of their high inherent fertility and their ideal physical condition, together with the favorable altitude at which they are located. No supplementary treatment is necessary to bring these lands into perfect tilth. However, some attention must be given them to maintain their humus at the optimum. Ordinarily the minimum of tillage will be necessary for preparing the seed bed of these silty soils. Two plowings, at most, and an equal amount of disc harrowing should be ample in most cases. On growth such as pamakani (unless the shrubs

Fig. 8.—Fall plowing of a heavy compacted soil with a 14-inch, two-way, mold-board, sulky plow.

Fig. 9.—Clod mashing a rough, cloddy soil with homemade plank drag.

have been plowed under and need time to decay) even one good plowing may be all that is necessary or even desirable.

On the other hand most of our heavier soils need several plowings, harrowings and clod mashing. The pineapple-planter has found it profitable to plow as many as five times or more. In general it may prove advisable to give many of our potato lands three good plowings and as many harrowings before planting. In any event the soil must be brought into good tilth before the potato seed is put in the ground.

For spring planting, fall plowing in the preceding type of soil is recommended, and for fall planting the ground should be made ready in the spring. Subsoiling and the first regular plowings

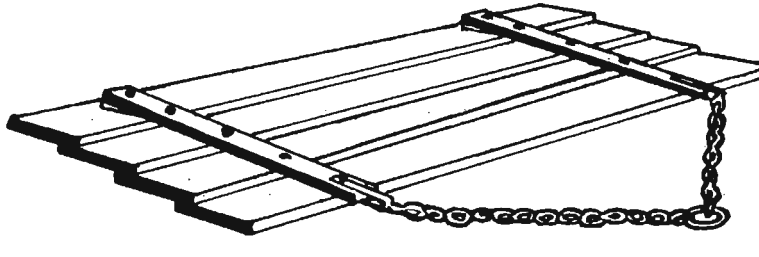

Fig. 10.—A cheap and effective homemade plank drag or "clod masher."

should usually be done a considerable time, a month or two, or even three, before the crop is planted. The resulting improvement in tilth favors nitrification and makes available the otherwise inert, unavailable plant food. Other advantages of getting the ground into condition early in the season, whether fall or spring, is that it often permits a better distribution of labor. Besides, forehandedness prevents the farmer from getting into a jam with his heavy plow work.

If green manure or sod land or weedy growth is to be turned under, it is essential that the turning-under be done well ahead of potato-planting, allowing the vegetable material time to decompose. Early plowing followed by a period of bare fallow is also a method of destroying many insect pests. Fall plowing, and letting the rough plowed land lie exposed to weathering over the winter months, will greatly improve the physical condition and availability of plant food in heavy soils. In wet seasons, especially on sloping land, the danger of erosion can be greatly minimized by plowing the furrows across the slope instead of down hill. A fur-

Fig. 11.—Deep plowing on a hillside to prepare a perfect seed-bed and at the same time conserve the soil against erosion. Use the "two-way reversible" disc plow, running the furrows with the contour of the land. This leaves the sub-surface corrugated and thus assists in holding the soil in place even after it becomes saturated with water. Potato field on New Era Homestead Farm, Haiku, Maui.

ther safeguard against erosion from excessive winter rains is to provide head ditches to carry excess water away from the plowed field. In the spring when the soil is sufficiently dried out it may be leveled with disc harrows, and, if necessary, again plowed and further conditioned for planting.

Since mold-board plows rarely scour in our Hawaiian soils, the disc plow is greatly to be recommended for conditioning the soil at least after the first "breaking." Both mold-board and disc plows are made in a reversible type, whereby hillside plowing is greatly facilitated, in that one may plow going and coming across-slope in place of back furrowing.

Two additional tillage implements may be recommended for use by the potato grower. One is the homemade plank-drag or "clod-masher" to fine and firm the heavier soils; and the land-roiler for firming the extremely light, loose soils such as characterize the deep, silt areas of some of our uplands.

The potato farmer should remember above all things that his crop, to thrive to the utmost, requires a deep, mellow, moist soil, and that it must be well drained and aerated. In addition it must, for a maximum yield, contain ample plant food to meet all demands.

ROTATION AND FERTILIZATION

The potato is a greedy feeder. Vigorous-growing, highly productive crops consume large amounts of plant food in the form of readily available soil nutrients. This is doubtless one of the main reasons why the rich, virgin Kula soils produced such enormous yields of fine potatoes a half century or more ago, when these naturally fertile soils were first brought under cultivation. Unfortunately the farmers who have followed the pioneers failed to realize that soil fertility could not be maintained indefinitely without returning plant food materials to the soil.

For profitable potato culture both rotation and fertilization are of utmost importance. The many and various advantages of a well-planned, systematic rotation are based on the fact that it tends to control such soil-inhabiting disease organisms as cause potato scab and rhizoctonia. Likewise does rotation tend to lessen the various pests that infest the plant. Lastly, the balance of fertility, especially the humus of the soil, is more easily maintained

when a succession of other crops such as corn and beans, are grown in rotation with the potatoes.

The management of soils deficient in organic matter, commonly termed "humus," might well include a suitable green-manuring crop, such as velvet beans, soy beans or cow peas. Of the latter type the so-called Black Eye cow pea [11] used extensively by the Chinese in Hawaii as a sprouted grain under the name "Mit tau," is especially well-suited for use as a cover and green-manuring crop, and has the further advantage of producing usable seed. Considerable seed could be harvested from these crops before turning them under as green manure, thus paying in part the cost of production .

Regarding direct fertilization, most of the research in the nutrition of the potato seems to indicate that calcium (lime) is essential in the *early* development of the plant but this constituent should never be applied to excess as it favors some tuber scab diseases. Phosphorus appears to greatly stimulate general growth and tuber production and is a very essential element to apply in the form of fertilizers, especially in the uplands where this element is usually wanting. The best growth of vegetative parts is usually associated with a high nitrogen supply but excessive nitrogen fertilization causes the potato plant to run to top growth. Since the

[11] Dolichos sesquipedalis

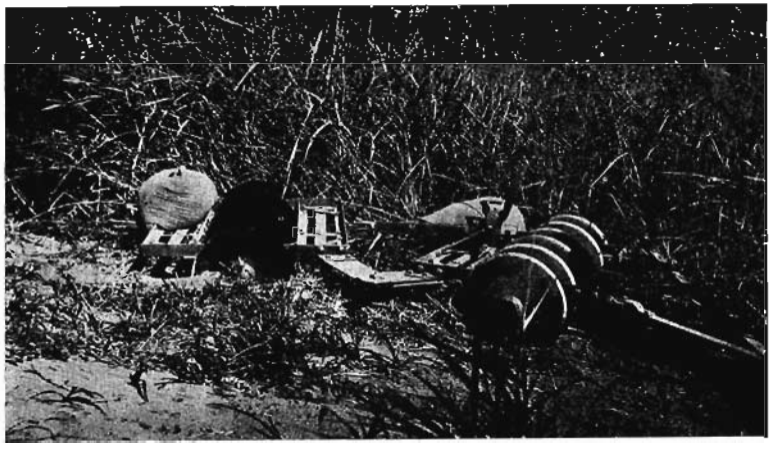

Fig. 12.—Disking down a green-manure crop preliminary to plowing under.

potato removes larger amounts of potash from the soil than do most other plants, one would suppose that this element is especially important, which it doubtless is. Experiments, however, have shown that this element need not be supplied in very large quantities when fertilizing the crop, certainly not in excess of phosphorus. Some forms of potash are found to be toxic to potatoes and it is usually safest to furnish the potash in the sulphate form. The source of nitrogen does not appear to be very important. Since potatoes appear to prefer a slightly acid soil to one with an alkali reaction, the excessive use of nitrate of soda may in time favor scabbiness. It is therefore recommended that the acid forming sulphate of ammonia be tested and compared with treatment by nitrate of soda. Likewise have urea and other synthetic forms of nitrogen given favorable results when used in complete fertilizers. In rainy locations where there is danger from undue leaching, organic nitrogen as found in blood meal, fish meal, and tankage, is to be preferred over the more soluble nitrogen salts. Possibly the best practice in using the concentrated chemical fertilizers is to make up formulas with several forms of nitrogen, phosphorus and potash. We would suggest the following mixture as a good general all-round fertilizer[12]: Nitrogen, 4 per cent, made up of

[12] See methods for conducting fertilizer tests in the section on fertilizer and variety tests page 55.

Fig. 13.—Plowing under a green-manure crop with a disc-plow. New Era Homestead Farm.

dried blood and nitrate of soda, in equal parts. The nitrate of soda can be replaced by either sulphate of ammonia or urea. Phosphoric acid, 12 per cent, half of it acid phosphate and half of it reverted or very finely ground bone. Potash, 8 per cent, in the form of a sulphate. This is termed a complete fertilizer and has the technical formula: 4-12-8, meaning the percentages of the several fertilizer elements contained therein.

Dependent upon the inherent fertility of the soil and or the amount of manure previously applied, we would recommend the use of from 500 to 2000 pounds high grade potato fertilizer per acre applied at time of planting. The cost of such treatments will range from $15.00 to $65.00 per acre. Applying fertilizer in the plant furrow rather than broadcasting is by far the best method under most conditions. Natural manures, however, should, of course, be broadcasted.

Furrow out plant rows immediately preceding the planting. Apply fertilizer in bottom of furrow immediately, then mix and cover with soil by use of five-tooth cultivator set as close as possible. The seed potatoes are planted immediately following the fertilization. If crop needs stimulating during the growing season give light side-dressings of nitrate of soda or sulphate of ammonia, not to exceed 150 pounds per acre.

Potatoes usually respond to stable and barnyard manure, composts, and green manuring. At least ten tons per acre of well decomposed vegetable material should be applied a month or two before planting the crop. Twenty-five and even fifty tons of manure per acre is not an unusual application every other year in old established potato growing sections.

As an aid to maintaining the organic content and a fair balance of fertility in the soil, as well as to control various potato diseases such as common scab, rhizoctonia, early blight and nematodes, a definite system of rotation should be practiced as indicated above. Potatoes should not be grown on the same land oftener than once in three years unless conditions are exceptionally favorable. Potatoes may follow almost any garden crop other than the root crops. The utilization of old alfalfa lands as well as some grass sods gives outstanding results.

IRRIGATION

As has already been pointed out, many potato failures in

Hawaii in the past have been due to excessive drouth at a critical period of the crop's growth. Too arid locations should therefore be avoided unless ample irrigation water is available. With water for irrigation available, crops, excepting in localities especially favored in their moisture supply, will become doubly insured against failure. In ordinary dry seasons in soils fairly retentive of moisture, will be needed to carry the crop through. The best results are obtained when the first irrigation is applied as the tubers first begin to form, rather than earlier or later. On the other hand some experiments go to show that a one-inch-per-week irrigation for from twelve to sixteen weeks has resulted in higher yields than the less frequent irrigations using the same total amount of water. Evidently the season, type of soil and other factors must be all taken into consideration and it would be well for the potato grower to experiment to determine the best method for his particular conditions. Irregular irrigation is harmful in any event.

MULCHING

The mulching of potatoes with rice straw, rice hulls, or dried plant refuse of any kind is worth a trial. Care should be taken that the mulch does not harbor disease spores or noxious weed seeds. As has already been emphasized, potatoes thrive best in a cool, moist climate. During the period from June to September the temperature in the lowlands of Hawaii is too warm for the potato crop. It is to lower the soil temperature and to assist in conserving moisture that a straw mulch is used. Some experiment stations *almost doubled their yields when straw was applied to the depth of about ten inches between the rows soon after the potato tops had emerged from the ground.* Such a layer will amount to about ten tons per acre. Irrigation water if applied in a slow stream is not interferred with nor does it disturb the mulch and there may be a distinct saving in water. Another advantage of mulching is that it saves weeding. These savings should more than offset the cost of the straw and its application.

However, only where straw is at hand in sufficient quantities and at a relatively low cost is it profitably used on a commercial scale, unless there be developed a special trade for fancy "new-early" potatoes, which would justify this extra cost.

Hawaii should aim to develop a special trade in early or

Fig. 14.—Rice straw used for mulching potato fields.

market, garden-grown potatoes supplementing the late or main field-grown crop. The former crop will be produced from late fall and winter plantings, ready for harvest in December, January and February and the latter from spring plantings, ready for harvesting in May and June.

GREEN MANURING

Green manuring as a means to soil amendment in place of barnyard manure should be given serious consideration by the potato farmer. Wherever there is enough land to justify letting a part of it lie unproductive, especially when there is a shortage of manure, it is usually feasible to practice green manuring.

In general a leguminous green-manuring crop is to be preferred over nonleguminous crops because of the added nitrogen supplied.

While the main object of green manuring is to add vegetable matter to the soil to improve its physical condition as well as to add plant food there are other benefits, such as affording a protective cover to the soil against drying winds and scorching sun, and to reduce soil erosion and the leaching of plant food. Likewise does a dense cover crop smother out many of the noxious weeds.

Green manuring when rightly applied is almost certain to increase the subsequent crops with which it enters into rotation.

In general it pays to fertilize leguminous green manuring crops with some form of the phosphates. To get the greatest benefit from green manuring crops they should be turned under at least a month or two before the succeeding crop is planted. For light, sandy soils, only succulent green material should be plowed under to give the maximum binding substance. In heavy soils, on the other hand, more mature vegetation should be incorporated in the soil to separate and loosen the particles.

The following leguminous crops are well adapted to green manuring in both the lowlands and uplands up to 3000 feet elevation: Cowpeas; varieties Brabhan, Whip-o-will and Large Blackeye; Soy beans; O-too-tan, Laredo and Biloxi; Mung bean; Hastings; Velvet beans; Brazilian, Lyon, Black Mauritius and Extra Early Bush. All but the Early Bush variety send out long trailers.

In altitudes above 3000 feet, vetch, lupines and horse beans thrive better than the legumes recommended for the lowlands.

Plant all of the above in drills (rows). If late in the season and the ground is dry, plant in deep furrows.

When the plants have attained their maximum growth they should be turned under with any other crop residue that may be available. If the green manure crops are in seed at time of plowing under many seeds will germinate and produce a valuable volunteer crop thus doubling the organic matter at little or no extra cost.

The yield of vegetable matter from green manuring crops will vary with the variety and season. Ten to thirty tons of green matter per acre per crop or season is the usual yield. A small amount of fertilizer applied at time of planting will often double the yield. Under favorable conditions a good green manuring crop will produce, in from three to five months, vegetable matter equivalent to ten tons of manure and should be of about equal value. The cost should not exceed $25.00 an acre for a crop of green manure.

SEED POTATOES

The importance of good seed stocks, that is, tubers for planting, cannot be overstated. This "seed," (whole tubers or cut pieces used for planting, also called "sets") are, other conditions being favorable, the most important factor for producing banner yields of highest quality, and it is safe to say, that as many

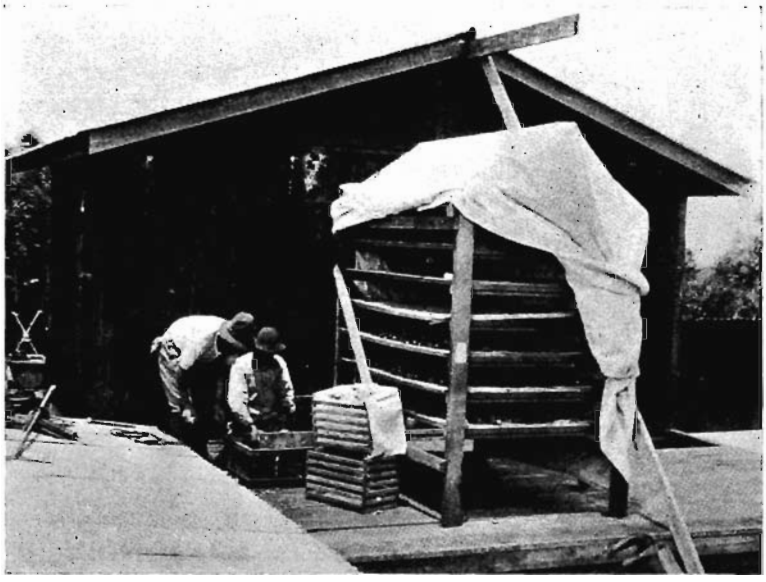

Fig. 15.—Greening and sprouting seed potatoes.

failures in potato growing in Hawaii are due to poor seed or unsuited varieties as to any other one cause.

Some of the principal factors that qualify good seed potatoes are, according to Jones and Rosa [13], (1) the source, in relation to hardiness, vigor and disease infection; (2) tuber shape and type; (3) time and method of cutting; (4) size of tuber; (5) size of set; (6) effect of greening and sprouting; (7) maturity, and (8) degree of dormancy.

Source. Environmental conditions appear to exert a marked influence on the seed and it has generally been found that tubers produced in the cooler climates produce healthier and more vigorous seed than those produced in warmer climates. Potatoes grown at the higher altitudes in Hawaii, as in Kula, Maui, and likewise in the uplands above Hamakua, and at Waimea, Hawaii, have generally given good results when planted in the lowlands. However, owing to lack of inspection for freedom of disease and purity of variety, both of which are insured by government officials in stocks from the Mainland, the beginner in potato culture in Hawaii is urged to purchase his foundation seed stocks from

[13] In charge of the Division of Truck Crops, College of Agriculture, University of California. See "Truck Crop Plants," Chapter XX, Section A., McCraw Hill Company, 1928.

reliable Mainland sources. The seed should be certified as to purity of variety and strain as well as freedom from disease. Such stocks are guaranteed by reputable coast seedsmen. Prices will range from $2.50 to $5.00 per 100 pounds, an outlay that will prove a good investment. Poor seed, of mixed or unknown variety, oversprouted and possibly disease-infested, is dear at any price and should never be planted.

Size of Tubers. While it is rather generally assumed that when tubers are planted whole the yield increases proportionately with the size of seed, it is the writer's experience that medium sized tubers, weighing two to four ounces, other things being equal, are as productive as larger tubers, provided of course their heredity is the same. The same rule appears to apply when cut sets are planted. The important consideration is that the seed or "set" is sound and of good breeding and the conditions favorable for growth. From good, sound seed stocks we have usually secured about 500 sets (seed pieces) per 100 pounds of tubers. This makes the average weight per set slightly over three ounces. Many growers consider it more economical to plant two-ounce pieces and this is the prevalent practice over a wide area of Mainland potato production. While we do not advocate as a general practice the use of very small seed pieces (under 1½ or 2 ounces)

Fig. 16.—Cutting potato-sets by hand. Mechanical seed-cutters greatly reduce the labor of this time-consuming job.

or very close planting (12"x24"), experience indicates that the largest, though not necessarily the most profitable, yields are produced by the use of this intensive method. Granting that the use of large amounts of seed per acre with the view to obtaining the maximum yield may be most profitable at times, we prefer medium quantities (1000 pounds per acre), planting medium sized pieces (2 to 3 ounces) rather than very small or extra large sets in large quantities. The cost of seed at time of planting as well as the prospective selling price of the crop largely determines the amount of seed that may be planted profitably. Under favorable growing conditions, on high priced land and when prices for the product are high, close planting with the view to obtaining a maximum yield may be advisable. The average amount of seed planted on the Mainland is around 600 pounds per acre. The writer recommends planting 1000 pounds per acre under the usual Hawaiian conditions. In his own practice when all conditions were most favorable he has planted up to a ton of seed per acre, but this latter amount is very rarely called for anywhere, certainly not in extensive field culture.

Conditioning Tubers for Seed. Seed potatoes should be fully matured in the ground and "cured" in the bin for a month or two before they are greened and sprouted. Spread the tubers when

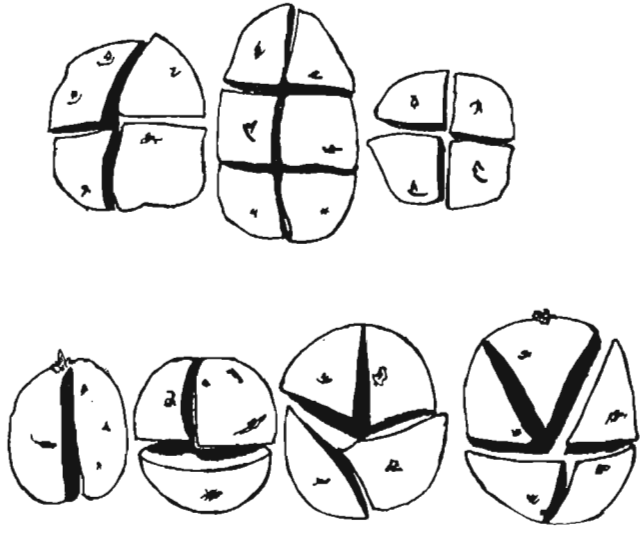

Fig. 17.—Diagram showing how to cut potatoes into seed-pieces.

"cured and rested" in thin layers or preferably in a single layer on dry ground or in flats, either indoors or out of doors as circumstances warrant. Light is necessary to develop chlorophyll (green coloring matter), in the cortex, and to encourage the development of short, stocky sprouts from the "eyes." The reason why the sprouts of tubers stored in bags or in the dark are white and spindly is because they have been deprived of light. Such stocks are unfit for seed or at best are of inferior quality. Much of Hawaii's failures in potato production in the past have been due to poor conditioning of the seed. Before planting see that the seed is sound, free from disease, well matured and ripened and properly greened or at least sprouted. When the sprouts are from ⅛ to ¼ inch long is the best time for planting.

Dormancy. The normal period of dormancy in most varieties of potatoes appears to be from two to four months, during which period most tubers do not sprout, repardless of treatment. Since it is sometimes desirable to either hasten or retard sprouting it may be well to know that cold storage at temperature below forty degress F. will hold back germination, while temperature of 50° to 60° F., and over, will stimulate sprouting.

Jones and Rosa quote Denny (1926) as reporting striking stimulation of growth by the treatment of dormant tubers with ethylene chlorhydrin, ethylene dichloride, potassium thiocyanate, and other compounds. Probably the most practicable means for breaking the dormancy of tubers preparatory to planting is to expose them to the fumes of ethylene chlorlydrin for 24 hours. One-half of one cubic centimeter of the 40 per cent aqueous solution is recommended per liter of the fumigation chamber. This process should prove useful to Kula potato planters, who have found difficulty in germinating some of their seed, and to others who desire to plant at off seasons when prices are likely to be high.

"Green sprouting" or "light sprouting" seed potatoes before planting is a common practice wherever potatoes are grown. The most successful potato growers at Kula on Maui practice this method. The practice rose from the fact that seed potatoes keep poorly in long storage, and because "greened" seed is superior to seed which has been sprouted in the dark with its consequent wilting of tubers. The advantages of greening are variously stated to be (1) that the process is a "germination" test for tubers that have weak sprouts at the time of cutting and are thus easily culled out; (2) that the short, compact green sprouts which result from exposure to light are less easily injured and appear above ground much more uniformly than do the sprouts developed in darkness;

(3) that light sprouted or "greened" seed almost invariably produced larger and more uniform stands, especially in the heavier soils, and lastly, and most important (4) that this method enables the grower to carry over his seed longer for later planting, which is likely to become a necessity in Hawaii if we should seek to grow winter and early spring crops of new potatoes for a special market. It will be worth while for Hawaiian potato growers to test the comparative value of stored against greened seed potatoes under their own conditions.

The best method of greening seed potatoes intended for late fall or winter planting is to select the best spring or summer crop of tubers, or those which, though of good quality, bring the lowest market price and store them in dark storage as long as feasible, say until July to September, and then expose them gradually to full light for from three to six weeks before planting. The tubers may also be exposed to subdued light, in a cool place, from the time they are harvested until almost ready for planting, and then exposed to full light for a short period to harden off the sprouts. Some Kula farmers spread their seed potatoes under wide spreading trees after harvest where they remain until planting time. This method appears to be well suited for small tubers. We consider a cool lath house which gives partial but uniform shade the better protection. Exposure to cool nights and showers appears not to be detrimental to the greening of seed potatoes.

Seed potatoes exposed to strong but indirect sunlight develop short, tough, green sprouts that are not easily rubbed off or injured in handling and emerge from the soil sooner than sprouts from dormant seed. Wholly dormant seed should not be planted as a general rule.

In any event every effort should be made to avoid the development of long, spindly, tender sprouts and wilted or shrivelled tubers.

Whatever the process of sprouting, the tubers should be spread thinly, to a single thickness if possible. Then when they become ready for planting select those most advanced to be planted first. *It pays to re-sort the seed at planting time,* utilizing only well shaped, sound, disease-free viril tubers. Each seed piece should contain one or two healthy eyes or sprouts. Seed pieces or whole tubers may range from 1½ to 3 ounces in weight. The seed should be planted soon after it is cut. If to be held over for a day or two dust the cut surface with powdered sulphur. Read especially the section on potato diseases and pest control, pages 59 to 73.

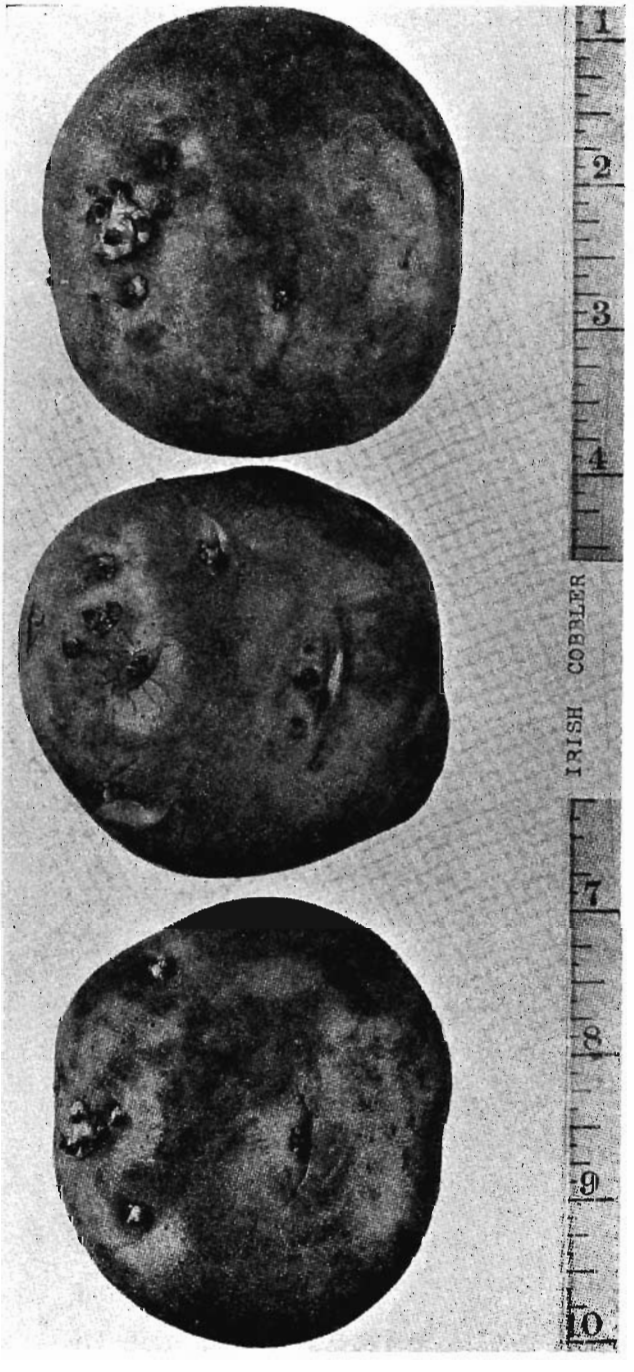

Fig. 18.—"Three Graces" in the potato family, Irish Cobbler variety. A desirable type over a large section of the Mainland and ideal seed size. After Plate III, Bulletin 176, U. S. Department of Agriculture

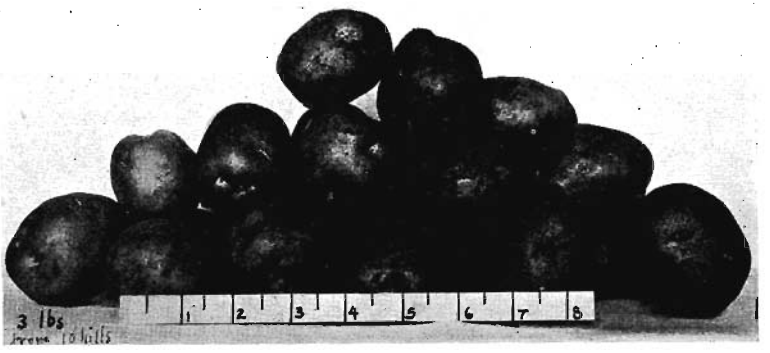

Fig. 19.—Fancy early "new potatoes," Irish Cobbler variety, produced on Oahu. The yield was at the rate of about 5,225 pounds (52 sacks) per acre. While the yield was small, the price was high.

CHOICE OF VARIETIES

Suitability of varieties and strains both in regard to cultural adaptability and market requirements are among the most important factors in the success of commercial potato production.

If the market is critical as to type of tuber and season of availability, select those several varieties that best meet the market requirements. Then make comprehensive comparative cultural tests to determine which of them is best suited to the cultural conditions under which the crop must be grown. If on the other hand, the market is not particular as to type and variety, so long as the culinary qualities are good, the grower will be fortunate in having a wider range of varieties to select from. The one he finally chooses will naturally be the one he finds most prolific and profitable.

In old potato-growing regions varietal adaptations are usually well established. When this is the case it is best not to attempt any radical change, unless of course one is certain of a definite improvement in some new type or variety. Hawaii, however, has yet to determine the "best" varieties for her manifold cultural conditions and to some extent her markets, which in the past, have been less critical than many of the Mainland markets.

If our abandoned lowland rice areas become important potato growing sections, as seems possible, there will doubtless be developed quite distinct varieties from those that thrive best in the fine silty uplands such as the Kula, Maui, district. Again if there should develop a large demand for "new" or "early" potatoes, the

varieties chosen might differ from those employed in the main crop.

The only way to determine the *best* varieties to grow under a certain set of conditions is to apply comparative varietal and cultural tests extending over a period of years, and to place the results on the market for the approval or disapproval of the consuming public. Obviously, wherever a distinct market type is already established and in demand, the grower will endeavour to supply that demand, since the choice of variety must be governed by its adaptability to the market as well as to its cultural environment.

Fig. 20.—A random hill of potatoes weighing 3 pounds harvested at Ulupalakua, Maui, July 14, 1931. The crop from which this hill was dug should yield 150 sacks per acre.

The leading commercial varieties of potatoes are few in number compared to the extended list of varieties catalogued. The following list includes those considered by the authorities to be the best of the strictly commercial varieties of potatoes grown on the Pacific Coast. All of these varieties have been grown by the author, whose comments and recommendations for trial follow:

EARLY VARIETIES

American Wonder. Elongated, slightly compressed, large size and uniform in shape. Eyes few and flush with surface. Skin white, of excellent quality. Matures in about 100 days from planting. One of the best varieties grown at Haiku. Recommended for trial.

Earliest of All. Roundish, flattened shape, smooth, eyes few and shallow, white skin and flesh. Tubers bunched close in hill, large percentage of tubers salable because of uniformity. Easily dug. One of the best quality and most heavily yielding potatoes grown at New Era Homestead Farms.

Early White Rose. Resembles somewhat Burbank in appearance but is much earlier and better adapted to most Hawaiian conditions. Has few eyes and a smooth skin. A very excellent variety for the market gardener and produces good yields under favorable conditions. Especially suited for "new, early" potatoes. Recommended for trial by all Hawaii potato growers.

Irish Cobbler. Roundish, smooth, skin creamy white, of best quality and an excellent producer. Recommended for trial.

In addition to the above four superior early white skinned varieties, the following three early pinkish and red skinned varieties have succeeded well in Hawaii but are not in present market demand because of color.

Early Rose. Slightly elongated, medium size, fairly smooth, pinkish skin of fine quality and fairly prolific.

Garnet Chili. Irregular, roundish form, deep eyes, red skin, white flesh. Of excellent quality and yields well.

Triumph (Bliss'). Roundish, solid, red skin, of good quality and a good yielding variety. An old standard sort which all potato growers should test.

MEDIUM AND LATE VARIETIES

Burbank. Long, cylindrical, white tubers of best quality and heavy yielding when not attacked by blight. The old standard California variety.

Burbank Russet. Similar to above but deeply netted and russeted, an excellent potato in every way.

Burbank Low Top. Similar to the original Burbank Seedling except that tops are somewhat dwarfed and less rank. Considered the best of the Burbank type for most Hawaiian conditions.

British Queen. Oval shape, cream white skin and white flesh somewhat earlier than the Burbanks, but said to be inferior in quality. Yields well under favorable conditions. Extensively imported into Hawaii. All things considered, probably the best variety for the average planter to grow until he has tested out other varieties.

Yamato or Hamakua Hybrid No. 4. An elongated, cylindrical tuber the result of a cross between Burbank and the Portuguese Purple Potato, resembles the Burbank in form but the cream ground is often blotched with red. Fairly blight-resistant. Especially suited for heavy soils and rainy districts.

The above twelve varieties have been grown successfully at Haiku, Maui, and some of them in Kula. After some seven years personal experience, the writer unhesitatingly recommends the earlier maturing varieties in preference to late maturing sorts.

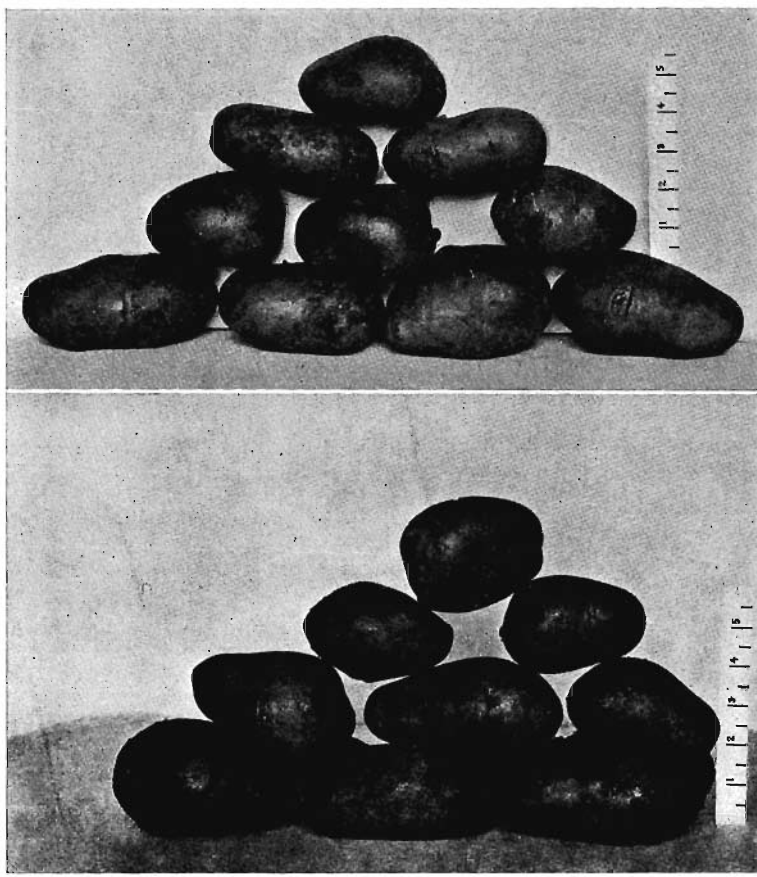

Fig. 21.—Two random hills of potatoes from reclaimed rice-lands at Lumahai, Hanalei district, Kauai, yielding at the rate of over 100 bags per acre. Messrs. Thompson and Lund report on this crop as follows: "This group of rice growers produced about five tons of the finest Brittish Queen potatoes we have ever seen in the Territory. They were produced in crop-rotation with rice. The potato crop brought $3.00 per 100 pounds in the Lihue and Honolulu markets."

Late sorts, such as the Burbanks, are frequently attacked by late blight and the crop yield as well as quality have suffered severely even though sprayed.

All of the early varieties listed above are worthy of trial and the progressive potato grower would do well to make comparative tests to determine cultural adaptability and market acceptability of as many varieties as he can handle successfully.

Of the medium or late varieties we would recommend first British or Hyde's Queen and, second, Burbank Low Top. Where late blight is prevalent and the market requirements not too exacting, the Yamato or Hamakua Hybrid No. 4 is recommended for trial.

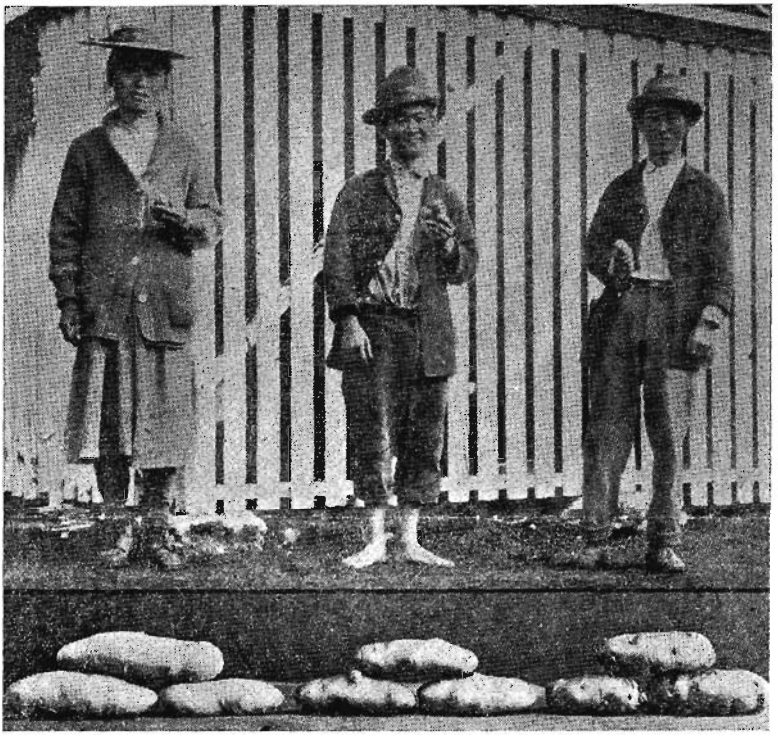

Fig. 22.—Yamato family of Hamakua, originators of the "Hamakua Hybrid" potato. Note the potatoes below. On the left is the "Burbank" and on the right the "Portuguese Purple," which varieties were crossed to combine the appearance of the "Burbank" with the wilt resisting qualities of the "Portuguese Purple" to produce the "Yamato Hybrid No. 4," shown in the center. *(Reproduction of photo published by the Advertiser Publishing Co. September 14, 1920, for the Extension Division of the U. S. Experiment Station, Honolulu, Hawaii.)*

Record Yields. Burbank Low Top has held the world's record for yield in large-area, commercial planting. Mr. Fred Rindge, owner of Rindge Island Farm in the Stockton Delta, California, produced in 1925 an average of 562 sacks per acre. One acre yielded 577½ sacks! Hawaiian growers should aim to grow an average, one year with another, of not less than 100 sacks (166 bushels or 10,000 lbs.) U. S. No. 1 grade per acre. The best commercially grown yield at Haiku Homestead Farm was 240 bushels (14,400 lbs.) or 144 sacks per acre. The Kula and Makawao regions of Maui have done equally well on more extended areas.

Fig. 23.—Product of one hill, 4 pounds of Netted Gem potatoes, grown by George Mundon at Hoolehua on the Island of Molokai, July, 1931.

Every prospective potato grower should plan a comprehensive potato test. This would involve planting at least one-tenth of an acre to each of several varieties. Foundation seed stocks should be prime and certified as to purity and freedom of disease. Seed pieces should be of approximately the same size. The soil should be uniform in fertility and tilth and the seed of all the varieties under test should be planted at the same time and cared for alike. Much value would be added to such a test if half the field were fertilized to determine the value of this added treatment. (See section on fertilization and plot experiments, page 56.)

The progressive potato grower will study carefully the market requirements. Whenever an especially fine shipment of potatoes is received from the Coast, or elsewhere, it might be well to purchase a sack for trial planting. Always treat a new lot of seed

potatoes with disinfectant before planting to avoid the risk of introducing new diseases.

PRODUCTION OF HIGH GRADE SEED POTATOES [14]

Until potato growers in Hawaii can demonstrate their ability to grow uniformly high-grade seed stocks, year after year, which means the production of pure strains of disease-free stocks of good size and shape, there is little hope for the development of a local certified seed potato industry. However, should the potato industry grow as it should, there is no reason why the best potato farmers should not develop superior strains which would be in high demand for seed purposes. Such a business may become highly profitable and a real benefit to the community at large.

Fig. 24.—Row-breeding of seed-potatoes. New Era Homestead Farm.

The first requisite for embarking in the seed-potato business is to have available a favorable locality as to soil and climate. The second step is to start off with the best obtainable strains of one or more standard market varieties. The third step is to practice good farming methods for the production of well developed seed

[14] This chapter is largely compiled from Wm. Stuart's excellent treatise entitled, "Seed Potatoes and How to Produce Them," U. S. Department of Agriculture, Farmers Bulletin No. 1332, to which the reader is referred.

stocks which must be free from disease and insect pests, especially such pests as infest the tubers. Lastly, the seed stocks must be carefully handled and made available when the farmr is ready for planting.

The methods for improving a variety or strain through breeding are as follows:

Tuber-Unit Method. This consists of selecting from the seed-potato bin a considerable number of the most perfectly shaped tubers, averaging, say, 8 ounces each. Each tuber is quartered into four as nearly equal parts as possible, by splitting the bud-eye cluster twice from seed to stem end of the tuber (see figure 17). The four pieces of each tuber are dropped consecutively in the row at 15 or 18 inches apart in the furrow. Skip one "hill" and plant the next tuber pieces, and so on until the planting is completed. This definitely isolates the plants grown from each tuber. It enables the grower to detect weak strains and mixtures which are then readily "rogued," retaining only the strong, vigorous, pure strain types.

From each of the selected units, ten of the best tubers may be retained for the next season's planting. The following season's crop, derived from the selected stock, should at least quadruple the previous season's selections, and so on until ample stocks of a superior strain has been developed. The progeny of each selection should be kept by itself and the data covering yield, etc., carefully recorded for future reference.

Hill Selection Method. This consists of marking the most promising plants in a good field of commercially grown potatoes during the growing season and finally at harvest time, saving only those which are most outstanding throughout the season. The progeny of each hill should be kept separate and a complete record of performance kept. Plant the various progenies on the tuber-unit or progeny-row basis during the following season. After final selections are made, the multiplication of seed stocks is rapid, the increase varying from ten to twentyfold, so that a second or third year's selection yielding, say, five bushels of select seed, may increase in one more year to 50 or 100 bushels. Such seed stocks should be worth from $2 to $3 per bushel for foundation stock. Superior new varieties or strains are occasionally developed through "sports" or mutations.

Mass Selection Method. This differs from hill selection in that the tubers from the individually selected plants are not kept separate. This practice, while not nearly as intensive as the separate

Fig. 25.—Breeding seed-potatoes by the tuber unit, individual hill method. New Era Homestead Farm.

hill selection progeny method, is nevertheless a great improvement over no selection at all, or even mere field roguing as generally practiced.

Field Roguing. This has for its object the elimination of all diseased, weak, off-type and varietal mixture plants during the growing season. If carefully done such roguing will greatly improve the quality of an otherwise inferior potato population. In this field-roguing method no further attempt is made to select the progeny of superior individual plants at harvest time, the whole crop being dug and all desirable seed stock being gathered and stored in bulk.

Strain Testing. This involves the securing of as many as possible desirable lots of seed stock of the same variety from different growers for comparative testing under as uniform cultural conditions as possible. Experimental studies of this kind often reveal the fact that some strains of seed stock are far superior to others. *Differences in yield of tubers exceeding 100 bushels per acre have been noted between the lowest and highest yielding strains.* This last statement, if no other, should convince every potato grower of the importance of securing the best possible foundation stock when he starts out on his potato-growing enterprise. To know the most reliable sources of seed is indeed valuable knowledge.

And such knowledge should greatly encourage the prospective seed potato grower to give his best effort to attaining a high standing in his business.

PLANTING AND CULTIVATING

As Hawaii develops its potato industry two distinct planting seasons are likely to develop. The spring or main-crop planting season will begin as soon as weather and soil conditions will permit, say, in February, March and April, depending on altitude and exposure, which will be followed by a late fall crop for supplying a more limited market with fancy "early" or "new" potatoes, which may in time develop into an export trade of considerable importance. This late planting-season may range from October to December. Only specially favored localities are likely to profit in this late season production. For the earlier fall plantings, cool, moist localities must be selected, while for the late fall and winter plantings, well sheltered localities, not excessively wet and having warm, well drained soils should be favored.

Fig. 26.—Marking and furrowing potato-rows for wide-spaced flat culture.

To determine the best time for planting, the grower must study his season and markets. In favorable locations or in mild seasons it is well to plant as early as possible. In any event the seed-bed

must be in good tilth and the seed in proper condition for planting. This takes careful planning and considerable experience, especially when carried out on a large commercial scale. Early crops, other things being equal, usually bring the best prices and are most profitable. The growers who can beat the imported shipments to market are much more likely to get good prices than those who harvest their crops when heavy shipments come in from abroad. Furthermore, the potato crop does poorly during our summer months so that late summer crops are to be avoided in all but exceptionally favorable localities. Few or no plantings should be made after May first, excepting at the higher altitudes, as in the Kula district on Maui, or about Waiki on Hawaii.

Plant Spacing. Large yields of marketable tubers are possible only from a good stand of sound potatoes, properly spaced. Soils of high fertility and optimum moisture content will support a closer stand of plants than soils low in fertility and moisture. The table at the end of this chapter gives the number of hills per acre for various spacings from ten inches to three feet.

Although both drill-row and check-row systems are in general use on the Mainland, furrow-row planting as generally practiced in Hawaii is recommended. Under favorable soil and climatic conditions we recommend spacing the rows 30 inches apart and dropping the seed 12 to 15 inches apart in the row. This will give 17424 and 13939 hills per acre respectively (see table at end of chapter). Should the farmer get an average of one pound of marketable potatoes per hill in a 90 per cent stand, the lowest efficiency that any commercial potato grower can afford to tolerate, the respective yields would be 15,681 pounds (261 bushels) and 12,545 pounds (209 bushels). On this basis even at the comparatively low price of $1.50 per hundred pounds the gross income would range at from $187. to $234. per acre. The well-established and experienced potato grower in Hawaii should not only equal, but in a period of years should surpass the estimates given. While yields of less than 100 bags (165 bushels) per acre are the rule in Hawaii, any farmer who cannot attain this moderate yield with a year's experience, or two, should assail some other branch of agriculture. Estimated costs of production are given in the section that follows which it would be well to study before embarking on an extensive scale of potato growing.

Planting. Seed potatoes (sets) may be planted by hand or by mechanical planters. The latter are of two types, the automatic or one-man planter, and the two-man, non-automatic planter. Both have their advantages and disadvantages. The main advantage of

Fig. 27.—A two-row planter.

the former is that it saves the labor of one man. For plantings exceeding ten acres a one-row, two horse, one-man automatic planter with fertilizer attachment costing around $100 should prove a good investment. For large areas, say, fifty or more acres, a two-row automatic planter costing around $200 would probably prove more economical than the one-row machine.

Hand planting is slow and tedious but the beginner cannot afford to buy expensive equipment until he has learned the rudiments of sound cultural methods.

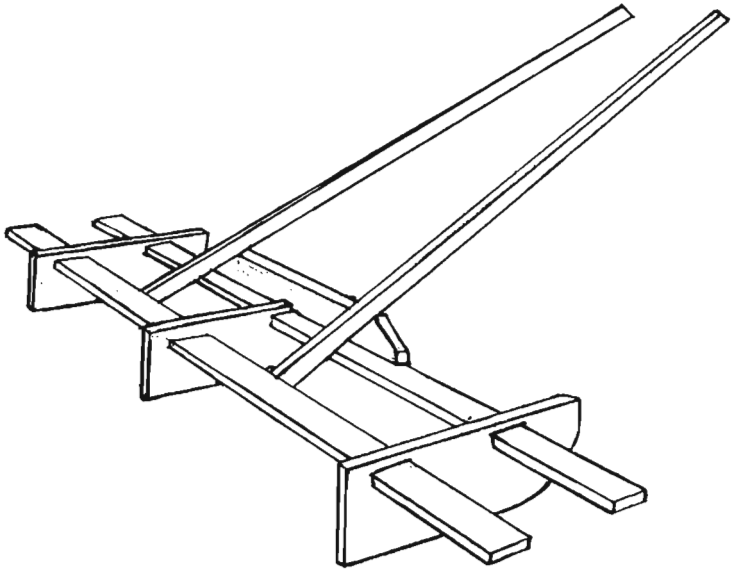

Fig. 28.—Homemade adjustable sled marker.

After the land has been brought to a good tilth and planked in order to level and smooth the surface of the ground, line off the rows with a sled marker (see Fig. 28). Next furrow out the rows with a ten or twelve-inch single or double mould-board plow. The seed is dropped in the bottom of the furrow at proper distances and then covered to a depth of about four inches. In heavy soils cover somewhat less and in very light soils somewhat more deeply, the range of planting depth being three to six inches depending on soil and moisture conditions. Hand planted seed may be covered by means of a hoe or by plowing a furrow from either or both sides of the planted row. The former is the better method if the soil is overly moist, the use of the plow is to be favored if the soil is in ideal tilth and the area extensive. If one horse is used for covering the seed use an offset clevis on the plow beam to enable the horse to walk alongside of the planted furrow. If two horses are driven, use a wide double-tree to enable the team to straddle the row.

In light soils after the entire planting is completed run over the field with a light plank drag to firm and smooth off the surface of the ground. This leaves the job in the best possible shape. When a machine planter is used all the planting operations including covering the seed is done automatically. It is a fine sight to see an acre of well planted potato-vines appear above ground and develop apace. One such experience will prevent even a poor farmer from being satisfied with sloppy workmanship ever after.

Should the surface of the ground become encrusted through untimely rains and should undue weed growth develop while the plants are still young, it is a good practice to run over the ground with a riding mulcher and surface cultivator. This implement has long, springy teeth like those of a horse-drawn hay-rake.

Horse cultivation should begin as soon as possible after the potato plants begin to show above ground. For this purpose there is no better implement than the one-horse, twelve-tooth, combined harrow, cultivator and pulverizer. As the plants become larger substitute the one-horse, plain, five-tooth cultivator and cultivate more deeply. Subsequent cultivations, say, at two-week intervals, should each be more shallow than the preceding. Continued deep cultivation close to the plants will destroy many of the essential plant roots, to the great detriment of the crop. The last cultivations should be just before the potatoes show full flower.

TABULATION

Showing the number of hills or plants on an acre of land, for each planting interval from 10 inches to 3 feet
(After Waring.)

Distance	10 in.	12 in.	15 in.	18 in.	20 in.	2 ft.	2½ ft.	3 ft.
10 in.	62726							
12 in.	52272	43560						
15 in.	41817	34848	27878					
18 in.	34848	29040	23232	19360				
20 in.	31363	26136	20908	17424	15681			
2 ft.	26136	21780	17424	14520	13068	10890		
2½ ft.	20908	17424	13939	11616	10454	8712	6969	
3 ft.	17424	14520	11616	9680	8712	7260	5808	4840

At this time a low ridge should be thrown toward the plants, care being taken not to form too high a ridge which might cause the soil to dry out unduly and result in a decrease in yield. Skillful and adequate horse cultivation saves expensive hand hoeing. One hand hoeing, to get at the weeds close to the plants where the cultivator cannot reach, should be ample in most seasons.

HARVESTING

The potato continues to develop until the vines are practically dead, and to insure "keeping" qualities it is best to defer harvesting the crop until the mature stage is reached. However, to obtain the better prices usually brought by "new, early" potatoes the crop may be dug while the tubers are still young and "green". From the standpoint of yield and keeping qualities, however, the main crop should not be harvested until the vines are entirely dead. Experiments have shown that from the blossoming period to complete maturity, the daily increase in yield per acre under good growing conditions may range from five to ten bushels. *Therefore, only when early market prices are sufficiently high to outbalance the sacrifice in yield and poor keeping qualities is it advisable to dig the crop before it is fully mature.*

Fig. 29.—A fine stand of potatoes in the Makawao district, East Maui. Rainfall, 40 inches per annum. Yield 130 sacks per acre.

Methods of digging the potato crop may vary from the use of the potato form, the tined potato hoe, the common hoe or shovel and "the use of the hands," to use of the modern mechanical horse-drawn or tractor-drawn digger.

Old settlers of the Makawao and Kula districts on Maui have told the writer of the culture of the big white tubers in the deep, mellow, silty soils that prevailed at the higher level. The tubers were universally dug by hand, but not in an ordinary primitive manner, but most "scientifically", since as the plants approached maturity the farmer would work his hand in under the growing vine and through his experienced sense of touch, select, and pluck the largest tubers. This was a sort of "milking" of the potato vine. This process was repeated over and over until the vine died, when the remainder of the crop was harvested, also wholly by hand.

It is a far call from the unique "Haleakala method" of harvesting potatoes to our modern two and four horse mechanical digger and picker, which digs and delivers the potato either in crates on the digger platform or dumps them in piles windrowed crosswise of the field, the vines being deposited to the rear of the machine out of the way.

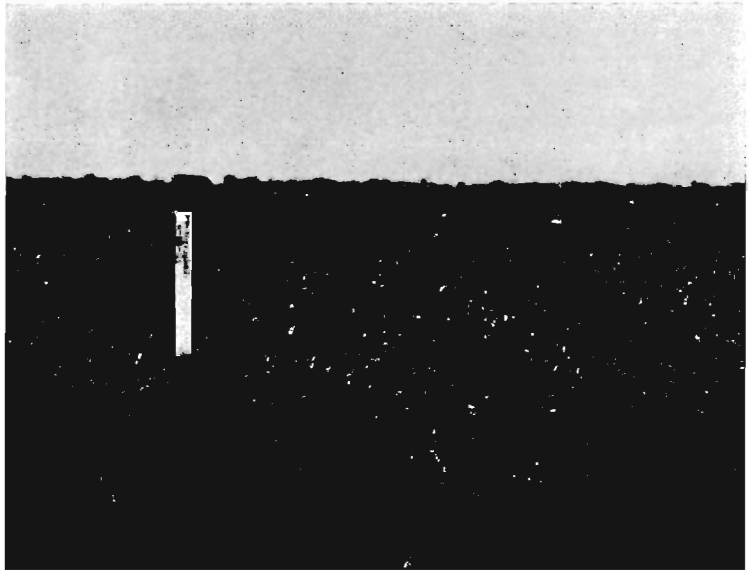

Fig. 30.—An average potato field, plants spaced 18 inches by 30 inches, giving 11,616 hills per acre, Makawao, Maui. Yields 100 sacks per acre.

A satisfactory potato digger with rear shaker and vine separator which delivers the tubers in a compact row, thus greatly reducing the labor of picking up, can be purchased for slightly more than $100.00. Where ten acres or more are planted to potatoes every year such a labor saving implement will prove a good investment. The next best type of implement for harvesting potatoes is the two-horse shovel-plow-like shaker potato digger. These are simple, effective and of low cost. Lastly, an ordinary two-horse, turning (mold-board) plow may be used to advantage over hand digging.

Fig. 31.—A two-row potato digger and shaker which leaves the potatoes in rows.

If possible the potatoes should be dug at a time when the soil is reasonably dry. Unless the sun is too severe, the tubers may be exposed to full rays for an hour or two to harden the skin, also causing the moist, adhering soil particles to dry and fall way. Badly soiled potatoes may be washed, a growing practice among California growers.

Great care should be taken in harvesting the crop to prevent sun scald, bruises and other mechanical injury. Careless handling of newly dug potatoes is responsible for large avoidable losses. The slatted bushel crate is probably the best storage container and is especially recommended for temporary storage of potatoes dug in wet weather.

Gathering potatoes in the field is facilitated by the use of wire picking baskets such as shown in the accompanying illus-

tration (see Fig. 32). Such baskets can also be used to advantage for dipping seed potatoes in disinfecting solution, or to souse potatoes for washing.

If graded in the field, potatoes may be bagged where grown and delivered directly to shipping point without supplementary handling, thus saving considerable expense for extra hauling and storage.

Fig. 32.—Electric welded wire potato picking and dipping basket.

Much of Hawaii's success as a potato producer will depend upon the quality and grading of its product.

Potatoes carefully graded to size and quality command a better price and are much more easily marketed than ungraded stock. Market quality requirements should be studied and every effort should be made to meet the wants of the best trade. The most efficient way to increase the demand for potatoes is to improve the market quality.

The use of certified seed has done much, not only to increase yields but to improve the uniformity of the tubers, thus greatly lessening the amount of grading necessary and reducing the number of culls to the minimum.

Hand-grading like hand-digging is no longer practiced by the progressive potato grower. For the small grower an automatic

Fig. 33.—Field of Hamakua (Yamato hybrid) potato grown near Glenwood on the Island of Hawaii on old tree fern lands. Rainfall, 120 inches per annum.

man-power grader costing around $50.00 will grade potatoes (and onions) to conform to government grades or to meet requirements of any local market at the rate of 150 bushels (the product of an acre) per hour. Larger power graders costing $100.00 will grade up to 500 bushels per hour.

If a large central grading and bagging plant should result from cooperative handling a modern conveyor system will greatly facilitate the work of handling.

Further consideration of the important factor of grading appears below in the section on standards, grading and marketing, by A. S. T. Lund, Extension Agent for Farm Management and Marketing. Also see Bulletin No. 13, "A Guide to Cooperative Organization in Hawaii."

STORAGE

While in general it may be best for most growers to dispose of their potato crop immediately upon harvest, occasions may arise when it becomes desirable to place part of the crop in storage.

It is poor business to unload potatoes on a glutted market, especially when storage for a few months may help to stabilize prices.

The essentials of good storage are:

(1) Clean, dry, sound, mature tubers to begin with. Immature tubers with thin, tender skin, shrink rapidly during the early storage period, ranging up to ten per cent. Well matured potatoes may shrink less than half that amount. The average shrinkage of potatoes over a three months' period is said to be about five per cent.

(2) Potato tubers can be kept best and longest when the temperature can be maintained between 40 and 50 degrees F. At higher temperatures respiration is increased and sprouting is likely to take place. When humidity is too low shrinkage is increased. When too high, conditions are more favorable for the development of organisms which cause decay. *Ventilation is the most important means for regulating both temperature and humidity.*

(3) The ordinary cellar provides poor storage for potatoes. If an outdoor cellar is not available it is possible to store potatoes in a temporary pit. Storage pits should be dug in a well drained locality. Dig the pit three or four feet deep and of equal or greater width. Place a six-inch layer of straw at the bottom and along the sides of the pit to keep the potatoes from coming into direct contact with the soil. After the potatoes are placed in the pit and the pile rounded off evenly cover with a generous layer of straw and then cover with soil to the depth of eight to twelve inches. Ample ventilation should be provided.

Farmers who intend growing potatoes extensively would do well to provide adequate storage cellars. But experimental storage should be carried on for a year or two before extensive storage is undertaken.[15]

STANDARDS, GRADES AND MARKETING[16]

After the potatoes have been planted, cultivated and harvested,

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[15] See "Potato Storage and Storage Houses." U. S. Department of Agriculture, Farmers' Bulletin No. 847, for valuable pointers on storage and storage structures.

[16] Contributed by A. S. T. Lund, Farm Management and Marketing Agent, Agricultural Extension Service, University of Hawaii.

only the first half of the production-marketing program has been accomplished. The potatoes must still be sold. The marketing of potatoes is not an easy task, but chances may be greatly improved if every farmer would standardize his product. By standardizing we mean two things. First, the farmer must determine which is the best variety or varieties of potatoes for his locality. No attempt should be made to grow varieties which are known to be poor producers. Secondly, the farmers should standardize on quality and should follow regulations in digging, handling, assorting, sizing and packing into uniform crates.

Standardization is necessary if one expects the highest price for his potatoes. The wholesale merchant and jobber of Honolulu must of necessity handle potatoes on a very narrow margin,

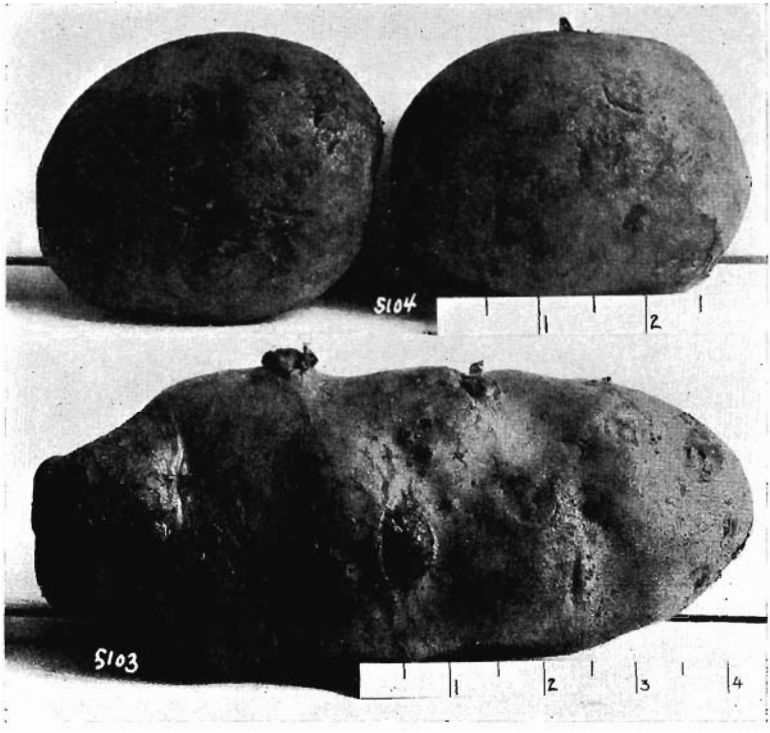

Fig. 34.—Imported "spuds," graded as U. S. No. 1. The two upper are "British Queen," weighing ½ pound each. The lower one is a large "Shafter," weighing 1½ pounds. Such stock sold for around $2.00 per hundred pounds wholesale at mid-season. (Low price period 1931)

consequently he must have a uniform grade of potatoes, free from injury and rot, that can be moved without a loss.

Potatoes are sold by grades in Honolulu. The grades used are the U. S. Grades and Standards of the Bureau of Economics, U. S. Department of Agriculture. The establishment of standard potato grades is an outcome of the world war. At the present time we have four standard grades of potatoes: U. S. Fancy No. 1; U. S. No. 1; U. S. No. 1 Small, and U. S. No. 2.[17] In addition to the above we have in the Honolulu trade another grade known as "75% combination," meaning that seventy-five per cent of the potatoes in the lot must be of U. S. No. 1 grade and the remain-

[17]For further information regarding U. S. Grades and Standards, write to the Marketing Specialist, Agricultural Extension Service, University of Hawaii.

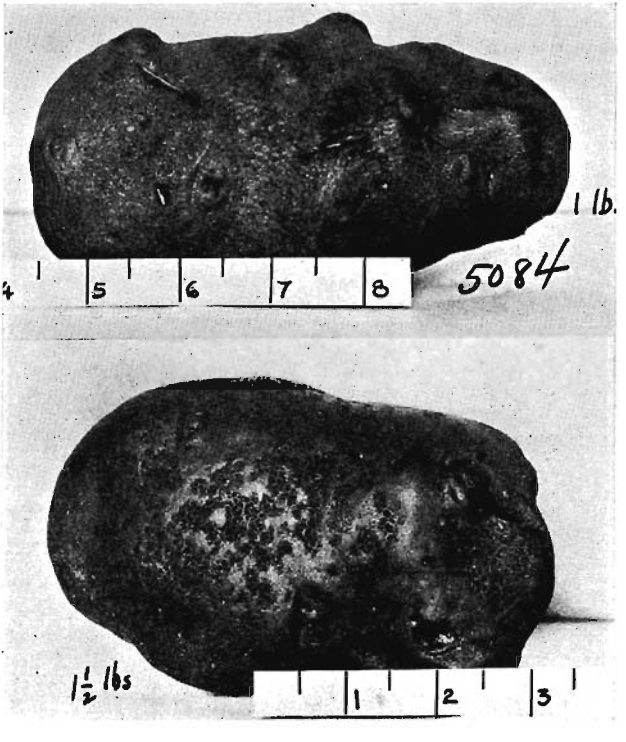

Fig. 35.—"Busters" from Molokai, potatoes averaging better than a pound each. This is good hotel and restaurant stock, but not sought after by the fancy trade. These brought the grower $1.50 to $1.65 per 100 pounds f. o. b. Molokai.

ing twenty-five per cent may be of any other grade. This is the most popular grade in Honolulu at present. Its specifications are as follows: *"U. S. No. 1 shall consist of potatoes of similar varietal characteristics which are not badly misshapen, which are free from freezing injury and soft rot and from damage caused by dirt or other foreign matter, sunburn, second growth, growth cracks, hollow heart, cuts, scab, blight, dry rot, disease, insect or mechanical injury, or by other means. The diameter of potatoes of round varieties shall not be less than 1⅞ and of potatoes of long varieties 1¾ inches.*

"In order to allow for variations incident to proper grading and handling, not more than five per cent, by weight, of any lot may be below the prescribed size, and in addition, not more than six per cent, by weight, may be below the remaining requirements of the grade, but not to exceed one-third of this six per cent tolerance shall be allowed for potatoes affected by soft rot."[18]

Grading must be carefully done. It is best accomplished through a cooperative marketing association. Here experts grade the potatoes of all the growers into uniform lots corresponding to the U. S. Grades and Standards. After grading, the potatoes must be packed in uniform new, clean containers. Second-hand containers should not be used. Potatoes are shipped in barrels, sacks, crates, and in bulk. In the Territory the best container is the sack. There are many sizes of burlap sacks in use throughout the United States but a sack containing 100 pounds is the best type for our conditions. Crates can also be used but if a crate is used it should not have over one bushel capacity.

Potatoes are often repacked for the retail trade into smaller corrugated paper containers. The weights of these special packs are usually about 15 to 30 pounds, the 15 pound size being the most popular in the Honolulu market.

Before containers are selected by any group of growers, it is well for them to refer to the Department of Commerce through the Director of the Bureau of Standards for information on the Federal Laws pertaining to the sizes of containers authorized by law.

The selling of large quantities of locally grown potatoes in the

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[18]For fuller information on U. S. Grades see U. S. Department of Agriculture Circular 238, entitled, "U. S. Grades for Potatoes."

Honolulu market is a difficult matter at present, and the fault lies largely with the Hawaiian farmer. The farmer does not stop to consider the markets, and as a result he ships potatoes of every size, and description. The day is past, however, when buyers will handle such stocks. The farmers in the Territory must grade their potatoes according to U. S. Grades and Standards if they expect to obtain a fair return for their efforts.

Assistance in grading and marketing can be secured from the county extension agents and from the extension agent for farm management and marketing, Agricultural Extension Service, University of Hawaii.

EXPERIMENTS ON VARIETIES AND FERTILIZERS

On all but rich, virgin soils the beginner in potato culture would do well to plan a simple fertilizer test at the outset of his enterprise. The grower is also urged to make a comparative test between two or more varieties of potatoes. Such a test might well be combined with the fertilizer test. The accompanying plan, Fig. 36, should be self-explanatory. It will be noted that this plan provides for five fertilizer and two check plots. Crossing these fertilizer plots, two (or more) varieties of potatoes may be planted in accordance with good field practice. As outlined herewith provision is made to compare two varieties. (A and B). One of these may be of a variety already extensively grown in the vicinity. In the adjacent plot, certified imported seed of the same variety or some other promising variety may be grown in comparison. Under this plan each subdivided plot would be 1/20 acre in size. Such plots should produce from a fourth of a bag to one bag of potatoes each. Only treatments giving yields exceeding 25 per cent over the check plots should be given consideration. Frequently the difference in yield and quality of the best plot over the poorest plot exceeds 100 per cent.

Added reliability will accrue from such tests if they are carried on year after year. Careful records of the season should accompany other detailed information.

The results from such an experiment as outlined will show (1) the comparative value of two varieties with and without the several fertilizer treatments and (2) the more detailed influence of various fertilizer treatments on the potato crop as a whole.

Plot No. 1. Indicates what the land will produce without any fertilizer.

POTATO VARIETY - FERTILIZER TEST PLAN

Seven test plots, each 1/10 acre in size (93-1/3 by 46-2/3 feet), in two sections to test two varieties of potatoes.

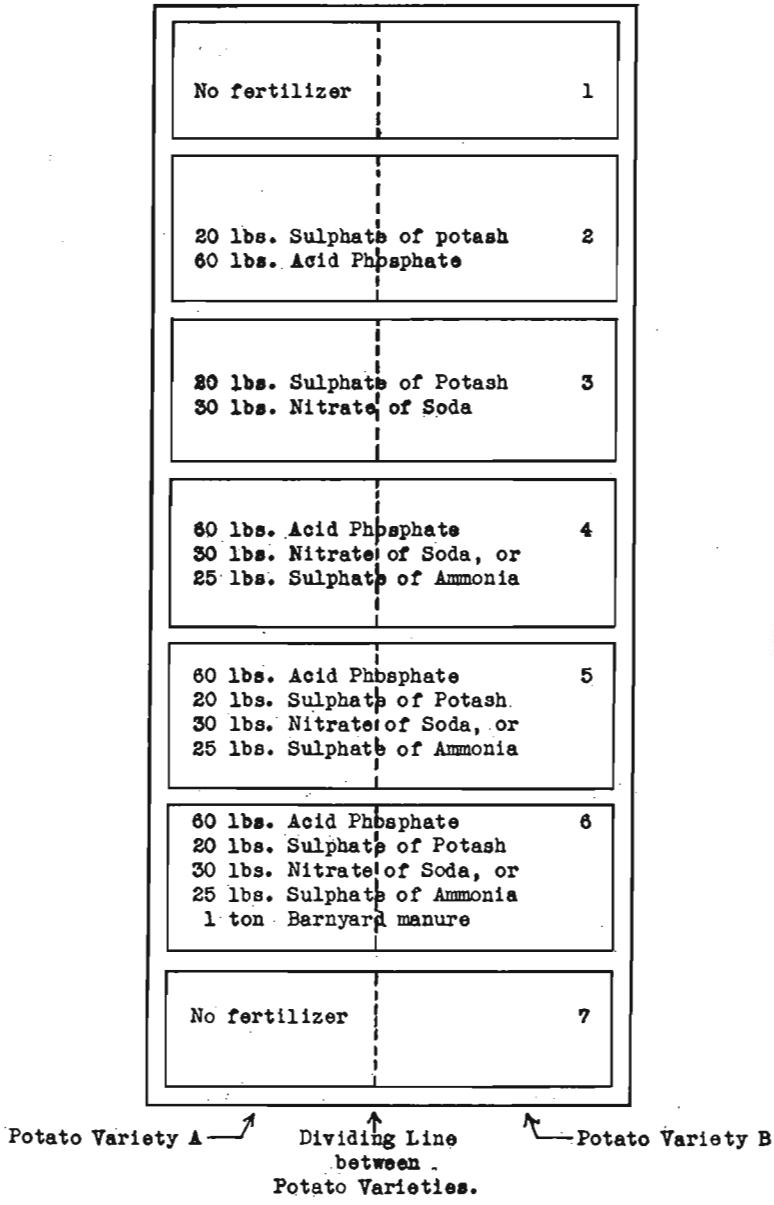

Fig. 36.—Potato Variety-Fertilizer test plan.

Plot No. 2. The effect of phosphoric acid and potash.

Plot No. 3. The effect of potash and nitrogen.

Plot No. 4. The effect of phosphoric acid and nitrogen.

Plot No. 5. The effect of a "complete fertilizer"; that is, one containing potash, phosphoric acid and nitrogen, when applied at the rate of about a half ton per acre.

Plot No. 6. The effect of the above fertilizer together with barnyard manure applied at the rate of ten tons per acre.

Plot No. 7. What the soil will produce without any fertilizer; it is also a check on Plot No. 1; a comparison of the yields from Plots No. 1, and No. 2 and indicates the degree of uniformity of the intervening area.

The above simple plan can, of course, be greatly elaborated. For instance, the same fertilizers can be applied in different quantities, at different periods of growth, or additional fertilizer materials can be tested. Likewise instead of only two varieties, three, four or more, varieties may be tested. The experimenter is, however, cautioned against using plots less than 1/20 acre in size for any one test.

COST OF GROWING POTATOES

It appears that the cost of growing potatoes on a commercial scale in Hawaii has never yet been determined. The following estimate is based on acre plantings at Haiku, Maui, during the period from 1915 to 1921.

Estimated Cost of Growing Ten Acres of Potatoes
Under Favorable Conditions in Hawaii

Land rental and taxes @ $20.00 per acre	$200.00
2 Plowings @ $10.00 per acre	100.00
Disking and planking five times @ $10.00 per acre	100.00
½ ton high grade fertilizer @ $30.00 per acre	300.00
1000 lbs. certified seed @ $35.00 per acre	350.00
Disinfecting seed (labor & material) @ $2.00	20.00
Cutting seed by hand @ $2.00 per acre	20.00
Planting with mechanical planter, team and two men @ $3.00 per acre	30.00
Hand weeding and horse cultivation @ $10.00 per acre	100.00
Spraying crop five times @ $5.00 per acre	50.00
Digging crop with mechanical digger and picker @ $10.00 per acre	100.00

Grading tubers by mechanical grader @ $5.00	50.00
Storage and miscellaneous @ $2.50 per acre	25.00
Containers (burlap sacks) 102 @ .05 per acre $5.10	51.00
	$1496.00
Average cost per acre	149.60

With average yields of 102 bags (10,200 pounds) of marketable (U. S. No. 1) potatoes per acre, as produced at New Era Homestead Farm, the production cost per 100 pound bag was $1.46. The average price realized per 100 pounds at the farm was $2.25. The net profit per acre under the above conditions was $80.58. Cull potatoes average about one ton per acre valued at $10.00 as hog feed. Thus the total net income per acre was around $90.00.

The experienced potato grower, favorably located, should be able to reduce these costs of production from 10 to 25 per cent and to increase his profits proportionately. Records kept by the Maine Experiment Station of a ten acre field of potatoes show the cost to have been $699.30. Stewart[19] in his excellent text, "The Potato," gives numerous cost accounts ranging from $51.00 to $166.00 per acre, but he rightly emphasizes the fact that the cost per bushel, rather than the cost per acre should be the criterion. The average yield per acre under favorable Hawaiian conditions should not be less than 100 bags, or 1000 bags from ten acres. Yields of 150 bags per acre should be striven for, although the average production in Hawaii at present probably does not exceed two-thirds that amount.

Potatoes should be grown of a quality, and at a time, when they will command at least $2.00 per bag of 100 pounds. At this rate the 100 pound yield would leave a net profit of only $56.00 per acre, hardly sufficient margin, considering the risk. However, a 150 bag (250 bushel) yield would give the substantial profit of $156.00 per acre. The good potato grower might well make his slogan "An average of $100.00 net per acre per annum," and be satisfied with no less. Unless the goal is set high there can be no high attainment in potato culture or other agricultural accomplishment any more than in other forms of enterprise.

POTATO DISEASES AND PEST CONTROL

One of the factors responsible for the decline in the potato

[19]William Stewart, "The Potato", Lippincott, 1923.

industry in Hawaii is doubtless the presence of diseases and pests, to which the crop gradually became subjected as it increased in area and volume. In recognition of this the Hawaii Agricultural Experiment Station published in 1920 a bulletin from which the following data are mainly abstracted. It would be well for all prospective, as well as present, potato growers to get a copy of this bulletin.[20]

Potato Diseases Known To Occur In Hawaii

In order that plant diseases may be intelligently controlled, an understanding of their nature is necessary. The diseases to which the potato is subject may be divided into two classes: (1) Those caused by organisms, as fungi, bacteria, insects, etc., which may be called parasitic diseases; (2) those induced by unfavorable growing conditions or by obscure and undetermined causes, which may be termed non-parasitic diseases.

The parasitic organisms which cause diseases of the first group may be present in the soil, introduced on the seed, or brought to the soil and the growing crop from adjacent fields by wind or

[20]"Potato Diseases in Hawaii and Their Control", by C. W. Carpenter. Bulletin No. 45, Hawaii Agricultural Experiment Station, 1920.

Fig. 37.—The first of five sprayings on six-weeks-old potatoes intercropped with corn. Spraying being done by means of knapsacks and compressed-air sprayers. New Era Homestead Farm.

water. Under favoring conditions in the presence of the potato plant, the disease progresses more or less virulently. A number of parasitic diseases are found to be factors in potato production in Hawaii. The fungus diseases include Fusarium wilt (*Fusarium oxysporum*), late blight (*Phytophthora infestans*), black scurf and rosette (*Rhizoctonia solani*), early blight (*Alternaria solani*), common or corky scab (*Actinomyces chromogenus*), tuber rots (*Fusarium oxyporum, F. radicicola, and F. coeruleum*). Diseases are also induced by insect pests, including tuber moth (*Phthorimaea operculella*), cutworms and a similar leaf-eating worm locally called "poko," and mites (unidentified forms of *Tetranychidae*).

Non-parasitic diseases of the potato may be occasioned by unfavorable environment such as unsatisfactory soil composition, uneven growth due to prevailing weather conditions, or mechanical or chemical injury from injudicious applications of arsenical sprays. Bright, hot sunlight after certain kinds of weather frequently causes sunscald and tip-burn of the leaves. It may be noticed that many of the diseases usually classed as non-parasitic, though imperfectly understood, can be controlled through seed selection and elimination of undesirable strains. Such are the apparently inherited conditions known as leaf roll, curly dwarf, and mosaic, which probably will not be serious factors in the Hawaiian potato industry.

Potato Seed Disinfection. Diseases such as corky scab, Rhizoctonia scab, and rosette, which are carried on the surface of the seed, can be controlled in some degree by soaking the seed in a disinfecting solution. *Seed disinfection will be of little value if the soil is already infected with the diseases for which the seed is treated.* It is on the whole better practice not to cut the tubers before soaking them in the disinfecting solution. For immediate planting, however, the tubers may be cut before dipping.

The solutions most frequently employed for potato disinfection are formalin and corrosive sublimate. Either is suitable for the corky scab, but the evidence favors the latter solution for the Rhizoctonia diseases (black scurf and rosette).

The usual formalin solution is made up as follows:

Formalin (40 per cent formaldehyde)	1 pint
Water	30 gallons

The sacks containing the potatoes should be immersed in this solution for two hours, after which the tubers should be re-

moved and spread to dry. Thirty gallons of the solution is sufficient for disinfecting about 30 bushels of seed.

Corrosive sublimate has the disadvantage of being a *deadly poison* if taken internally, and it should be handled with this fact always in mind. The solution corrodes metal and therefore only wood and non-metalic containers should be used. The formula is as follows:

Corrosive sublimate	4 ounces
Water	30 gallons

Dissolve the chemical in a few gallons of hot water and dilute to 30 gallons. Immerse the sacks contining the tubers for two hours, then remove and spread the potatoes to dry. As this solution looses its strength after treating four to six lots of potatoes, fresh solution should be substituted.

Handling of the seed potatoes during treatment is best done with the aid of wire baskets or slatted wood crates. Metal containers, however, cannot be used with corrosive sublimate. Burlap bags are less desirable, as they cause the solution to lose strength and impede the rapid coating of the tubers. A drain board should be attached to the dipping vat to carry the surplus solution back into the vat, in order to conserve the disinfectant.

The organisms causing Fusarium wilt, rosette, black scurf, corky scab, etc., live indefinitely in the soil, but it is generally believed that in the absence of susceptible plants the virility of the organism is lessened and the number decreased. The tuber moth, which is most serious in dry years, can perhaps be held under control through clean cultivation and rotation combined with intelligent spraying with arsenicals. Crop rotation, combined with the use of good seed and preventive sprays, offers promising opportunities for improving the Hawaiian potato industry through increased yields and better quality.

Soil Reaction. As certain organisms are favored by an acid soil while others are encouraged by an alkaline soil, (the later being favorable to the development of corky scab), lime or wood ashes should never be applied to potato fields. They tend to produce an alkaline soil reaction and are sure to encourage scab. On the other hand, the plowing under of green-manure crops will tend to make the soil acid and thus reduce the damage from this disease. The Rhizoctonia diseases are thought to be worse on heavy, poorly drained, acid soils. Correcting the drainage and aeration of such soils is beneficial.

Fig. 38.—The last of the five sprayings, the crop approaching maturity. New Era Homestead Farm.

Spraying, spray mixtures, baits, etc. In order to protect the potato plant against various insect pests and fungus diseases, sundry chemicals are sprayed or dusted thereon or used as baits. The chemical should vary with the nature of the pest—there are no cure-alls. The material may serve as a protection of the foliage against fungus infection or as a contact or internal poison for insect pests. In certain weather conditions, a coating of spray may act mechanically to prevent sun injury of the foliage.

Bordeaux Mixture for the Control of Foliage Diseases. The most widely used fungicidal spray for the prevention of foliage diseases of the potato is Bordeaux mixture. The experiments carried on with this spray by the writer, both acting alone and working cooperatively with others in Hawaii for the prevention of the late blight disease, have been very encouraging. The fact that late blight is present upon almost every potato crop grown, and that when the weather is too dry for this disease the early blight is serious, should be sufficient argument in favor of universal spraying of potatoes with Bordeaux.

Standard Bordeaux [21] mixture is made up according to the

[21]To make "Instant Bordeaux" see Agricultural Notes No. 2, August 1929, "A Better Copper Spray for the Control of Plant Diseases."

following formula, which is often referred to as 5:5:50 Bordeaux.

Bluestone (copper sulphate)	5 pounds
Quicklime (not air slacked)	5 pounds
Water, to make	50 gallons

The mixture is prepared by hanging the bluestone, preferably overnight, in a sack immersed, (the top just under the surface), in a gallon of water in a wooden container. If time is a factor, pulverize the bluestone and dissolve it in a gallon of hot water. Dilute to 25 gallons. Make a lime paste by slaking the 5 pounds of lime in a small quantity of water, adding enough water to prevent its boiling dry. When the boiling ceases, stir to a smooth cream and add water to make 25 gallons. Just before the Bordeaux mixture is required for use, pour the 25 gallons of diluted bluestone and 25 gallons of diluted lime at the same time into a wooden container and stir vigorously. Stir and strain into the spray tank and agitate occasionally while spraying, as even properly-made Bordeaux settles, gradually. The bluestone solution and the lime solution can be kept separately for approximately one month, but when mixed together should be used the same day. However, if sugar is stirred in at the rate of 1/10 pound to 10 gallons on the day the mixture is made, Bordeaux may be kept several days in covered wood containers.

Where considerable spraying is to be done, it is advantageous to prepare stock solutions of the bluestone and of the lime. It is convenient to prepare these solutions so that each gallon contains a pound of chemical. Then to make 50 gallons of Bordeaux, it is necessary only to take 5 gallons of the bluestone stock solution and dilute it to 25 gallons, to dilute similarly 5 gallons of the lime stock solution, and to mix the two diluted solutions.

It is as easy to prepare Bordeaux mixture by the right method as by any other, and properly made Bordeaux is much more effective than the mixtures of uncertain physical and chemical composition which result from haphazard methods. For the most effective Bordeaux it is essential that the bluestone solution and the lime suspension be diluted before combining. When properly made and properly applied, Bordeaux has remarkable adhesive properties, once it becomes dry on foliage.

The active principle of Bordeaux mixture is the copper, but in order not to injure the foliage, and to render the treatment more lasting, the copper is made insoluble by the use of lime. When the diluted solutions come together, minute precipitation membranes are formed. In spraying, the plant is covered with a

thin layer of these membranes. The copper in these membranes, rendered slowly soluble by the action of the carbon dioxide of the air, forms a solution in the minute films and droplets of water on the leaves, which prevents the germination of fungus spores.

The Bordeaux should be applied *on both upper and lower surfaces* of the leaves and at the highest pressure obtainable, to insure thorough protection and economic distribution. Each plant should be sprayed long enough to cover all parts, but not sufficiently long to allow the spray to collect in drops and run off, as in the latter case the spray is not only wasted but is less adhesive. The plants will hardly show the spray when it has been properly and thoroughly applied with sufficient pressure and in the desirable misty form.

Perhaps under Hawaiian conditions some variations of the formula for Bordeaux as given may be found advisable. Possibly 4 pounds of bluestone and 4 pounds of lime in 50 gallons of the mixture would do the work satisfactorily. (Send to the Extension Service for a copy of Agricultural Notes No. 2).

The Acid-Mercury Dip. The acid-mercury dip is the result of an effort to devise a treatment for seed potatoes that would require less time and labor than those in common use. This method has been tested for five years and has been found to be as effective as any method so far devised. Its chief virtue, however, lies in its simplicity. It requires less time and labor than any other recommended method.

In addition to the shorter time and less labor required, the acid-mercury dip has the following advantages over the older methods.

1. Mercuric chloride dissolves very rapidly in the acidulated solution; it dissolves very slowly and with difficulty in cold water.

2. Hard water or alkali-water may be used when acid is added because the acid overcomes the hardness of the water.

3. No heating equipment is required.

4. No temperature control is necessary.

5. There is greater latitude in the time of treatment. Tubers may be soaked in the solution for 40 minutes without injury if properly handled after treatment.

6. With such latitude there is less danger of poor control by too short a treatment.

Seed treatment is an important method of increasing yield and quality of potatoes. Three destructive diseases, common scab, Rhizoctonia, and blackleg, are sometimes transmitted on, or in the seed tubers and can be partly prevented by seed treatment. As the organisms causing these diseases are known to survive in the soil, seed treatment is not absolute insurance against disease. Crop rotation and all good cultural practices are necessary to insure the best results.

Directions for Using Acid-Mercury Dip. 1. Add 6 ounces of mercuric chloride to one quart of commercial hydrochloric acid (muriatic acid). It will dissolve immediately. This solution may be purchased already mixed.

2. Measure out 25 gallons of water in a wooden barrel, tub, or concrete tank. A metal container may be used if thoroughly painted inside with heavy asphaltum paint. The solution will corrode metal.

3. Pour the quart of acid containing the mercuric chloride into the water and mix thoroughly.

4. A wooden crate, or wire basket thoroughly painted with asphaltum paint, should be used for dipping the potatoes.

5. Dip the potatoes in the solution and allow them to remain for at least five minutes. If there is much scurf on the tubers they may be soaked longer. Soaking 40 minutes will not injure them.

6. It is better to treat the tubers before cutting, although they may be treated after cutting if desired. In this case, they should be planted the same day they are treated.

7. Twenty-five gallons of the solution is enough to treat 40 to 50 bushels of potatoes, after which the solution is likely to be too weak. It can be brought back to approximately original strength by adding one-half pint of the stock solution and enough water to bring the solution back to 25 gallons. After 40 or 50 more bushels have been treated the solution should be discarded and a new one made.

8. Unless the tubers are planted immediately they must be spread out to dry. *Do not store treated potatoes while they are wet.* This is likely to injure them.

9. The diluted treating solution is not strong enough to injure the hands in ordinary practice. The strong acid should, however, be handled with care.

10. Remember that *Mercuric Chloride is a poison.*

Modifications of Bordeaux Mixture for the Control of Leaf-eating Insects. For controlling leaf-eating insects, such as the army worm or "poko," and as a possible aid in combating the tuber moth, Paris green may be used in Bordeaux at the rate of 1 pound to 50 gallons. Usually Bordeaux mixture contains a sufficient excess of lime to neutralize the Paris green and no burning of the foliage results, but if lime of doubtful quality is used in preparing the Bordeaux, an amount of lime equal in weight to the Paris green should be added to prevent burning.

The usual method of destroying leaf-cutting insects however, is by adding arsenate of lead to Bordeaux mixture at the rate of about 3 pounds to 50 gallons. Whether this form of poisoning will prove more satisfactory for the leaf-eating cutworms or "pokos" than the locally commonly used flour-Paris-green dust, or the bran-molasses-Paris-green bait, remains to be tested by the grower. We favor the first and last treatment used in combination.

Lime-Sulphur Spray or Dry Sulphur for The Control of Mites. For the control of the potato mite which in dry and hot situations causes the young leaves, first to become bronzed on the under surface, then browned and finally results in the death of young growth and premature development of the plant, a lime-sulphur spray made up as follows has been found effective:

Sulphur	1 pound
Quicklime	1 pound
Water to make	20 gallons

Boil the sulphur and quicklime in a gallon of water in a kettle or pan until they combine into a yellowish, sirupy liquid, this usually requiring about three-quarters of an hour. Dilute to make 20 gallons of spray mixture.

Dry sulphur dusted upon the foliage with an insect-powder blower is likewise effective in the control of mites.

Soil Fungicides for Sclerotium Wilt. Ammoniacal copper carbonate solution and "eau celeste," which contain copper in soluble form, are recommended as soil fungicides in case of Sclerotium wilt. The chemicals needed to make sufficient solution for 50 gallons of copper carbonate fungicide are as follows:

Copper carbonate	5 ounces
Ammonia (26° Baume)	3 pints
Water to make	50 gallons

To a gallon of water in a wooden vessel add the ammonia and stir. Add the copper carbonate a little at a time, stirring constantly. Continue to add the chemical until no more will dissolve. Allow any undissolved carbonate to settle to the bottom and draw off the clear blue supernatant liquid. This solution does not keep well for more than a few days, and is best prepared fresh as needed. For use dilute the solution to 50 gallons.

Since bluestone may be more readily obtained than copper carbonate, the formula for another soil fungicide, (eau celeste) is given.

Bluestone (copper sulphate)	2 pounds
Ammonia	3 pints
Water to make	50 gallons

Dissolve the bluestone in a gallon of water. When dissolved, add the ammonia to it. Transfer to bottles that can be tightly corked if the solution is not to be used at once. For use dilute to 50 gallons. A half-teacupful of either of these solutions sprayed in time at the base of each plant is said to protect the plant against Sclerotium wilt.

Poison Baits for Army Worms. Where an invasion of army worms comes from adjacent grassland, cultivated fields may be protected by surrounding with a line of poison bait or establishing such a line along the threatened side. Ditches sprinkled with lime serve the same purpose.

Paris-green Bran Mash as Bait for Cutworms. With 50 pounds of bran thoroughly mix while dry 1 pound Paris-green. To make the bait attractive chop fine six lemons or waste citrus product, papaya, etc., and add to the mixture, or add a quart of cheap molasses. Thoroughly mix and add sufficient water to moisten the mixture, but not enough to make it sloppy and thus interfere with its easy and economical distribution.

Arsenate of lead may be substituted for the Paris green, using four to six times as much, or of white arsenic half as much as of Paris green may be used.

Criddle Mixture for Cutworms. The following formula is largely quoted as an effective bait for cutworms. As a cheap substitute for cereal baits it is well worth trying.

Fresh horse dung	60 pounds
Salt	2 pounds
Paris green	1 pound

The Paris green is mixed with enough water to form a thin paste and it is then thoroughly mixed with the horse dung.

Aphids (Plant Lice). Occasionally the potato crop is attacked by plant lice. These insects are small and usually attack the underside of the leaves, so that their early attack goes unnoticed, and consequently, due to their rapid increase, a crop may be seriously infested before control measures are thought to be necessary by the grower.

The aphid is a sucking insect, getting its food from under the surface of the leaves. Thus a stomach poison, such as arsenate of lead, by which means chewing insects are controlled, will have no effect on plant lice, and a *contact* insecticide must be used.

The best remedy is nicotine sulphate 40 per cent (Black Leaf "40") used as a spray in the proportion of 1-1000. The following formula will combine the ingredients in the proper proportions:

Black Leaf "40"	12 ounces
Whale oil or laundry soap	4 pounds
Water	100 gallons

The above quantity should be sufficient to thoroughly spray one acre.

If the nicotine sulphate is not available a strong solution of soap and water can be effectively used as a spray in the following proportions:

Whale oil soap or laundry soap	16 pounds
Water	100 gallons

Dissolve the soap in five or ten gallons of hot water then add water to make 100 gallons.

These sprays are most effective when high pressure sprayers are used. And since these pests are usually most prevalent on the under side of the leaves they are most effectively controlled by the use of sprayers equipped with an extension rod and a 45° angle nozzle. Sliding the rod along the ground under the vines directing the spray upward will greatly facilitate thorough spraying.

Good results may also be effected by dusting the vines with Nicotine Sulphate dust. This is prepared by mixing one pound

of 40 per cent nicotine sulphate with 100 pounds hydrated lime. Thoroughly dry the lime after mixing and sift to a very fine powder.

If potatoes are sprayed with Bordeaux when aphids are prevalent the nicotine sulphate can be added to the Bordeaux, this saving the extra spraying.

Nematodes (Gallworms or Eelworms). The potato gallworm or eelworm, one of a large number of species of nematodes, is a factor of considerable importance in potato production in Hawaii. These minute pests are not insects but microscopic roundworms. The same sort of parasite is responsible for the root-knot disease of various crops. The gallworm attacks the potato tubers and causes the skin to become roughened or cracked and covered with irregular galls or pimples. Badly infested tubers shrivel up, remain partly developed, and become soft and otherwise unfit for table use. When broken across, such tubers show a line of glistening specks just beneath the skin. These are the encysted nematodes.

There are few cultivated crops not subject to attack by species of gallworms, and when once established in a field their elimination is difficult. They are readily carried into new soils by infested seed tubers, implements, etc. Infested seed potatoes, which are of course unfit for planting, constitute a serious menace to the potato industry. Such tubers are best cooked and fed to hogs. Every effort should be made to limit the spread of this pest as all others.

Control: Seed potatoes should be carefully examined for the presence of nematode galls before planting. As far as possible, seed stock should be secured from fields known to be free from this pest. Break open any suspicious looking tubers and examine the outer third of the flesh for minute brownish spots with pearly white centers. In case of doubt, such tubers should not be planted, and specimens should be submitted to the Extension Service for examination.

There are over 500 plants susceptible to the attacks of gallworms, including many garden crops. It profits little to plant potatoes upon infested soil, this serving only to increase the number of parasites. If possible, a rotation should be practiced using nonsusceptible crops wherever possible. Subjecting the land to long periods of bare fallow is an effective but costly method of control.

Tuber Moth (*Phthorimaea operculella*). The tuber moth is the most serious insect pest of the Irish potato in Hawaii because of the damage it does and the difficulty with which it is controlled. Carpenter [22] states that it ranks second only to late blight as a potential pest of this crop, though the conditions favorable to the one are unfavorable to the other. This insect also attacks tomato, eggplant, and tobacco (as splitworm), though less actively than it does the potato.

The moth, which is small and grayish in color lays its eggs upon the leaves or other parts of the plant. The larvae or worms quickly enter the leaves, mining between the surfaces, or bore into the stem or tubers. Affected tubers soon rot, owing to invasion by one or more of the numerous wound bacteria or fungi. In Hawaii there are probably several generations of the pest during the year. The moth is most prevalent during the dry season, that is, from May to October. The damage it does in drought years is almost unbelievable.

Control: The tuber moth is very difficult to control, even under the best systems of potato culture, and the regrettable lack of ad-

[22] Carpenter, C. W., Hawaii Agricultural Experiment Station, Bulletin 45, p. 29-30. 1920.

Fig. 39.—Cultivation of potatoes on high ridges, a method of protecting the plants from the tuber moth. Ridging of this sort also facilitates irrigation.

equate care in Hawaii greatly increases the difficulties. With potatoes growing in every month of the year, with practically no rotation practiced, and with volunteer potatoes allowed to mature with corn or beans, where an indifferent rotation obtains, the outlook is not encouraging. The procedure outlined on the Mainland for the control of this pest is cited below, and as far as practicable these methods should be followed.

Clean cultivation: All volunteer potato plants as well as all solanaceous weeds should be destroyed. When a potato crop is harvested the vines and all small tubers should be gathered up and burned.

Crop rotation: Crop rotation is essential, and the cooperation of all growers of a section is necessary. Crops which can be used in rotation with potatoes are beans, peas, corn, cowpeas, alfalfa, clover, soy beans, and peanuts.

Hilling: Hilling up the potato plants much more than is generally practiced here, thus increasing the depth of the tubers, will probably help to prevent tuber infestation during the maturing of the crop. In deep, mellow, silty soils, the crop can be planted rather more deeply and hilled higher than in moist, heavy soils.

Digging and sorting: The crop should be dug as soon as mature and brought in from the field before late afternoon. If the tubers are infested, as indicated by the mining often visible just under the skin, and by slight webbing near the eyes, they should be carefully sorted at once. Those infested should be either destroyed immediately by burning or fumigated if they are held for use as stock feed.

Those still unimpared should be fumigated as described below and placed out of reach of the moths and of further infestation.

Fumigation: Place the tubers to be fumigated in a room that can be sealed. For every 1,000 cubic feet of space to be fumigated place from 1 to 2 pounds of carbon bisulphide in a shallow dish or pan and set it in the top of the room. The amount of the chemical varies with the tightness of the room. For small containers the following amounts are recommended: Ten-gallon "sake" barrel, one-tenth to one-fifth ounce; 50-gallon wine barrel, one-half to one ounce. After the chemical is placed in the top of the room or container, seal up immediately and leave undisturbed for 24 hours. Remove and ventilate the material for a short time and place in moth-proof storage, if possible. If the potatoes are held in storage for any length of time they should be

examined at frequent intervals for further infestation and treated again if necessary. Seed potatoes may be fumigated if the lot is suspected of containing worm-infested tubers. They must be fumigated before the sprouts are prominent, as otherwise the tubers will be killed. *Carbon bisulphide is volatile and highly inflammable. Keep away from fire. The fumes are poisonous. Do not inhale.*

Spraying: The use of Paris green or other arsenicals in Bordeaux mixture, when the latter is being regularly applied, will probably be of some benefit in combating the tuber moth.

APPENDIX

IMPORTATION OF IRISH POTATOES TO HAWAII

1873 - 1930

(For the fiscal year, ending June 30)

Year	Bushels	Value
1873	5,949	$ 4,998.19
1874	5,605	4,737.58
1875	5,251	5,610.98
1876	5,947	4,442.54
1877	9,025	6,445.46
1878	13,207	12,512.97
1879	20,047	13,560.90
1880	29,958	15,113.06
1881	36,411	23,913.11
1882	33,983	31,464.01
1883	5,198	3,124.06
1884	37,315	21,551.40
1885	41,451	21,798.06
1886	3,455	2,300.01
1887	5,641	3,257.94
1888	37,119	18,155.87
1889	44,972	22,428.31
1890	32,229	29,516.39
1891	32,408	19,459.59
1892	1,895	1,282.61
1893	102	581.19
1894	689	684.16
1895	659	954.81
1896	10,540	6,615.04
1897	23,651	13,650.52
1898	24,157	14,297.54
1899	19,437	17,274.52
1900	45,477	30,271.00
1901	60,874	40,517.73
1902	78,980	52,569.08
1903	98,610	53,564.00
1904	107,661	79,971.00
1905	94,815	67,737.00
1906	89,444	55,621.00
1907	90,235	86,982.00
1908	99,158	79,232.00
1909	114,639	99,550.00
1910	129,093	88,191.00
1911	111,921	118,758.00
1912	158,872	158,109.00
1913	208,525	95,265.00
1914	216,360	142,248.00
1915	222,121	159,798.00
1916	223,981	179,675.00
1917	167,275	283,537.00
1918	210,865	236,359.00
1919	189,706	240,814.00
1920	152,409	327,039.00
1921	253,293	310,532.00
1922	283,137	291,504.00
1923	283,564	254,041.00
1924	283,149	324,838.00
1925	292,968	335,889.00
1926	261,638	449,492.00
1927	267,368	311,154.00
1928	314,206	289,063.00
1929	296,843	220,417.00
1930	307,592	321,687.00

APPENDIX

MONTHLY IMPORTS OF IRISH POTATOES FROM THE MAINLAND TO HAWAII

1930

Port of Shipment	San Francisco		Washington		Los Angeles		Oregon	
Months	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
January	4,638 bu.	$ 7,101.00	22,197 bu.	$ 31,357.00	.....	.....	.....	.....
February	3,394 bu.	4,975.00	21,409 bu.	28,588.00	.....	.....	.....	.....
March	2,781 bu.	4,244.00	22,402 bu.	32,670.00	136 bu.	$ 274.00	.....	.....
April	2,653 bu.	4,853.00	20,031 bu.	29,926.00	82 bu.	185.00	.....	.....
May	1,305 bu.	2,676.00	23,261 bu.	41,195.00	12 bu.	18.00	400 bu.	$ 705.00
June	6,458 bu.	10,516.00	1,639 bu.	3,140.00	382 bu.	552.00	.....	.....
July	18,107 bu.	26,582.00	2,154 bu.	2,990.00	663 bu.	994.00	.....	.....
August	19,138 bu.	21,516.00	7,804 bu.	9,224.00	49 bu.	62.00	.....	.....
September	11,308 bu.	12,224.00	15,222 bu.	13,292.00	.....	.....	.....	.....
October	14,089 bu.	14,682.00	23,116 bu.	20,587.00	45 bu.	57.00	.....	.....
November	7,149 bu.	7,084.00	20,066 bu.	18,155.00	26 bu.	47.00	100 bu.	140.00
December	3,349 bu.	3,185.00	15,813 bu.	12,078.00	125 bu.	135.00	.....	.....
TOTALS FROM EACH PORT	94,369 bu.	$119,638.00	195,114 bu.	$243,162.00	1,520 bu.	$2,324.00	500 bu.	$ 845.00

GRAND TOTAL FROM ALL SOURCES: 291,503 bu. valued at $365,969.00.

APPENDIX

EXCERPTS ON POTATO CULTURE IN HAWAII FROM HAWAII AGRICULTURAL EXPERIMENT STATION PUBLICATIONS 1901-1931

Importance of good tilth and green manuring for heavy soils. "It was clearly shown that the best tilth possible should be provided on heavy soils . . . It was found necessary to incorporate in the soil liberal amounts of organic matter. The most practical method was to turn under one or two good crops of velvet beans or cowpeas. About 25 tons of green matter per acre, when turned under will ordinarily suffice to supply the requisite amount of organic matter in the soil." (Report, 1919, p. 65).

Comment. Unless heavy soils, or any soils for that matter, are brought into good tilth it is useless to attempt to grow potatoes successfully. Naturally heavy, cloddy, or coarsely granular soils are improved in their physical texture by means of green-manuring. Not less than 25 tons of green vegetation is necessary for mixture with the large mass of soil particles represented in an acre foot (approximately 4,000,000 pounds). Not the least value of such green-manuring crops is their cover (mulching) influence. The heaviest soils will be greatly benefited in their tilth by means of long time crop covers. Rough fall plowing thereby exposing the clods to the winter influence of weathering is also very beneficial. To break down rough cloddy land on short notice, perhaps no implement is quite as effective as a homemade plank drag. See Fig. 10. Also see Press Bulletin No. 40 Hawaii Agricultural Experiment Station 1915, how to make "A Cheap and Effective Homemade Plank Drag."

Value of Commercial Fertilizers in Growing Potatoes. "It has been found from experiments covering four successive seasons' plantings that to secure profitable yields it is essential to supplement the green-manure with liberal applications of commercial fertilizer. At Haiku, a comparative test of standard chemical fertilizers showed conclusively that the phosphates are the controlling factor in maintaining a high degree of soil fertility . . . An application of 500 pounds of either superphosphate or reverted phosphate, placed in the hills at the time of planting, gave an increased yield of from 150 to 400 per cent over untreated plots. Finely ground bone meal also gave satisfactory results." (Report, 1919, p. 65).

Comment. All soils do not react in the same way, nor is it possible to know what fertilizer treatment is best without making

fertilizer tests, soil analysis is not sufficient criterion to base a rational fertilizer practice on. New Era Homestead Farm's success was largely the result of good tillage and fertilization. Consult the sections on Fertilization and Green Manuring in the present paper; also the section on Fertilizer Tests.

COMPARATIVE YIELDS OF 23 VARIETIES OF POTATOES TESTED AT HAIKU FOR THREE YEARS OR MORE.

Results of Potato Variety Tests at Haiku Demonstration and Experiment Farm, Showing Approximate Average Yields, in Pounds per Acre, Based on three or more crops.

Relative rank of variety	Variety tested	Approximate average yield per acre.
		Pounds
1	Earliest of All	10,200
2	Producer	9,600
3	Snow	8,350
4	White Rose	8,100
5	Bliss Triumph	7,700
6	Early Rose	7,600
7	Early Sunrise	7,400
8	Early Freeman	7,350
9	American Wonder	7,250
10	Green Mountain	7,000
11	Pride of Multnomah	6,500
12	Netted Gem	6,450
13	Early Prizetaker	6,400
14	Gold Coin	6,200
15	Kula White	6,150
16	Kula Flat	6,050
17	Scotch Rose	6,000
18	Burbank, low top	5,950
19	Burbank, high top	5,400
20	Burbank, Kula seed	4,650
21	Hamakua Hybrid (Kula, Kim strain)	4,000
22	Hamakua Hybrid (Yamato strain)	3,800
23	Hamakua Hybrid (New Era strain)	3,250

These figures are taken from the Annual Report of the Hawaii Experiment Station, 1919, p. 66.

Comment. Every extensive potato grower should establish at least a limited trial ground to test some of the most promising varieties for his conditions. At present the most available seed is British Queen. The writer would recommend testing in comparison any or all of the first four in the above list together with American Wonder and Netted Gem. No one can predict in advance which will prove the best variety for particular conditions.

Potato Diseases and Insect Pests. "Fundamentally diseases and insect pests are the most important factors (of potato crop failure in Hawaii), the other factors mentioned, (1. Use of poor seed; 2. Continuous cropping; 3 Unsatisfactory soil conditions) being nearby contributing causes." Potato diseases in Hawaii and their control. Bulletin No. 45, 1920.

"One of the most critical problems in potato culture is the eradication of the so-called blights, the tuber moth, and the newly found leaf mite. However, intelligent and persistent treatment results in satisfactory control. But their cost must be reckoned with." Report, 1919, p. 65.

Comment. We would not minimize the above statement and full cognizance should be taken of this factor, nevertheless, the progressive potato grower is now in a better position than ever to control most potato diseases and insect pests which in the past were doubtless the most serious obstacles to his success.

Mr. Carpenter's valuable bulletin should be in every potato grower's library and carefully studied before potato culture is undertaken on a large scale.

Carpenter states: "A considerable number of demonstration sprayings of potatoes with 5:5:50 Bordeaux mixture has been made both on Oahu and on Maui from which it appears that this disease (late-blight, Phytophthora infestans) can be largely prevented by proper spraying. It is being recommended that plants be sprayed first when 6 to 8 inches high and about two weeks thereafter and after rains, or in other words often enough to keep the plants, and especially the new growth, continuously protected. The blight generally appears shortly after the time of blossoming. Indication of what results may be expected from the intelligent use of Bordeaux mixture in controlling the late blight disease is stated as follows: The yields of two (60 hill) rows of unsprayed plants were, respectively, 66 and 78 pounds, and for the sprayed rows, respectively, 110 and 117 pounds a total gain of 82 pounds or 57 per cent. The value of the increased yield was $4.10 obtained at a cost of 20 cents for material. Since the blight had already attacked the plants the maximum beneficial effects of the spray was not obtained." (See Figs. 1 and 2, Plate IV.) Report, 1917, p. 86.

"During the year considerable additional evidence was accumulated showing the effectiveness of Bordeaux mixture as a preventive of late blight. Increased yields of sprayed over un-

sprayed plots of 50 to 200 per cent were obtained." Report, 1918, p. 40.

Comment. Many other concrete examples of successful spraying practice could be cited did space permit. There can be no question but that spraying with fungicides should be considered as a regular practice in potato culture in Hawaii.

Potato Disease (cont.) Resistant Varieties. "The Irish potato was formerly cultivated on an extensive scale in these islands. Within the last ten years a disease has become widely prevalent which has about ruined the industry . . To determine whether there were not some varieties of potatoes that would prove resistant to the black wilt disease, the use of a plot of land in Kula, Maui, in the center of the potato growing district was donated to the Station by Mrs. Randal von Tempsky. On this land 45 varieties of seed potatoes grown in Maine were planted. Out of this large number of varieties, the "June," proved to be entirely resistant to the black wilt. Two other varieties were partly resistant, while the remaining 42 sorts were completely destroyed at the time they commenced to flower." Report, 1902, p. 312.

"Evidence in hand indicates that the Hamakua Hybrid has a very promising degree of resistance to the Phytophthora leaf blight in these islands . . . At the Glenwood substation two variety tests by different investigators have shown the practical value of the Hamakua Hybrid in that district where it was successfully grown in one patch of 4 acres with a reported yield of 401 bags. Glenwood section has an annual rainfall of some 250 inches." Report, 1918, p. 41.

"The new Hamakua hybrid potato, known as Yamato No. 4 . . . is a great improvement over the original in form, color, smoothness, and culinary qualities. It retains the resistance to blight which characterizes the original variety." Report, 1920, p. 60.

Comment. While there is some hope that superior potato varieties resistant to disease may be developed in time, farmers must for the present rely on systematic fungicidal dipping and spraying practice to insure against loss from disease especially when growing standard varieties. That the Hamakua or Yamato Hybrid has demonstrated its inherent resistance to the commoner diseases, especially the late blight so universally prevalent, there can be no question. This should give added zeal for further improvement.

Potato Disease, (cont.) Control by Cultural Methods. "Successive plantings of Irish potatoes from November 7 until March

7 show that better yields are obtained by planting at the latter date. The fall planting was attacked by root-rot fungus . . . and a stem rot . . . . These fungi are more destructive on early planted potatoes and in wet weather. The later planted crops were not so badly attacked by root-rot, but were killed by blight . . . Experiments with various size seed pieces were made, but the yield in most cases was determined more by the number of days' growth before blighting than by the seed." Report, 1913, p. 39.

Comment. Some potato diseases are doubtless seasonable and may possibly be controlled in part at least by planting at the most favorable seasons. Late maturing potatoes have usually been found to blight more severely than the early maturing ones. However, more study is necessary to determine the controlling factors in this phenomena.

We are indebted to A. S. T. Lund for recovering the following interesting excerpts from certain issues of "Polynesian," an English daily published in Honolulu in the '50's.

August 23, 1851

"Proceedings of a meeting of the potato growers of Kula, Maui, in the vicinity of the harbor of Kalepolepo. At a meeting of the potato growers on the 17th day of June, at Waiohuli, the following agreement was entered into in regard to the price of potatoes: Resolved, by the people, that we will sell good potatoes at three dollars a barrel, and if of inferior quality, the buyer and seller will agree upon the price.

J. H. Napela, Secretary

Wailuku, Maui"

Advertisement, August 16, 1851.

"Irish Potatoes - Families, hotels and shipping supplied with potatoes at the lowest market rate by Aldrick and Russ."

Advertisement September 6, 1851:

"The Best Quality

of

Irish Potatoes

in any quantities

at the

lowest prices

by

L. L. Torbert

at

Honuaula, East Maui

Cargoes bought on commission at $1.50 per ton or 12½¢ per bbl. There is a greater proportion of the Red potatoes at Honuaula than any other part of the potato region; Honuaula is the most convenient anchorage at the island of Maui to get the cargo on board."

Cooperative Extension Work in Agriculture and Home Economics, University of Hawaii and United States Department of Agriculture Cooperating. Acts of May 8 and June 30, 1914.