HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge,
Honolulu, Hawaii.

BULLETIN No. 45.

Under the supervision of the STATES RELATIONS SERVICE,
Office of Experiment Stations, U. S. Department of Agriculture.

POTATO DISEASES IN HAWAII AND THEIR CONTROL.

BY

C. W. CARPENTER, Plant Pathologist.

Issued January 24, 1920.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

Hawaii Agricultural Experiment Station,
Honolulu, Hawaii, October 25, 1918.

Sir: I have the honor to submit herewith and to recommend for publication as Bulletin No. 45 of the Hawaii Agricultural Experiment Station a paper entitled "Potato Diseases in Hawaii and Their Control," by C. W. Carpenter, pathologist of the station. The potential as well as actual importance of the potato industry in the Hawaiian Islands makes the present paper both timely and valuable. The absence of cold winter weather, together with the almost continuous cultivation of patches to potatoes throughout the year in most sections, makes the problem of control of potato diseases much more difficult than in the mainland of the United States.

Respectfully,

J. M. Westgate,
Agronomist in Charge.

Dr. A. C. True,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. True, *Director.*

Publication authorized.
D. F. Houston,
Secretary of Agriculture.

POTATO DISEASES IN HAWAII AND THEIR CONTROL.

CONTENTS.

INTRODUCTION.

The growing of Irish or white potatoes in Hawaii was at one time a relatively important industry. According to Sedgwick,[1] in the middle of the last century potatoes stood at the head of the list of exports and in 1849 the number of barrels exported was 51,957. Since that time production has dwindled and consumption increased until, in the year 1916, 189,212 bushels were imported from the coast States, an amount approximately equal to former exports. Various factors, not the least of which is the introduction of diseases, have tended to make the growing of this crop difficult, while repeated crop failures and discouraging marketing features are potent elements in lessening production. The largely increased consumption has resulted from the proportionate increase in the number of people using this crop.

A considerable quantity of potatoes is still raised in the islands in spite of the frequent crop failures. The greater part is grown in the Kula and Makawao sections of Maui and near Waimea and Hamakua, Hawaii. Small patches of from one-quarter to 5 acres are the rule, and a considerable quantity is grown for home use. An approximation as to the present annual production is hard to reach, though it is probably not in excess of 30,000 bushels.

As a sound agricultural policy it is desirable that this languishing industry be fostered, and that so far as possible the Territory be self-supporting with respect to this commodity. It is believed that by the application of improved cultural practices, fertilization, and pest-control methods present production can be doubled or trebled without any increase in acreage. The present rate of import of this staple furnishes an indication of the available market.

Since the writer came to this station in 1916, attention has been largely devoted to a study of the potato crop and the reasons for

[1] Sedgwick, T. F. Potatoes. Hawaii Sta. Rpt. 1901, p. 374.

crop failures. It is estimated that from one cause or another at least 50 per cent of the crop has been lost during the period under observation. The experience of the past two years justifies the conclusion that potato-crop failures in the islands result from the following causes: (1) Use of poor seed, (2) continuous cropping, (3) diseases and insect pests, and (4) unsatisfactory soil conditions. Fundamentally diseases and insect pests are the most important factors, the others mentioned being merely contributing causes.

The diseases which have come under observation have been identified, and the experience gained furnishes ground for the assumption that control measures found useful for combating these same diseases in other sections are applicable here with but little modification. It is realized that attention has not been devoted to this problem for a sufficiently long period to furnish a basis for more than tentative conclusions upon many of the problems of potato production, but this bulletin has been written in order to put the results of the study into the nature of potato failures and control measures into shape suitable for meeting the increasing demand for information.

Attention is directed to certain cultural practices in their relation to disease, and the preventive and control measures which have been found applicable are described. Where no data are available for Hawaiian conditions, information as to methods in use in other localities is freely drawn upon. The diseases, insect pests, and other causes of lessened yields thus far observed are discussed. Several serious diseases affecting the Irish potato in other localities but not yet found in the islands are described in order that Hawaiian potato growers may guard against their introduction.

PREVENTION AND CONTROL OF POTATO PESTS.

GOOD SEED.

The question of what constitutes good seed is fundamental in the growing of a healthy potato crop. Good seed potatoes should be true to variety, from productive plants, firm, free from disease, uniform in size and shape, not overripe, and not weakened by sprouting. Such seed is difficult to obtain in Hawaii. It is probable that satisfactory local seed can best be obtained by each grower's maintaining a seed plat, or possibly a few growers in each section might well specialize in seed production.

Certified seed.—The best seed is that from the mainland, certified by the authorities of the States. The label "Certified Seed" shows that the seed has been grown under a system of State inspection. According to the varying requirements of the different States such seed is free from certain diseases and shows only a definite allowable minimum of other specified diseases.

The mere fact that the seed purchased is from the coast is not sufficient indication of freedom from disease. Imported seed and table stock used for seed purposes in the Territory are constantly found infected with several serious diseases, among which are Fusarium wilt, Rhizoctonia, black scurf, corky scab, etc. (See figs. 1 and 2.) Unless the seed is carefully inspected there is always the possibility of introducing diseases not hitherto prevalent in the islands. If mainland seed is used, the certified sort should be in-

FIG. 1.—Potato diseases not controllable by treatment. Sort out and reject all tubers which look like these: A, Common scab, a severe case; B, internal browning; C, late blight dry rot; D, Fusarium dry rot; E, blackleg tuber rot; F, internal browning; G, a wilt-infected tuber with discolored ring at the stem end. (From U. S. Dept. Agr., Bur. Plant Indus., C., T., and F. C. D. Circ. 3.)

sisted upon. Before planting it should be examined, sorted, if necessary, and disinfected with one of the fungicidal solutions (p. 9).

The Fusarium wilt is a most serious disease almost constantly carried by imported seed (Pl. I) and very prevalent in California. Probably the best source of seed for Hawaii is the Willamette Valley, Oreg., where the Fusarium wilt is of infrequent occurrence. The seed certification boards of some States allow a small percentage of blackleg in stands passed as certified stock. It is necessary, therefore, to inspect carefully all imported seed for blackleg-infected tubers (see fig. 7, p. 38) and to sort these out and destroy them.

The seed plat.—In the chief potato sections a portion of the farm should be set aside for growing seed potatoes for subsequent plant-

ings. Here the best available seed should be planted and plants carefully watched and cared for through the growing period.

Roguing.—Roguing the seed plat is practiced with the object of eliminating undesirable plants before the tubers are harvested in order that such plants may not be propagated. The plants are examined from time to time and those not true to the variety or those diseased or otherwise undesirable are destroyed. Varietal mixtures can best be detected at flowering time. In roguing, a knowledge of potato diseases is valuable.

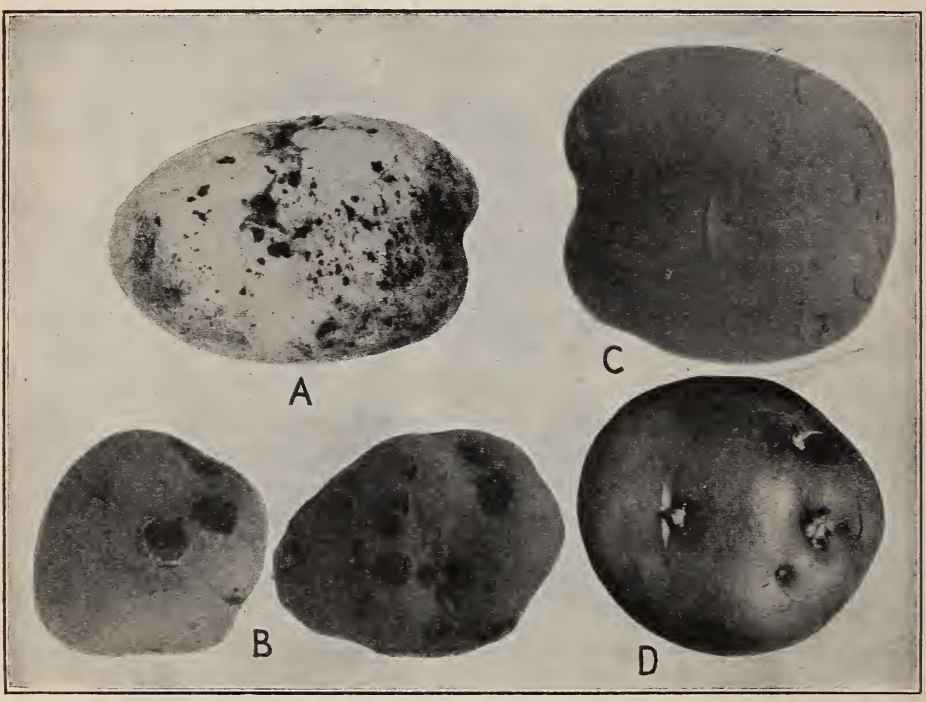

FIG. 2.—Potatoes that may be planted after treatment: A, Black scurf; B, common scab. Such potatoes may be planted after treatment, but it is better still to select perfect types of seed tubers, like those illustrated by C and D, for planting. (From U. S. Dept. Agr., Bur. Plant Indus., C., T., and F. C. D. Circ. 3.)

Seed from productive plants.—As many unproductive plants are found within a variety, selection should be practiced within the variety. Stuart[1] has recorded the following results with 12 varieties, showing the average yields from planting the progeny of strong and weak plants:

Strong tuber units: 3.28 pounds of primes, 1.18 pounds of culls, total 4.46 pounds.

Weak tuber units: 0.20 pound of primes, 0.51 pound of culls, total 0.71 pound.

[1] Stuart, W. Good seed potatoes and how to produce them. U. S. Dept. Agr., Farmers' Bul. 533 (1913), p. 7.

The strong plants gave more than 16 times as large a yield of primes or merchantable tubers and only a little more than twice as many culls as did the weak plants.

Uniformity.—Selection has shown that within a variety there are strains which, when isolated, behave in a more or less uniform manner with respect to size and shape of tubers. Selection should be practiced from the hills at the time of digging the seed plat, keeping as specially desirable seed, tubers from hills yielding a maximum number of healthy tubers of fair size and uniform shape.

Hill selection.—This method of selecting seed consists in marking, by stake or otherwise, the most desirable plants during the growing season. At digging time those marked plants having a maximum number of desirable tubers are specially set aside for seed. In this way desirable varietal characters of the plants and high-yielding qualities are selected together.

Immature seed.—European growers have come to believe that, other things being equal, larger crops are produced by immature seed than by mature seed. This refers to maturing of the seed in the ground. Most of the locally grown seed at present is immature, since the fields are regularly visited by blight or the tops dry up with the Fusarium wilt disease, etc., at about the time of flowering.

Large v. small seed tubers.—The use of small seed tubers can be countenanced only when these are known to be the progeny of productive plants. From the quotation from Stuart (p. 6) regarding the yield of strong and weak plants it will be seen that the strong plants produced more than 16 times as great a weight of large tubers as the weak plants, but only a little more than twice as great a weight of small tubers. In selecting small tubers from the lot it is evident that a large proportion of tubers from unproductive plants would be chosen.

Ballou[1] writes as follows regarding the use of large and small tubers for seed:

> [The use of large tubers gives]: (a) A very heavy, perhaps almost total, percentage of the high-yielding strains; (b) a heavy percentage of the average or moderate-yielding strains; (c) a very small percentage of the inferior or low-yielding strains.
>
> [The use of small tubers gives]: (a) A very insignificant percentage of the superior or high-yielding strains; (b) a small percentage of the moderate-yielding strains; (c) a very heavy, almost total, percentage of the low-yielding or inferior strains.

The significance of the above data with respect to the common local practice of marketing all fair-sized tubers and keeping only the culls for seed needs no comment.

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[1] Ballou, F. H. The status of the potato-growing industry in Ohio. Ohio Sta. Bul. 218 (1910), p. 587.

Whole v. cut seed.—Provided the young plant is furnished with a sufficient supply of nourishment by the seed piece until able to elaborate its own food, there does not appear to be any difference whether the seed be entire tubers or cut pieces. It is true, however, that within limits the larger the seed piece the larger will be the resultant crop, but the smaller the percentage of marketable tubers. Whole tubers insure a good stand with greater freedom from disease. However, the growth of too many sprouts is to be discouraged, since too great a number of tubers will be set and comparatively few will be able to reach a satisfactory size.

Greening the seed by exposure to light.—In order to hasten the germination or sprouting of seed, that is, to shorten the rest period, it is a common practice in Kula, Maui, to spread the tubers to be used as seed, as soon as they are dug, under a thin shade of bushes for several weeks or until they sprout. It is claimed that they will sprout in about half the ordinary dormant period. There is as yet no experimental evidence to support or controvert this statement of the farmers. This exposure, especially to the high temperature of midday, probably serves to prevent any tendency of the seed to rot from the late blight fungus, but results in loss from other rots and from such insects as the tuber moth. The shortened period of dormancy, if a fact, is advantageous when potatoes are grown almost continuously and seed is difficult to obtain at certain seasons.

Seed selection in relation to disease control.—Seed selection is not only of value in obtaining pure high-yielding strains within a variety, but it is of fundamental importance in preventing those diseases which are carried by the seed. Such supposedly nonparasitic but inherent diseases as curly dwarf, leaf roll, etc.; the fungus diseases late blight, Fusarium wilt, rosette (Rhizoctonia), and those due to the scab fungi; as well as certain insect pests, are carried by the seed. For avoiding these diseases any of the following well-known methods of selection are available: (1) Selection from the pile or lot, (2) field selection, (3) hill selection, and (4) regional selection and use of certified seed.

Selection of healthy tubers of uniform size and shape for seed from the mass is valuable in disease control, though not necessarily so in obtaining productive strains. As mentioned above, hill selection is of value both in disease control and in obtaining productive strains. Regional selection and the use of certified seed may well serve as means of starting seed plats in Hawaii. Seed should not be obtained from regions or from fields where noxious pests are known to be prevalent.

Cutting seed.—In cutting potatoes for seed the tubers must be so cut that each seed piece or set shall have at least one strong eye, and it is desirable that each shall weigh about 1½ ounces. First cut a thin slice from the stem end of the tuber and examine the flesh for

discoloration of the vascular or woody ring. Brownish or black discoloration at this point indicates Fusarium wilt or other infection. Such tubers are not suitable for seed. Then cut the tuber lengthwise through the bud cluster at the end and through to the stem end. Then divide each half crosswise. With large tubers further division can be made, but the cuts should always be so made as to insure blocky pieces when possible. It requires about 22 bushels of seed adequately to plant an acre at the standard distance of rows 3 feet apart and seed pieces 1 foot apart in the row. Less than half this amount is commonly planted.

Potato seed disinfection.—Diseases such as corky scab, Rhizoctonia scab, and rosette (Pl. VIII), 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 disease for which the seed is treated. It is on the whole a 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 is in favor of 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)	pint	1
Water to make	gallons	30

The sacks containing the potatoes should be immersed in this solution for two hours, after which the tubers should be removed 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 internal poison*, and it should be handled with this fact always in mind. The solution corrodes metal and therefore only wood and nonmetallic containers should be used. The formula is as follows:

Corrosive sublimate	ounces	4
Water	gallons	30

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

SUITABLE POTATO SOIL.

Kind of soil and method of treatment.—So far as possible soil free from potato diseases should be chosen. As the Irish potato is a cool-climate crop, in the Hawaiian Islands it is at home at an ele-

vation of 2,000 to 3,000 feet or more on rather loose-textured, well-drained soils. In any case heavy wet soils poorly drained and hard to work are not suitable for potato culture. In some potato soils in Kula, Maui, the presence of a layer of hardpan a few inches under the surface indicates that shallow surface plowing has too long been practiced and that the conditions of apparent soil exhaustion might be largely improved in such fields by deeper plowing. Hilling up the plants might well receive more attention as an aid in checking attack by the potato tuber moth. Crop rotation should be practiced more and more here, not only to increase the fertility of the soil but also to combat the prevalent diseases and insect pests. Seed selection is almost useless or is of temporary value unless combined with rotation. 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. Similarly, the tuber moth, which is most serious in dry years, can possibly be held under control by 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 of 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 latter being favorable to the development of corky scab, lime or wood ashes should never be applied to potato fields, as 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.

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 used varies 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 alone and 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 it 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 mixture is made up according to the following formula, which is often referred to as 1:1:10 or 5:5:50 Bordeaux.

Bluestone (copper sulphate)	pound	1
Quicklime (not air slaked)	do	1
Water to make	gallons	10

The mixture is prepared by dissolving the bluestone by hanging it, 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 5 gallons. Make a lime paste by slaking the pound 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 5 gallons. Just before the Bordeaux mixture is required for use, pour the 5 gallons of diluted bluestone and 5 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, but Bordeaux mixture should be used the day it is made. However, if sugar is stirred in at the rate of $\frac{1}{10}$ pound to 10 gallons 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 last-

ing 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 minute membranes. The copper in the membranes, rendered slowly soluble by the action of the carbon dioxid of the air, forms a solution in any 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. (See fig. 3.)

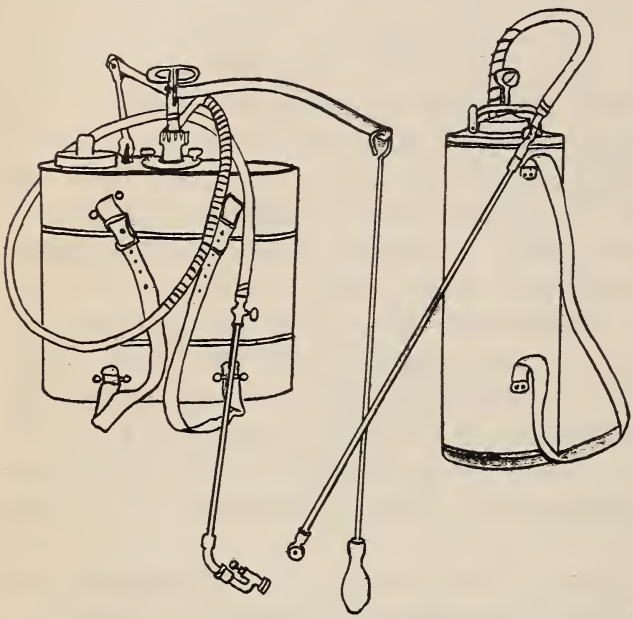


FIG. 3.—Desirable types of hand sprayers, with extension rods permitting thorough underspraying of the foliage.

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.

Where there is difficulty in spraying plants due to the waxy surface of the leaves, or where the spray does not stay on owing to heavy rains, a sticker made up according to the following formula may be used to advantage:

Resin	pound	1
Sal soda (crystals)	do	½
Water	gallon	½

The ingredients should be boiled together until a clear brown sirupy liquid appears, then cooled and added to 50 gallons of Bordeaux mixture (or proportionately for smaller quantities of spray).

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 (fig. 5, p. 31), 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 bait remains to be seen. For the tuber moth, arsenate of lead in Bordeaux will probably be of considerable benefit.

Lime-sulphur spray or dry sulphur for the control of mites.—For the control of the potato mite (Pls. XII and XIII), which in dry and hot situations causes the death of young growth and premature development of the plant, a lime-sulphur spray made up as follows has been found effective:

Sulphur	pound	1
Quicklime	do	1
Water to make	gallons	20

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 surphur 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 (p. 26). The chemicals needed to make sufficient solution for 50 gallons of copper carbonate fungicide are as follows:

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

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)	pounds	2
Ammonia	pints	3
Water to make	gallons	50

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 25 pounds of bran thoroughly mix while dry ½ 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	pounds	60
Salt	do	2
Paris green	pound	1

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

HANDLING, SORTING, GRADING, AND STORING.

To prevent bruising, potatoes should be carefully handled at all times. The slightest wound is sufficient to open the way for the entrance of rot-producing organisms. Care in handling is especially necessary at digging time when the skins are tender.

All bruised and rotted tubers should be sorted out before shipping or storing, and if the crop is to be stored any length of time re-sorting

may be necessary. Potatoes carefully graded as to size are much more readily sold at a good price than when large and small are mixed. All potatoes of inferior size should be sorted out and used on the farm. It is a poor policy to leave in the shipment any bruised or decaying tubers, as these are valueless and by wetting and otherwise making the lot unattractive they may result in considerable loss to the shipper through market charges for re-sorting.

Outside the cold-storage warehouses a sufficiently cold place for the storage of potatoes is difficult to maintain in Hawaii. For the best results a temperature of about 35° F. is required. It is probable that houses quite suitable for the storage of this crop could be constructed at the higher altitudes where potatoes are most successfully grown should there develop sufficient economic advantage in holding the crop. Since the potato consumption in the islands is so greatly in excess of the production, there is little incentive to store. However, a small storage place, screened against insects, tightly built, and provided with close-fitting doors, so as to take advantage of the night temperature, would be valuable in preventing loss from shipping to a glutted market. The place could be used for holding seed stock, for fumigating and storing beans, corn, etc.

POTATO DISEASES KNOWN TO OCCUR IN HAWAII.

CLASSIFICATION.

In order that plant diseases may be intelligently combated, an understanding of their nature is necessary. According to their causes 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 nonparasitic 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 water. Under favoring conditions in the presence of the potato plant, the disease progresses more or less virulently. The following parasitic diseases, grouped according to the nature of the parasite as fungus or insect, have been found factors in potato production in Hawaii: Fungus diseases, including 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 oxysporum*, *F. radicicola*, and *F. coeruleum*); insect pests, including tuber moth (*Phthorimæa operculella*), cutworms and a similar leaf-eating worm

locally called "poko," and mites (unidentified form of Tetranychidæ).

The nonparasitic 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 tipburn of the leaves. It may be noted that many of the diseases usually classed as nonparasitic, though imperfectly understood, can be controlled through seed selection and elimination of undesirable strains. Such are the inherited diseases, leaf roll, curly dwarf, and mosaic, which probably will not be serious factors in the Hawaiian potato industry.

IDENTIFICATION.

Many times a knowledge on the part of the grower of the different diseases which attack the potato would save crops now needlessly lost through failure at the critical time to apply the proper treatment to hold the disease in check.

Plants which appear unhealthy for any reason should be examined with the following points in mind; and with the accompanying key as a guide, a working knowledge of epidemic diseases in Hawaii is soon acquired. All growers should learn at least to recognize late blight, early blight, mite disease, Fusarium wilt, and rosette.

Points to be Noted in Examining a Plant.

Note how the plant differs from the normal. If the leaves have diseased spots, note their character. If the leaves wilt, note which ones do so, the new small leaves or the lower older leaves. The presence of worms in the leaves and stems indicates tuber moth. If the new top growth curls, twists, becomes fuzzy, and dries up, while at the same time the leaves become bronzed on the lower side, it is the work of the potato mite. If the lower leaves wilt and drop off more than normally or some leaves roll up in tubular form and no diseased spots are present, examine the underground stem near the soil level. If it is girdled with a cankerous, dry, brown lesion, Rhizoctonia may be present, causing rosette disease, or if the stem is here a shell with the center rotted out, the plant is perhaps attacked by Sclerotium wilt. Sometimes the stem borer does similar damage, in which case the burrow is readily traced and the worm found. If the stem appears normal externally, split it with a knife and examine the inside at the ground level and below. If the vascular tissue—that is, the woody portion a short distance in from the surface—shows a brown discoloration which is traceable toward the root system, the plant is suffering from lack of water because its water-conducting apparatus is plugged by fungus threads (Fusarium wilt).

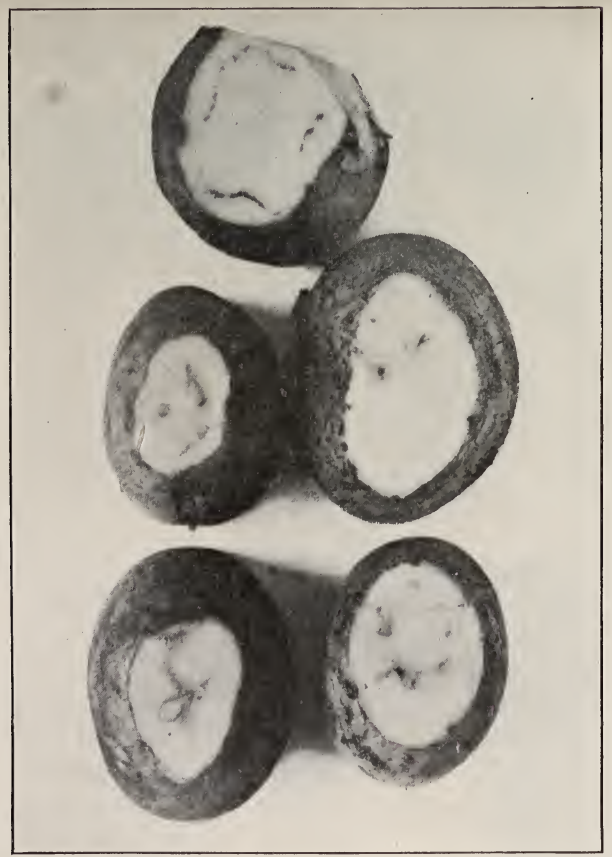
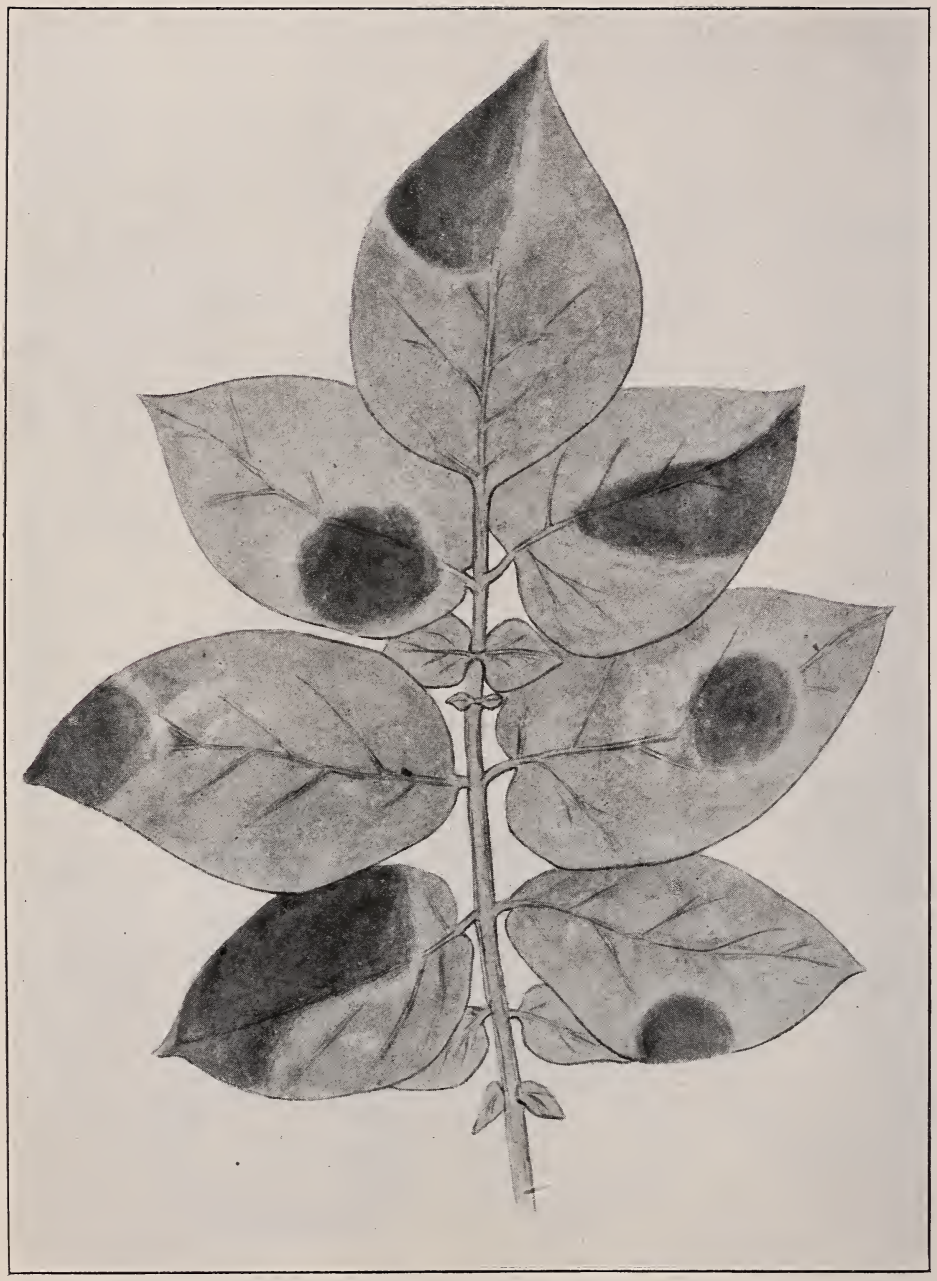


FIG. 1.—CUT STEM END OF TUBERS SHOWING DISCOLORED VASCULAR RING.

FIG. 2.—STEMS SPLIT TO SHOW DISCOLORATION.

FUSARIUM WILT DISEASE.



POTATO LEAVES SHOWING LATE BLIGHT.

FIG. 1.—ROWS AT LEFT SPRAYED ONCE WITH BORDEAUX MIXTURE, ROWS IN CENTER NOT SPRAYED.

FIG. 2.—CENTER ROWS SPRAYED, OUTSIDE ROWS NOT SPRAYED.

FIG. 3.—POTATOES PILED FOR COMPARISON.

POTATO SPRAYING EXPERIMENTS.

FIG. 1.—SEVEN-ACRE FIELD OF POTATOES IN WHICH LATE BLIGHT WAS CONTROLLED BY THOROUGH SPRAYING WITH BORDEAUX MIXTURE.

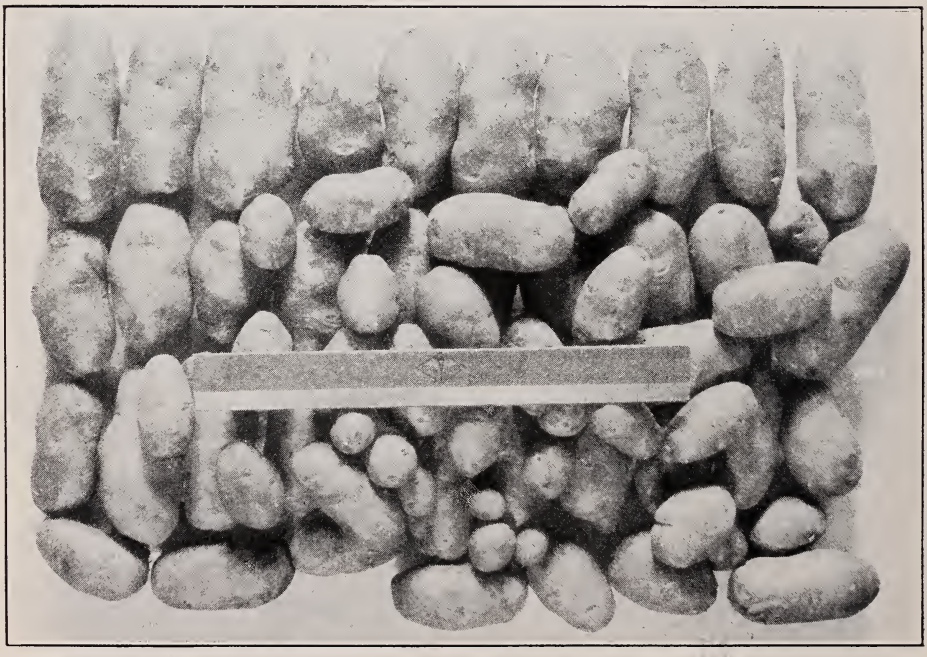


FIG. 2.—YIELD OF 10 AVERAGE HILLS IN ABOVE FIELD; WEIGHT, 17½ POUNDS.

FIG. 1.—COMPARATIVE TEST OF EARLY ROSE AND HAMAKUA HYBRID VARIETIES. EARLY ROSE DEAD OF LATE BLIGHT IN 60 DAYS.

FIG. 2.—YIELD OF 96 HILLS OF EARLY ROSE VARIETY AT 60 DAYS; WEIGHT, 7½ POUNDS.

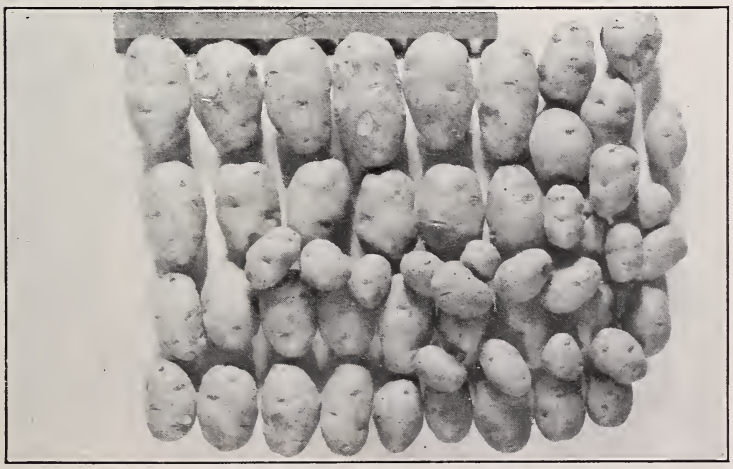


FIG. 3.—YIELD OF 20 HILLS OF HAMAKUA HYBRID VARIETY AT 90 DAYS; WEIGHT, 9½ POUNDS.

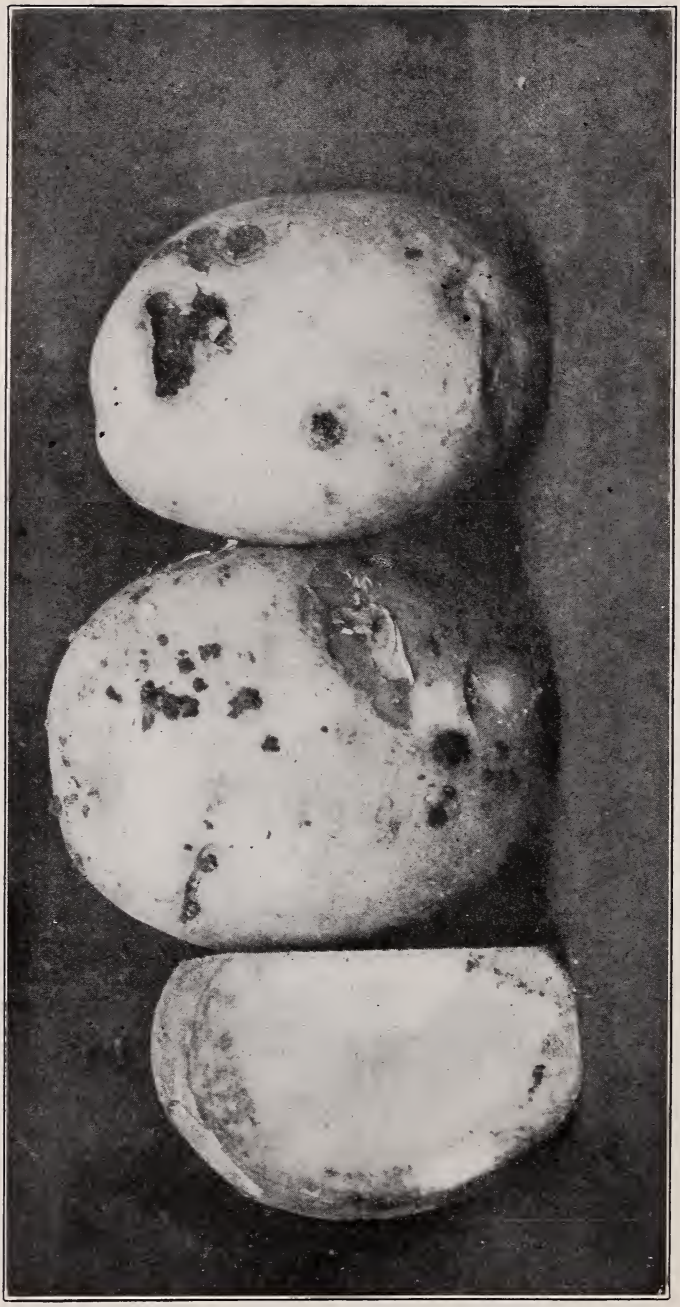
EARLY OR DRY BLIGHT OF POTATOES.

Note concentric rings in diseased spots.

FIG. 1.—STEMS OF YOUNG POTATO PLANTS GIRDLED BELOW SOIL BY RHIZOCTONIA.

FIG. 2.—STEM OF POTATO GIRDLED BY RHIZOCTONIA.

Note closely set tubers.



SOME POTATO DISEASES.

Left, cut tuber showing presence of late blight rot; center, black scurf due to Rhizoctonia (causing rosette on aboveground parts); right, common appearance of Maui potatoes, probably due to Rhizoctonia followed by wireworms, etc.

LEAF ROLL AND ROSETTE ASSOCIATED WITH STEM LESIONS DUE TO RHIZOCTONIA.

AERIAL TUBERS PRODUCED AS A RESULT OF STEM GIRDLING BY RHIZOCTONIA.

FIG. 1.—POTATO SECTION SHOWING INJURY BY LARVÆ OF TUBER MOTH.
(From U. S. Dept. Agr. Bul. 427.)

FIG. 2.—INJURY BY POTATO TUBER MOTH TO POTATO PLANTS, SHOWING MINES IN LEAVES, PETIOLES, AND STEMS.
(From U. S. Dept. Agr. Bul. 427.)

MITE DISEASE OF POTATO SHOWING CHARACTERISTIC APPEARANCE OF BUDS, SHOOTS, AND LEAVES. ADULT MITE, YOUNG MITE, AND EGG. X 160.

FIG. 1.—MITE-INFESTED POTATO PLANT.

FIG. 2.—ABOVE PLANT 10 DAYS AFTER SPRAYING WITH LIME-SULPHUR.

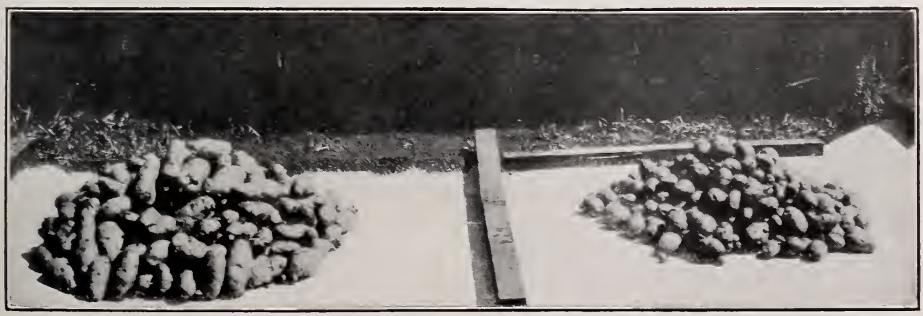


FIG. 3.—LEFT, YIELD OF 50 PLANTS SPRAYED FOUR TIMES, WEIGHT OF TUBERS 49 POUNDS; RIGHT, YIELD OF 50 UNSPRAYED PLANTS, WEIGHT OF TUBERS 24 POUNDS.

FIG. 1.—NEMATODE-INFESTED POTATOES.

FIG. 2.—NEMATODE-INFESTED TUBERS CUT TO SHOW THE WATERY AREAS OR SPOTS NEAR THE PEEL.

KEY TO POTATO DISEASES.

Foliage diseases:
Leaf spots.
Spots small, one-sixteenth to one-fourth inch in diameter, rounded to angular, brown, and becoming dry and falling out, leaving shothole effect. Spots often marked with concentric lines or successive borders of growth. Prevalent in dry seasons.
Early blight (Pl. VI and p. 23).
Spots one-fourth to one-half inch or more in diameter, rounded, spreading rapidly, and bordered by lighter yellow-green zone; on underside of leaf in damp weather a delicate frost-like mildew may be seen; in wet weather the plants entirely rot in a few days. Preventive treatment must be given before disease starts or as soon thereafter as possible; if plants are badly attacked, spraying will not be worth while.
Late blight (Pl. II and p. 20).
Wilting and rolling of leaves, etc.
Young leaves and new growth first affected. Leaves bronzed on underside, twisted, and curled up, becoming fuzzy and drying up, the plant dying from the top downward. Mites can be found with hand lens. Prevalent in the dry season.
Potato mite disease (Pls. XII and XIII and p. 31).
Plant appears to suffer from lack of water and dies prematurely; lower leaves wilt and drop off; interior of lower stem at ground level shows browning of vascular or woody portion.
Fusarium wilt (Pl. I and p. 18).
Leaves more or less rolled and tubular; plant spreads out and grows all to top; tubers few, small, and set close to stem in a bunch or forced out of the soil; tubers forming in axils or leaves in advanced cases; stem girdled below ground with brown cankerous lesion.
(Rosette (Rhizoctonia) (Pls. VII, VIII, and IX and p. 24).
Lower leaves wilt; stem at soil level rotted through or hollow, with white fungus growth producing mustard-seed-like sclerotia.
Sclerotium wilt (p. 25).
Leaves roll up in tubular form, or plant wilts and generally appears as if the stem were broken off; interior of stem may show burrow of the stem borer, or possibly the plant is cut at soil level by cutworms.
Borer, cutworms, etc. (Text fig. 5 and p. 30).
Tuber diseases.
Tuber rots.
Field rots.
Burrows with worms inside and soft ill-smelling rot, following foliage infestation by leaf-mining worm.
Tuber moth (Pl. XI and p. 29).
Brown dry rot running just under surface of tuber, which often has a purple tinge. This is the late blight rot, usually followed by various soft rot organisms; it occurs in heavy, cold, wet soils when late blight has attacked the tops.
Late blight rot (Pl. VIII and p. 28).

Tuber diseases—Continued.

Tuber rots—Continued.

Storage rots. Wet and dry rots of various appearances, often with mycelium-lined cavities and frequently rather soft and watery-brownish. These are the Fusarium rots which follow wilt infection of plants and most commonly start at the stem end. Slight wounds also furnish entrance to the several wound-invading, Fusarium-rotting organisms.

Fusarium rots (p. 28).

Surface blemishes.

Rough, corky scab spots scattered over surface or covering it entirely.

Corky scab (Text figs. 1 and 2 and p. 26).

Small black raised masses resembling dirt on skin; not readily washed off but easily scraped off with the nail. Badly attacked tubers roughened and cracked open. A trouble occurring simultaneously with rosette and caused by the same organism.

Black scurf or russet scab (Pl. VIII and p. 24).

Numerous small galls and pimples on the surface of the tuber. Within the galls are minute, pearly-white, glistening bodies. If the tuber be cut a row of these glistening bodies may be traced about one-eighth inch under the peel. Affected tubers rot quickly.

Nematode or gallworm (Pl. XIV and p. 33).

PARASITIC DISEASES.

Fusarium Wilt (*Fusarium oxysporum*).

The wilt disease of Irish potatoes caused by the fungus *Fusarium oxysporum* is prevalent in the principal sections of the islands where this crop is grown. Potatoes from California, both seed and table stock often used here for seed, are frequently found infected with this disease. It is the most serious and persistent disease with which the growers of that State have to contend, and it is highly probable that the disease was introduced into Hawaii on seed from California.

The disease is characterized by a slight rolling and wilting of the leaves and premature drying of the plants. The lower leaves wilt, droop, and die first, and the color of the foliage in the early stages may be lighter than usual. As a rule the disease is not evident until the plants are about a foot or more high. The appearance of the plants is the same as that of plants suffering from lack of water, and this is really the case, even though there is plenty of water in the soil. Upon splitting, the woody portion of the underground stem is seen to be discolored, that is, more or less browned (Pl. I, fig. 2). The fungus *Fusarium oxysporum* enters the plant either from the seed or from the soil through the smaller roots and works its way up through the water-carrying vessels of the roots and stem, and often later through the stolons into the young developing tubers (Pl. I, fig. 1). The fungus mechanically obstructs the water ducts

or vascular system and limits the amount of water available to the plant. Whether there are other injuries to the plant through secretions of harmful products by the fungus has not been demonstrated.

The wilt disease results when seed carrying the disease is used or when healthy seed is planted upon soils already infected with the parasite. With continuous cropping the disease becomes more serious from year to year until finally, unless seed selection and crop rotation are practiced, potatoes can no longer be profitably grown. Some of the fields in Maui appear to have reached this stage, partly from soil exhaustion. The plants die and dry up shortly after blossoming, and the tubers remain small and only partly developed.

The fact that Fusarium wilt may be readily overlooked, the premature drying of the plants being mistaken for the natural result of prevailing weather conditions, constitutes an insidious danger, since diseased plants yield a preponderance of small unmarketable tubers, which, according to the Hawaiian method of marketing, are kept for seed, the large and medium sized tubers being sold. The result of this practice and of continuous cropping is that only in an occasional season can anything like a satisfactory crop be raised in fields where this disease is established.

Control.—The control measures which have been suggested for this disease consist chiefly of seed selection and crop rotation. Neither of these measures will entirely eliminate the wilt fungus, nor is it probable that a rotation of less than three years will appreciably improve badly infected fields, but it is expected that in the absence of susceptible crops for a three-year period the virulence of the disease will be reduced and one crop of potatoes can then be grown profitably provided healthy seed be used.

Seed from disease-free fields should be obtained whenever possible. If imported seed is used, it should be secured from regions where this disease is not prevalent and certified seed should be insisted upon (see p. 4).

Detection of wilt infection in seed.—The following is a useful though not absolutely sure means of detecting the presence of the wilt parasite in seed potatoes. The stem ends of a large number of the tubers to be tested are cut across with a knife, exposing the flesh within the tuber where the woody fibers from the stolon (rootlike stem to which the tuber is attached while growing) spread out to form the tuber ring. If a dark-colored or brown ring appears or brown fibers penetrate the flesh at this point (Pl. I, fig. 1), the tuber should be considered highly suspicious. If many tubers show such a discoloration, the whole lot should be rejected for seed purposes. Considering the prevalence of wilt infection in most available seed, it is advisable to cut off and discard the stem ends of all seed planted.

This test for wilt is not absolutely sure, as not all tubers carrying the wilt disease show the discoloration sufficiently to indicate definitely the presence of the fungus. Certain other diseases cause a somewhat similar discoloration, and in some cases tubers show a very slight yellowing of the vascular ring which appears to follow a long period of dormancy and to be unassociated with disease. In any event these doubtful tubers are not desirable types to propagate.

Late Blight (*Phytophthora infestans*).

No disease of the Irish potato is more destructive than the late blight when the conditions favor its development. Late blight is caused by the fungus *Phytophthora infestans*. The name late blight was probably given to this disease to indicate that it occurs most commonly late in the year and to contrast it with the early blight (*Alternaria solani*) which is prevalent in the dry weather of midsummer. It is apparent that the common names of these two diseases are without significance in Hawaii. The names dry blight and wet blight for early blight and late blight, respectively, are thought to be locally more appropriate common names.

Wet blight, or late blight, is widely prevalent and destructive in the Hawaiian Islands. It seems probable that this disease and the wilt disease (*Fusarium oxysporum*) are the most potent factors in lessening yields and discouraging potato growing in these islands. When the late blight appeared in Ireland in the middle of the last century it so devastated the potato crops, upon which the people largely depended for food, that famine resulted. Since that time the disease has become prevalent in many of the potato sections of the world, and it has been the object of special investigation wherever it occurs. Various means have been devised for its control, but there is no ground for hope that it can be exterminated, and potato growers will probably always have to contend with it.

The disease is manifested in the leaves by dark, more or less rounded, water-soaked spots or areas (Pl. II), which may or may not increase rapidly in size and number, according to weather conditions. Upon the lower surface of the leaves of affected plants growing in damp situations a characteristic delicate frostlike mildew appears. This is the parasitic fungus bearing its microscopic spores. The latter are minute seedlike bodies which, spattered about by rain or transferred by contact of the leaves with adjacent moist foliage, carry the disease from plant to plant. In this way a diseased spot upon one leaf may serve to infect a whole field in an incredibly short time. Similarly the spores falling and being washed upon the ground find their way to the developing tubers which they may infect, causing them to rot in the ground or subsequently in storage (Pl. VIII). With continued dry weather the spots upon the

leaves remain about the same size or spread slowly, but with heavy dews or rainy weather the disease progresses rapidly. In a few days the foliage may be all rotted away, the layman perhaps having overlooked the first few spots and being inclined to attribute the trouble to the rain or the hot sun following the rain, etc. In Hawaii, protracted hot weather is sometimes observed to control the disease completely.

Weather conditions which favor this blight are as follows: High relative humidity, low soil temperature, and a high moisture content of the soil. Since such general conditions frequently prevail in the main potato sections of Hawaii, this disease may be expected to appear on almost every crop planted in these localities. Such is the rule. In some places one crop a year may suffer less than the others. The damage from this disease is popularly supposed to be due to the hot sun shining upon wet foliage following light sprinkling rains. There is no question that the major portion of the trouble thus described is the wet or late blight, and not sunscald or tipburn.

In the islands the wet blight is probably carried from crop to crop, as these follow each other almost continuously in the same or adjacent fields, largely by volunteer plants. Where any sort of rotation is practiced, volunteer potato plants are allowed to mature and are dug. This custom will have to be discouraged in any attempt to control diseases and insect pests.

Control.—The control measures worked out for this disease consist entirely of methods of preventing infection. Healthy and vigorous seed stock and rotation of crops are important. Fortunately, Bordeaux mixture, applied thoroughly and in time to the foliage, has proved beneficial in controlling this disease (Pls. III and IV). The insoluble copper in the mixture gradually becomes soluble and prevents the germination of the spores of the fungus which fall on the moist leaves. To be effective the spray must cover the entire surface of the foliage, and it must be there before the spores find lodgment. After infection has taken place, the parasite is out of reach of the spray.

The practical application of Bordeaux mixture to many of the larger fields is being rapidly worked out. In some sections where the blight is most destructive and where the potato would otherwise be at its best, as in the Glenwood section of Hawaii, the frequent and excessive rains make thorough and timely spraying an uncertain and, for the most part, an impossible matter. Even under these conditions, spraying may afford some relief when the weather conditions are such as to permit the spray to dry. The Hamakua Hybrid potato promises to resist the blight under the conditions at

Glenwood, and there is every indication that this variety may solve the blight problem for such districts.

The spraying with Bordeaux mixture thus far carried on by the writer and his associates for the prevention of wet blight or late blight has resulted in an increase in the crop of from 50 to 200 per cent by weight. (See Pls. III and IV.)

Resistant varieties.—For many years attention has been directed to the development of varieties resistant to the late blight in Europe and on the mainland of the United States, but thus far without striking success. Varieties showing resistance have been types not in demand on the American markets.

A type of potato originated by Miss Yamata, of Honokaa, Hawaii, is reported to be much more successfully grown in that locality than any other sort. This type of resistant potato, of which there are two strains, has received the name Hamakua Hybrid from the district in which it first came to the attention of the station. One parent of both strains appears to have been the local variety known as the Portuguese Purple, originally brought to the islands by Portuguese immigrants. One form of the Hybrid is a white and purple mottled tuber, of the general shape of a Burbank, with rather deep sprouts and eyes. The other, possibly a cross between the Portuguese Purple and the Early Rose, has a pink spin and purple eyes and sprouts, and is a more desirable tuber for market.

Practical results support the view that this Hybrid has a promising degree of resistance to late blight in these islands, but experimental evidence is somewhat conflicting. At Glenwood two experiments by different workers have shown its practical value in that district. Four acres of the variety grown in this section yielded over 400 bags of 100 pounds each. At Castner a small patch of the Hybrid and the Portuguese Purple varieties planted October 20, 1917, was unaffected by late blight on February 1, 1918, when other potatoes planted at the same time within a few hundred feet were devastated by the disease. The grower stated that Burbank potatoes planted at the same time as the Hybrid and adjoining them were all dead in 60 days. The Hybrid, therefore, grew through a period of more than three months of weather suitable for late blight. They showed some early blight spots but no trace of the late blight disease.

In order to test the blight resistance of the Hamakua Hybrid, it was also grown in comparison with the Early Rose variety in a small plat at Castner substation (Pl. V). Owing to the poor soil there, the yield of neither variety is normal, but the resistance of the Hamakua Hybrid to late blight is striking. Both varieties grew well the first month, but at the end of 60 days the tops of the Early Rose had been destroyed by the late blight (Pl. V), the 96 hills yielding only $7\frac{1}{2}$ pounds of tubers the size of marbles. The Hamakua Hybrid re-

mained almost without a trace of blight spots, and at the end of the fourth month 20 hills were dug, yielding 9½ pounds of fair-sized tubers. The Hamakua Hybrid grew through weather favorable to blight for most of the period of the experiment.

It appears from the foregoing that the Hamakua Hybrid and one of its parents, the Portuguese Purple, possess a real resistance to the late blight under Hawaiian conditions. Should the indicated resistance to late blight of the Hamakua Hybrid be of more than local importance, the quality of the tubers can doubtless be improved by selection in the direction of market requirements, though there is not the discrimination here against colored and long potatoes that is characteristic of the eastern markets.

Early Blight or Dry Blight (*Alternaria solani*).

Early or dry blight, a fungus disease (Pl. VI) attacking only the foliage of the potato and producing a characteristic spotting and death of the leaves, is prevalent in the Territory in dry, hot seasons and occasionally may cause a loss of from 5 to 25 per cent of the crop in affected fields. As previously noted, the name "early blight" as applied to this disease on the mainland has little significance in Hawaii, unless it be that the disease attacks the plants earlier in their period of growth than is characteristic of the late or wet-weather blight. As previously noted, the name dry blight or dry-weather blight is locally more appropriate for this disease.

The parasitic fungus produces circular to more or less angular, dry, brown leaf spots, often with concentric markings with something of the appearance of a target (Pl. VI). The spots are from one-sixteenth to one-fourth inch in diameter and sometimes confluent, and frequently the dry tissue falls out, giving a shot- hole effect to the leaves. The spread of the spot may be limited in certain directions by the leaf veins, in which case it is more or less angular in shape. The spots caused by the dry blight are from the first dry and brown and the progress of the disease is comparatively slow. The badly affected leaves dry and die after a few weeks. The stems and tubers are not directly affected, but as a result of defoliation and early maturity of the plant the yield is materially reduced.

Early or dry blight appears to be only occasionally serious in the islands. The prolonged drought during the summer and fall of 1917 in the Hamakua district of the island of Hawaii was particularly favorable to its development. A loss of 25 per cent was observed in some cases, most of it due apparently to this disease, though the mite disease, subsequently to be discussed, and bud and leaf infestation with the tuber moth were undoubtedly responsible for a portion of the damage.

Control.—The experience of investigators on the mainland has shown that dry blight can be controlled by timely and thorough spraying with Bordeaux mixture. Where the conditions are favorable to the development and spread of this malady, the plants should be sprayed as recommended for the late or wet blight. As a general practice, potato plants in the islands should be sprayed from three to six times per crop with Bordeaux mixture, fewer sprayings being required in dry seasons than in wet seasons. In the former case the spray will prevent the attacks of the early or dry blight and in the latter the attacks of the late or wet blight.

Black Scurf (Russet Scab) and Rosette (*Rhizoctonia solani*).

The diseases of the potato commonly attributed to the parasitic fungus Rhizoctonia are quite diverse in their general aspects or signs, but they are conveniently grouped together for discussion. The Rhizoctonia fungus is a soil inhabitant which attacks the underground stem and roots of the plant (Pl. VII) with effects varying according to the portion injured.

Black scurf is the name commonly applied to the black accumulated mycelial masses or sclerotia of the fungus which adhere closely to the skin of the tuber in such a way as to be readily mistaken for bits of soil. (See Pl. VIII.) They do not wash off easily, although they are superficial and readily scraped off with the finger nail. This stage of the fungus does little damage other than to the appearance of the tuber, but it is by this resisting stage of the parasite that the disease is largely spread to new land and to new localities.

If tubers affected with the black scurf are planted, the sprouts may be attacked and girdled by the vegetative threads of the fungus. As a result of this action the following types of disease may occur:

Weak plants: The fungus kills or injuries the sprouts and a poor stand and weak plants result (Pl. VII, fig. 1).

Rosette disease and leaf roll: The leaves of the plant become light green and roll upward on the midrib as an axis, becoming tubular (Pl. IX). The plants may be more or less dwarfed. The few undersized tubers which form are set close to the stem, often pushing out of the ground (Pl. VII, fig. 2).

Aerial tubers: The stem below ground is girdled more or less completely. The food elaborated in the leaves and designed for subterranean tuber formation is diverted, and tubers form above ground in the leaf axils (Pl. X).

Growth to top: The stolons or stems of the young tubers are attacked by the fungus and the young tubers being partially cut off from nourishment fail to develop normally. The plant may develop luxuriantly and yield only a few small tubers.

Disfigured tubers: The tubers are frequently covered with the black scurf or sclerotial resting stage of the fungus. The same stage of the fungus is believed commonly to be responsible for rough brownish and russet areas on the surface of the tubers. Throughout such areas the skin is finely and irregularly cracked. Large cracks in tubers are also attributed to the action of this organism as well as to uneven growth, and deep pit-like holes often occur which may be caused by this fungus (Pl. VIII).

The name Rhizoctonia, as used here, is a group name for a number of closely related forms. This sort of fungus is a soil inhabitant which is thought to be favored by heavy, wet, sour soils, but in these islands it appears to be responsible for considerable damage even on porous, light, well-drained soils.

Control.—The measures found effective in controlling this soil organism are seed selection and seed disinfection in corrosive-sublimate solution (p. 9), combined with planting in uninfected soils or soils in which the liability of infection has been reduced by crop rotation. Root crops such as turnips and beets are susceptible to the parasite and should not be used in the rotation. The Rhizoctonia types of injury are very prevalent in Hawaiian fields, and attention to the control of these diseases will have to be given before any great increase in yield can be had in some localities.

Sclerotium Wilt (*Sclerotium rolfsii*).

The Sclerotium wilt disease is caused by the fungus *Sclerotium rolfsii*, described by Rolfs [1] as the cause of a wilt of tomato in Florida. Besides the tomato, this fungus causes a similar disease of the following plants: Potato, peanut, eggplant, bean, cowpea, summer squash, cabbage, beet, and melon. It is reported to be very destructive to the Irish potato in heavy, wet soils. This fungus has been isolated from diseased peanuts growing on the farm of the College of Hawaii, Oahu, and also from Hilo, Hawaii, but as yet Irish potatoes attacked by this disease in the islands have not come under the writer's observation. Larsen describes it as occurring on potatoes in the vicinity of Honolulu in 1913. He isolated the fungus and performed successful inoculations on potato plants. Since his publication is not generally available, and this disease is likely to be of occasional importance in some localities on the islands, the following quotation from his description is given:

> Sometime last January (1913) our attention was called to a field of potatoes in the vicinity of Honolulu which was being entirely destroyed as a result of some disease while the plants were still immature. On investigation it was found that the field in question, covering some 2 acres, was affected with a fungus malady known to mycologists as sclerotial disease. The same trouble was then found in other potato patches about Honolulu and occasionally on other host plants as well. In most cases the trouble was fatal to the affected plants, causing severe loss wherever it occcurred.
>
> The first indication of sclerotial disease is a slight drooping of some of the younger leaves and leaf tips. On succeeding days the wilting becomes more pronounced, until in the course of two to four days the entire shoot wilts and fails to recover. * * * Sometimes several or all the shoots wilt simultaneously. At the first indication of wilt, if one examines the base of an affected shoot, just below, and sometimes also a little above, the surface of the soil, one will find that the outer tissue through the cambium is decayed. * * * The decayed area may or may not extend clear around the stem. Eventually the

[1] Rolfs, P. H. Tomato diseases. Florida Sta. Bul. 117 (1913), p. 40.

fungus travels inward, past the woody bundles and across the entire shoot, which then falls over as if broken at the base. Even before this collapse takes place the disease will have penetrated beyond the woody vascular tissue into the soft and watery core, in which it travels upward and downward with great rapidity. The core tissue is quickly discolored and soon decays, leaving the woody circle of vascular tissue like a hollow skeleton of the original shoot. During moist weather conditions, a white mycelial growth may be seen over the affected tissue and in the hollow stem, and white mycelial strands may occur in the soil surrounding the plant. This mycelium soon produces small white tufts, which become round, smooth, and hard, and change from white to yellow, then finally to dark brown. Such hardened mycelial masses are known as sclerotia. They are the only reliable means of identifying the disease. When mature and dry they resemble mustard seed both in size and color. During dry weather these sclerotia do not develop under natural conditions, and artificial means may be adopted to induce their formation in order to diagnose the disease. This can be done by placing one of the affected shoots in a moist chamber * * *.

Larsen records alfalfa, coreopsis, taro, and Irish potato as affected with sclerotium in these islands.

Control.—Rolfs[1] found the Sclerotium disease of tomatoes susceptible of treatment with some soluble form of fungicide such as an ammoniacal solution of copper carbonate or eau celeste. He writes as follows regarding this means of treatment, which is very successful in Florida:

> One of these fungicides, preferably the ammoniacal solution of copper carbonate, should be sprayed on the soil about the stem of the plant. By spraying on a half teacupful at this point the plant is usually perfectly protected against infection. In using this remedy it should be remembered that where the fungus has gained entrance into the tissues of a plant before the fungicide has been applied, the remedy will be of no avail.

The formula and description of preparation of the two fungicide solutions is given on pages 13 and 14. As an additional means of controlling the ravages of the fungus, the soil about the plants should be loosened and exposed to the action of the sun and air. In dry weather this serves to kill the fungus to some extent, thus preventing infection.

Common or Corky Scab (*Actinomyces chromogenus*).

The disease known as common or corky scab attacks the growing tubers at any stage of development (figs. 1 A and 2 B). The centers of infection are first evident as small brownish spots on the surface of the tuber. The spots increase rapidly in size and depth until the whole surface may become covered with the unsightly, rough, scabby areas. In some cases the potatoes crack open or the spots are enlarged and deepened by insects. The scabs consist of accumulated corky tissue formed by the tuber in an attempt to protect the underlying tender tissues from the irritating action of the

[1] Rolfs, P. H. Tomato diseases. Florida Sta. Bul. 117 (1913), p. 41.

encroaching fungus. This disease is caused by a bacterial-like organism until recently known under the name *Oospora scabies*, but its relationship to another group of fungi having been shown, it is now called *Actinomyces chromogenus*.

The corky scab disease not only reduces the value of the crop but also appreciably lessens the yield. The losses through decreased yield have been estimated variously. For example, Goff [1] planted equal amounts of very scabby seed and seed free from scab on a soil which had been in clover sod. The scabby seed yielded 199⅜ pounds and the scab-free seed 477¾ pounds. The decreased yield is brought about through the failure of the seed to germinate and the lowered vitality of the plants. The value of the crop is reduced in several ways. The unsightliness of scabby potatoes and their changed taste and odor lower their market value. The increased liability to tuber decay and the the extra thick paring necessary in preparing the potato for the table result in considerable loss to the consumer.

This disease is not very prevalent in the islands, but at times on poorly drained, hard-packed soils or soils which have been limed it is more or less troublesome and probably the source of considerable loss.

Control.—Seed selection and disinfection, certain types of fertilization and soil treatment, and crop rotation have been found more or less successful in preventing the common or corky scab. The organism causing the disease is distributed for the most part by the use of scabby seed potatoes, and only scab-free tubers should be used for seed. To reduce the probability that scab organisms are carried to the soil by the seed, the latter should always be dipped in one of the potato-seed disinfecting solutions (p. 9).

Scabby and refuse potatoes should not be fed to farm animals if the manure from these animals is to be scattered on the potato land, as it has been demonstrated that the organism can survive passage through the alimentary tract of animals.

The development of the scab is favored by a high humus content of the soil and also by an alkaline reaction. To the latter fact may be attributed the unfavorable results of adding lime or wood ashes to potato soils. Halsted [2] obtained favorable results by fertilizing with kainit (Stassfurt salt containing 20 per cent potash). According to Beckwith [3] and Taft [4] muriate and sulphate of potash also reduce scab injury. The plowing in of green manure and, in fact, any cultural practice which tends to make the soil acid will reduce the common or corky scab on badly infected fields. Crop rotation has been sug-

[1] Goff, E. S. Experiments in potato culture. Wisconsin Sta. Rpt. 1892. pp. 278–280.
[2] Halstead, B. D. Field experiments with potatoes, I. New Jersey Sta. Bul. 112 (1895), pp. 1–12; Rpt. 1896, pp. 309–315.
[3] Beckwith, M. H. Potato scab. New York State Sta. Rpt. 1887, pp. 307–315.
[4] Taft, L. R. [Potato scab.] Michigan Sta. Bul. 57 (1890), pp. 23–25.

gested with the assumption that in the absence of the potato for a number of years the organism would die out. Inasmuch as turnips, beets, and other root crops are susceptible to attack, they should not be included in the rotation, as they would serve to carry over the disease.

Potato Tuber Rots (*Phytophthora infestans, Fusarium oxysporum, F. radicicola, and F. coeruleum*).

In spite of the fact that the major part of the potato crop of the islands is consumed soon after the tubers are dug, the total annual loss by rotting is an item of considerable importance. It is a serious source of trouble in keeping seed stock and often results in the use of inferior tubers for this purpose.

The type of rot most commonly observed is often called dry rot, though this name is frequently misleading, as the nature of the rot depends upon the amount of moisture and upon the temperature. With plenty of moisture and a moderately warm temperature the rot develops rapidly and is of the soft type. If the rot develops more slowly, or if wet rotting tubers dry out, the typical dry-rot phase is produced. These forms of rot are caused for the most part by three species of Fusarium known as *F. oxysporum*, *F. radicicola*, and *F. coeruleum*. Rotting of the tubers is very prevalent in the crop from wilt-infected vines.

Another tuber rot is caused by the late blight fungus. When the tops are destroyed by this blight, the tubers may rot badly in the ground. The spores of the fungus are washed from the leaves to the ground and thence to the tubers, which are infected. This rot is a firm brown discoloration extending through the surface layers of the tuber a short distance beneath the skin. In the earliest stages it shows through the skin as a slight brownish or purplish area, which later becomes more or less shrunken. In heavy, cold, wet soils this rot spreads rapidly through the tuber, and a soft, ill-smelling, secondary rot caused by bacteria hastens the destruction. In drier soils little evidence of rot may be present, and yet the tubers, if infected, will rot badly in storage.

Control.—The rotting of potatoes can be largely controlled by storage at a temperature of about 35° F., and where low temperature facilities are at hand such storage offers a practical means of conserving the potato crop. However, even at this temperature the rots progress slowly, and for best results the tubers should be carefully sorted before being put into storage. Storage facilities at such a temperature are rarely available to Hawaiian growers, and at present little advantage can be taken of this method of holding the crop or seed tubers. To prevent loss through rotting under conditions in the islands, attention should be directed toward the prevention of in-

fection through the use of good seed, crop rotation, control of diseases and insect pests as far as possible, careful handling of the crop, and storage at the lowest available temperature.

Tuber Moth (*Phthorimoea 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 can be controlled. 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 (fig. 4), lays its eggs upon the leaves or other parts of the plant. The larvæ or worms quickly enter the leaves, mining between the surfaces, or bore into the stem or tubers (Pl. XI). Affected tubers soon rot, due 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.

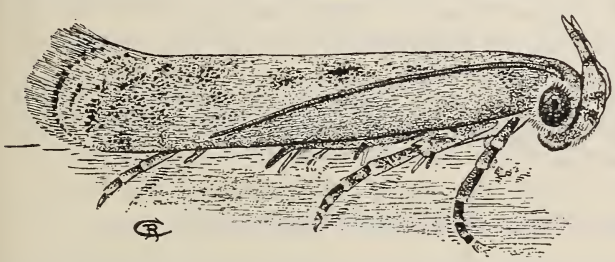


Fig. 4.—The potato tuber moth: Natural position at rest. Much enlarged. (From U. S. Dept. Agr. Bul. 427.)

Control.—The tuber moth is very difficult to control, even under the best systems of potato culture, and the regrettable lack of system in Hawaii greatly increases the difficulties. With potatoes growing in every month of the year, with practically no rotation in general, and with volunteer potatoes allowed to mature with corn or beans, etc., 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 pulled out and 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, and clover.

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.

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 is indi-

cated by 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 unimpaired 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 bisulphid 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 1 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 bisulphid 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 (p. 10) when the latter is being regularly applied will probably be of some benefit in combating the tuber moth.

Cutworms, Army Worms or "Pokos," Snails, Etc.

Of insects injurious to potatoes, the cutworms (fig. 5), especially the leaf-eating form locally known as "poko," rank next to the tuber

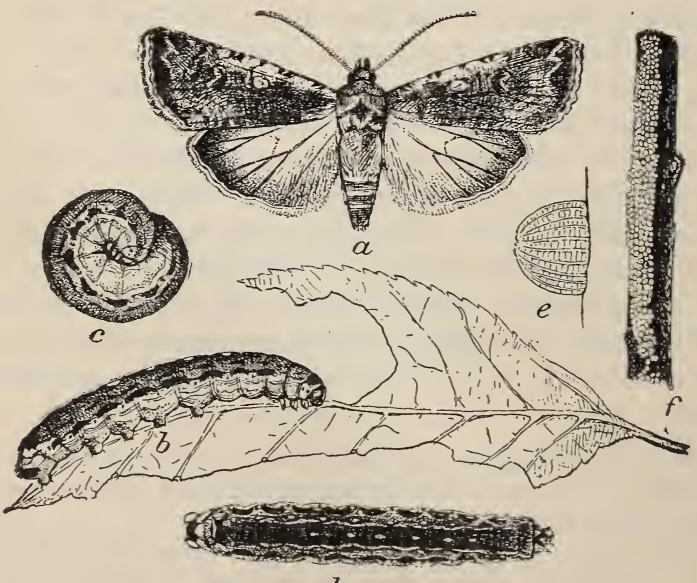


Fig. 5.—Variegated cutworm (*Peridroma margaritosa*): *a*, Moth; *b*, normal form of caterpillar, side view; *c*, same in curved position; *d*, dark form, view of back; *e*, greatly enlarged egg, seen from side; *f*, egg mass on twig. (From U. S. Dept. Agr., Farmers' Bul. 739.)

moth. The "poko" in the early summer months is a voracious feeder, and unless it is checked by artificial means it may entirely destroy the foliage of the potato vines. The "pokos" as well as the true cutworms are night feeders, which during the day may usually be found curled up in the soil at the base of the plant upon which they are feeding.

Control.—The growers of potatoes in the islands have been quite successful in controlling these worms with a poison bait. Before the war it was customary to use a bait made of the highest grade of wheat flour and Paris green, a high grade of flour having been found economical by the farmers because it is finer and can be spread more thoroughly over the vines and over more plants than the coarser grades. The poisoned flour is dusted in the late afternoon over the plants and the soil at the base of the same. Some burning of the foliage, or arsenical poisoning, results, but this is usually not serious (p. 35). This treatment is generally used and is considered effective by the growers. The cost of the flour used is a not inconsiderable factor in the expense of growing the crop. As a substitute method for the control of these pests, the poison baits of which the formulas are given on page 14 are now being successfully used. It seems probable that the leaf-eating worms could be controlled by the use of arsenicals with Bordeaux mixture (p. 13). Paris green is used at the rate of 1 pound to 50 gallons of Bordeaux. Where Paris green is used the burning of the foliage is prevented by the life in the Bordeaux, or, if necessary, an additional quantity of lime, equivalent to the amount of Paris green used, may be added for the purpose of neutralizing the free arsenious acid.

Mite Disease.

Irish potatoes growing in Hawaii in dry, hot situations, whether irrigated or not, are frequently seen to dry up and die from the growing tip downward. The small young leaves turn brown or become bronzed on the under surface, get abnormally "fuzzy," and twist or curl up, and soon the shoots and leaves dry up and die (Pl. XII). Often the plants grow well until about the time of flowering, when they gradually dry up and die prematurely. The yield of such plants is negligible. The young growth is found upon examination to be attacked by a multitude of minute mites, which are scarcely to be seen with a hand lens having a magnification of less than 20. These pests suck the juice from the tender foliage and ultimately kill it.

This disease of the Irish potato seems to be a new one; at least the writer has been unable to find such a malady mentioned in the literature. A somewhat related disease is described under the name

"phytoptosis" on the tomato in Florida by Rolfs.[1] The mite attacking the potato is quite different from the one found by Rolfs, however, this being Eriophyes or Phytoptus, while that infesting potatoes probably belongs to the same group as the so-called red spider (Tetranychidæ).

The mite disease was first noted by the writer early in May, 1917, in the vicinity of Honolulu and Castner, Oahu. It was soon found to be very prevalent and destructive after the weather became too dry and warm for the late blight disease. It is now recognized as a disease of considerable importance during dry seasons in the main potato sections, and has probably been destructive to the potato crops for many years. During the drought of the summer and fall of 1917, this disease caused losses estimated at as high as 25 per cent in some fields in the Hamakua district of Hawaii and the Makawao and Kula districts of Maui. Practically total losses were observed in gardens in the vicinity of Honolulu, where the conditions were not favorable to the crop, the weather being too dry and warm.

That this disease is caused by mites is established by the following facts: These organisms are always present in sufficient numbers on plants with the recognized symptoms to be considered responsible for the trouble; the reaction of the plant is such as has come to be associated with mite injury; if the mites are kept off potato plants by spraying or dusting with sulphur the plants grow normally, while adjacent unprotected rows are devastated; increases in yield of tubers of 100 per cent by weight have been obtained by spraying with lime-sulphur. (See Pl. XIII.)

The mites are oval shaped and almost colorless when young, becoming slightly brownish with maturity. When young they have three pairs of legs, later four pairs (Pl. XII). The eggs, which are numerous on the affected leaves, are sculptured or papillate.

Control.—Experiments (Pl. XIII) have shown that the mite disease can be almost if not entirely prevented by dusting the plants with sulphur or spraying them with a lime-sulphur spray. In dry, warm weather watch the potato plants carefully, and as soon as any of the small young leaves at the tip show signs of turning brown or becoming bronzed on the under surface, spray the entire surface of the plants with the lime-sulphur spray (p. 13) or dust the plants thoroughly with dry sulphur. Repeat as often as necessary.

The mite disease is entirely different in its symptoms from the late blight or wet blight disease and likewise from the early or dry blight, and there should be no confusion of these types. The mite disease can be confused with Fusarium wilt or other wilt disease unless careful examination is made. It seems that there has been

[1] Rolfs, P. H. [Tomato diseases.] Florida Sta. Buls. 21 (1893), pp. 23, 24; 47 (1898), pp. 143, 144.

confusion of these forms, and it is hoped that the descriptions of diseases herein will help the grower to distinguish them in order that the proper treatment may be applied. Bordeaux mixture, which is so serviceable as a preventive spray for the two blights above mentioned, will keep the mites off the plants for from one to two weeks, but eventually sprayed plants are as badly affected as if they had received no treatment. Sulphur, on the other hand, is effective against mites, but it is not to be recommended for the late blight if it is possible to use Bordeaux mixture.

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 round worms. The same sort of parasite is responsible for the rootknot disease of various crops. The gallworm attacks the tubers and causes the skin to become roughened or cracked and covered with irregular galls or pimples (Pl. XIV, fig. 1). 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 (Pl. XIV, fig. 2). 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 practically impossible. In greenhouses they can be killed by steam sterilization, but in the open field this is seldom practicable. They are carried into new soils by infested seed tubers, nursery stock, etc. Infested seed potatoes, which are of course unfit for planting, constitute a serious menace to the potato industry.

Gallworm injury to garden crops has been observed on Hawaii, Maui, and Oahu. A general infestation of fields with these pests would be disastrous, and it is essential that their spread be limited so far as possible. The cultivated fields of the Territory which are infested will be determined as opportunity permits and crops suggested for rotation where possible.

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 suspicous 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 station 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 the parasites. If possible, a rotation should be practiced using nonsusceptible crops where such are suitable. The following susceptible crops are to be avoided:

Alfalfa.	Cowpea.	Okra.	Soy bean.
Asparagus.	Cucumber.	Onion.	Strawberry.
Bean.	Eggplant.	Peach.	Tobacco.
Beet.	Field pea.	Pepper.	Tomato.
Cantaloup.	Fig.	Pumpkin	Watermelon.
Carrot.	Grape.	Rape.	
Celery.	Kale.	Salsify.	
Clover.	Lettuce.	Spinach.	

There are a few crops which can be safely planted upon infested soils. A three-year rotation would probably be the shortest that would be at all effective in eliminating the pests. At the end of that time one planting of potatoes or other susceptible crop could probably be made. Among the crops which are not seriously affected are the following:

Barley.	Peanut.	Rye.	Velvet bean.
Corn.	Pearl millet.	Sorghum.	Wheat.
Iron cowpea.	Redtop.	Timothy.	

Corn and sorghum are particularly desirable, as they permit clean cultivation and the removal of weeds which might harbor the pest.

NONPARASITIC DISEASES.

Sunscald, Sunburn of Tubers.

Under certain conditions of the weather the leaves of the potato plant may become sunburned. This condition may result when the sun comes out brightly after a period of cloudy or misty weather. The tender leaves wilt and later become dry and brown. This disease has not been found of much consequence in Hawaiian fields. Young plants frequently appear drooping in the middle of the day if the sun is hot following showers, but little burning or permanent injury to the plants has been observed.

When growing tubers become exposed to the action of the sunlight, they develop cholorophyll (leaf green) and are said to be sunburned (locally called "moonstruck"). As a result of diseases like Rhizoctonia root disease (p. 24), which cause the tubers to develop on short stolons and in a bunch next to the stem, the tubers are frequently forced out of the soil.

Control.—Hilling up the plants and attention to the control of such diseases will remedy the condition.

Leaf Tipburn.

The disease characterized by the drying up, dying, and rolling upward of the tips and the margins of the leaves during a period of

protracted dry weather is called tipburn (Pl. XV). The older, or lower, leaves are most affected. This trouble may possibly be mistaken for early or late blight. The absence of definite spots with concentric markings distinguishes it from the former, while the dry and upward-curling leaf margins of tipburn should serve to differentiate it from the late blight. Tipburn is most common on light soils which lose moisture rapidly. The disease results from the fact that under certain conditions the plant loses water faster by transpiration (evaporation from the leaves) than its roots can absorb water.

Control.—Good surface cultivation to conserve the soil moisture and spraying with Bordeaux mixture have been found valuable means of preventing tipburn.

Hollow Potato, Pronged Potatoes.

The peculiarity known as hollow potato or black heart occasionally occurs in Hawaii. As the name indicates, the centers of the tubers are hollow or blackened. This trouble is considered to be due to peculiar conditions of growth. Uneven development, such as rapid growth following a period of cessation of growth or slow growth during drought, is thought to be a factor in the production of hollow potato and is also thought to encourage the formation of prongy potatoes. Large, overgrown tubers are more frequently hollow than average sized tubers, and in mainland States certain varieties seem to be more commonly affected than others.

Arsenical Injury.

The application of Paris green to the leaves of the potato without mixing with it any neutralizing agent such as lime often causes the death of a portion of the leaf or of the entire leaf. Arsenate of lead is much less active in this way and is to be preferred for use on the foliage of plants. In a moist climate, basic arsenate of lead is probably the best form to be used. Powdered arsenate of lead might well be substituted for Paris green in the flour poison bait used for the cutworms and army worms ("poko") where the bait is dusted over the foliage. If Paris green is used, an equal amount of slaked lime should be added to prevent burning.

The application of arsenicals in spray form for pest control has been until recently but little practiced in the islands. Either Paris green or arsenate of lead can be used with Bordeaux mixture with little possibility of injuring the foliage. If Paris green rather than arsenate of lead is used, a small additional quantity of lime may be added to the Bordeaux to neutralize the Paris green. When a water suspension of Paris green is used for spraying, an equal amount of quicklime should be slaked and added to the water.

POTATO DISEASES NOT KNOWN TO OCCUR IN HAWAII.

There are a few very serious diseases and insect pests of the Irish potato and a number of rather minor importance which apparently have not yet become established in Hawaii. Among those which have not yet been observed are the following parasitic diseases: Black wart (which is one of the most destructive diseases of potatoes known), powdery scab, blackleg, southern bacterial wilt, silver scurf, Verticillium wilt, and leak; and the following supposedly nonparasitic diseases of unknown causation: Internal brown spot, net necrosis, curly dwarf, leaf roll, and mosaic. Among the insects injurious to the potato not yet detected here are the Colorado potato beetle

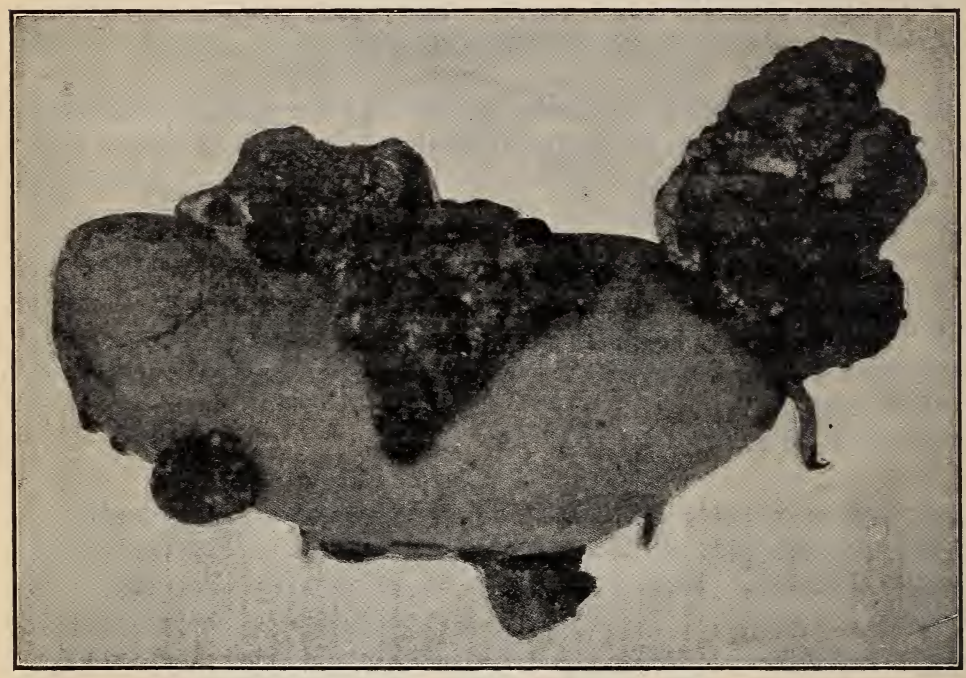


FIG. 6.—A potato affected with potato wart. (From U. S. Dept. Agr., Farmers' Bul. 544.)

and species of flea beetles. The diseases above enumerated are described in order that they may be recognized promptly and be the better guarded against. It is quite possible that some of these diseases are already present in the islands but have not yet come to notice. In any cases where diseases are thought to be like these hereinafter described, specimens should be forwarded without delay to this station for determination.

PARASITIC DISEASES.

BLACK WART (*Chrysophlyctis endobiotica*).

The black wart disease was discovered upon potatoes in Germany less than 25 years ago. Since its discovery it has spread with great rapidity in Europe and has recently appeared in Newfoundland. It

POTATO TIPBURN, A HOT-WEATHER REACTION OF POTATOES GROWN IN MIDSUMMER.

(From U. S. Dept. Agr. Bul. 64.)

has very recently been found in gardens in certain mining towns of Pennsylvania, and a survey of the infected region is now in progress. Black wart is probably brought into new localities on apparently healthy or only slightly diseased potatoes coming from infected fields, and it is thought to have been introduced into the United States on low-grade European table potatoes before the quarantine was established.

Black wart attacks the tubers chiefly and causes malformation and warty excresences, converting the tuber into a worthless mass (fig 6). The warts have given rise to such names as warty disease, black scab, canker, and cauliflower disease. Once infected, a soil can not be used for this crop again for many years, unless resistant varieties are found, as now seems possible. In the worst cases from 25 per cent up to the entire crop is affected. The disease grows worse each year potatoes are grown on infected soil, but so far as known no other crop is attacked.

The seriousness of this malady may be judged from the following quotations:

> A vigorous effort should be made, if found in the United States, to eradicate the trouble. All infected tubers should be boiled or burned, and no more potatoes should be planted on that field for eight years. Stock should not be allowed to run over infected areas and no part of any lot containing diseased potatoes should be used for seed purposes.[1]
>
> It has been stated that no sound potato is saved from a crop that is attacked. While the virulence of diseases like late blight or early blight is more or less dependent upon climatic conditions, this disease is not influenced in any known degree by physical or mechanical conditions. It may, therefore, be considered as the most serious pest attacking potatoes. Fields at harvest in affected areas present the most hopeless appearance; the disease has caused the greatest havoc in all localities where it has appeared.[2]

Powdery Scab (*Spongospora subterranea*).

Powdery scab has only recently been introduced into the mainland of the United States, first being found in Maine and subsequently in other New England States and more recently in Oregon and Washington, and it is also known to exist in British Columbia. This disease, which may be mistaken for corky or common scab, is caused by the slime mold *Spongospora subterranea*. There appears to be little indication that it would be serious if introduced here, the pathologists of the Eastern States being of the opinion that its spread will be largely controlled by climatic and soil factors. The fungus attacks the young tubers and develops as they mature in the ground. The center of infection becomes a pustular-like scab containing the spore balls of the fungus as a brown powder. The

[1] Field, Ethel C. [The wart disease of the potato.] U. S. Dept. Agr., Farmers' Bul. 489 (1912), p. 23.

[2] Güssow, H. T. A serious potato disease occurring in Newfoundland. Canada Dept. Agr. Bul. 63 (1909), p. 6.

spots are as a rule smaller than those of the corky or common scab, are more regularly rounded, and are characteristically bordered by the uplifted and torn skin. A canker stage also occurs, and it is this stage that causes the greatest loss. This scab may open the way to various storage rots.

Control.—Since this disease occurs in the coast States, importations of potatoes from these should be carefully inspected for signs of this disease, and all mainland potatoes to be used for seed should be disinfected with corrosive sublimate solution as a precautionary measure. This solution is known to be only partially effective in destroying powdery scab spores carried by the seed, but it is better than formalin. Lots of potatoes containing suspicious tubers should not be planted, and specimens should be forwarded to the station for examination.

FIG. 7.—A potato plant affected with blackleg in the summer stage, the result of planting diseased tubers. The lower part of the stem is shriveled and black, the leaves are yellow and rolled upward. (From U. S. Dept. Agr., Farmers' Bul. 544.)

BLACKLEG (*Bacillus phytophthorus*).

Blackleg is a serious bacterial disease of the potato occurring in the New England States, also in Washington and Oregon, and possibly in California, but not as yet observed in the Hawaiian Islands. This is a disease of the stem and tuber, and, as its name suggests, the lower part of the stem of affected plants becomes blackened. The tubers themselves are destroyed by a soft rot. In the advanced stages the stem shows a black color which extends from the seed piece to some distance above the ground (fig. 7). In the tubers a rot often extends from the stolon, or else the tubers may simply remain undeveloped. The use of infected seed results in a poor stand, and the plants become diseased.

In Europe the losses are reported at from 5 to 94 per cent, and in Maine the most common losses range from 1 to 5 per cent with occasional losses of 50 per cent. The damage is heaviest on low, wet, and poorly drained soils.

Control.—In Maine it is thought that the disease does not spread from hill to hill, and that it can be controlled there by seed selection and disinfection. Here, where there is little change of season, it is conceivable that the disease might remain in the field from crop to crop, and be much more serious. The porous, well-drained soils would tend to minimize the damage should this disease be introduced. The liability of introducing this disease as well as others is added evidence against the practice of using any imported seed except that which is certified. The latter should be planted only after it has been examined and disinfected, as a small percentage of this disease is allowed in the growing fields, the product of which may later be certified.

Southern Bacterial Wilt (*Bacillus solanacearum*).

This bacterial disease of the Irish potato is prevalent and destructive in the Atlantic States from Florida to New Jersey. Tomatoes, eggplant, peppers, and tobacco are also attacked. On tobacco the disease is known as the Granville wilt. This malady is most destructive in dry seasons and on dry soils. The affected plants wilt, recover during the night, and wilt again the next day. Then they become yellowed or blackened, and the forming tubers are attacked by a soft rot, which is accompanied by a very foul odor. Possibly this disease would be very destructive if introduced into the islands, but considering the remoteness of the infected districts, there seems little probability of this contingency.

Control.—Seed from uninfected fields should be selected and rotation of crops practiced. Other solanaceous crops should be avoided in the rotation. Insects should be controlled, as they are believed to carry the wilt from plant to plant.

Silver Scurf (*Spondylocladium atrovirens*).

This disease, probably recently introduced into the United States, is caused by the fungus *Spondylocladium atrovirens* and is characterized by a silvery appearance of the skin, with minute blackish patches of the fungus thereon. It is not considered as especially serious. The damage to the crop results from disfigurement, abnormal shrinkage and shriveling of the tubers, and decreased market value of the product.

Control.—Seed selection and disinfection in corrosive sublimate are advised for the control of silver scurf.

Verticillium Wilt (*Verticillium alboatrum*).

Another wilt disease scarcely to be distinguished from the Fusarium wilt is caused by the fungus *Verticillium alboatrum.* Besides the potato, this fungus attacks eggplant, tomato, okra, and cotton.

The disease occurs in the Atlantic States and also in the Pacific Coast States. In general the Verticillium can not be considered as serious as the Fusarium wilt, since only scattered plants in a field are attacked. Once a field is infected, however, the disease becomes more serious from year to year if cultivation of susceptible crops is continued.

Control.—The control measures suggested are the same as those for the Fusarium wilt (p. 19). In the rotation the following susceptible plants must be avoided: Eggplant, tomato and other solanaceous plants, okra, brambles, and cotton.

Leak or Melters (*Rhizopus nigricans* and *Pythium debaryanum*).

Leak or melters, the name applied to a rapid soft rot of tubers occurring in the delta lands of California, is a type of decay often causing serious loss in shipments to markets. The disease was at first attributed to the common bread mold fungus *Rhizopus nigricans*, but recent investigation has shown that it is in large part due to the fungus *Pythium debaryanum*. These fungi enter through wounds in the tubers made in digging.

Control.—Careful handling in digging and the sorting out of all bruised tubers previous to shipping has been found a practical means of control.

NONPARASITIC DISEASES.

Internal Brown Spot and Net Necrosis.

Brown spots and streaks in the flesh of the potato and more or less widespread net necrosis or netted brown streaks (vascular threads) occasionally occur under conditions of growth that are not well understood by pathologists. Dry weather and soils possibly deficient in some element of plant food are thought to be associated with this trouble. As found on the mainland it is sometimes associated with temperature changes, probably both during the maturing period and in storage. It is significant that neither internal brown spot nor net necrosis has been observed here, where a uniform temperature is the rule.

Curly Dwarf, Leaf Roll, and Mosaic.

The diseases known under the names curly dwarf, leaf roll, and mosaic are all imperfectly understood and the causes are entirely unknown at the present time. The first two are inherent troubles which appear to be associated with weakened strains of potatoes.

CONCLUSION.

The growing of Irish potatoes in Hawaii, though an industry of considerable importance, has been largely discouraged in recent years by persistent crop failures and unfavorable marketing conditions. It is desirable that the islands become self-supporting so far as possible with respect to this commodity. It is believed that the potato crop can be doubled without any increase of acreage by the adoption of modern agricultural methods.

Crop failures, which have been found to be a persistent source of loss, are brought about by the following factors: (1) The use of poor seed, (2) continuous cropping (as many as three or four crops a year with no systematic rotation for a half century or more), (3) diseases and insect pests, and (4) unsatisfactory soil conditions. Fundamentally the diseases have been the most important factor, with the other mentioned factors as contributing causes.

The diseases, so far as they have come to the attention of the writer, have been determined, and recommendations have been made for their control, both through the improvement of cultural practices and through special methods where required. Certain diseases which are destructive in other localities but have not yet been found here are described in order that their introduction may be the better guarded against.

The following diseases and pests of the Irish potato have been found to occur in Hawaii: Fusarium wilt (*Fusarium oxysporum*), late blight (*Phytophthora infestans*), early blight (*Alternaria solani*), black scurf and rosette (*Rhizoctonia solani*), Sclerotium wilt (*Sclerotium rolfsii*), common or corky scab (*Actinomyces chromogenus*), tuber rots (*Phytophthora infestans*, *Fusarium oxysporum*, *F. radicicola*, and *F. coeruleum*), tuber moth (*Phthorimaea operculella*), cutworms (and a similar leaf-eating worm locally called "poko"), mite disease (an unidentified form of Tetranychidæ), nematodes (*Heterodera* sp.); and the nonparasitic troubles sunscald, sunburn of tubers, leaf tipburn, hollow potato, pronged potatoes, arsenical injury.

The universal adoption of the practices of seed selection and disinfection, crop rotation, and spraying with Bordeaux mixture are recommended for the general improvement of the potato situation. Only through the use of healthy, vigorous seed and fertile, disease-free soils, maintained through crop rotation, can healthy crops be secured. When once healthy plants, in other words, plants worth saving, are assured, the value of Bordeaux mixture in preventing late blight, the most serious potato disease in Hawaii, will be more readily seen, and under improved cultural conditions spraying will

more readily be adopted as a universal practice. At the present time some of the growers are taking up spraying and other crop improvement measures with commendable zeal, and sprayed plats have shown increases of from 50 to 200 per cent over unsprayed plats. In controlling the late blight, a locally developed variety appears to offer considerable promise in resisting foliage injury.

The improvement of the potato crops can be permanently brought about only through a realization of the importance of the several factors involved in the crop failures, and especially the diseases and pests must be prevented. This can be accomplished only through the use of good seed, fertile, disease-free soil, and spraying, combined with the best cultural methods.