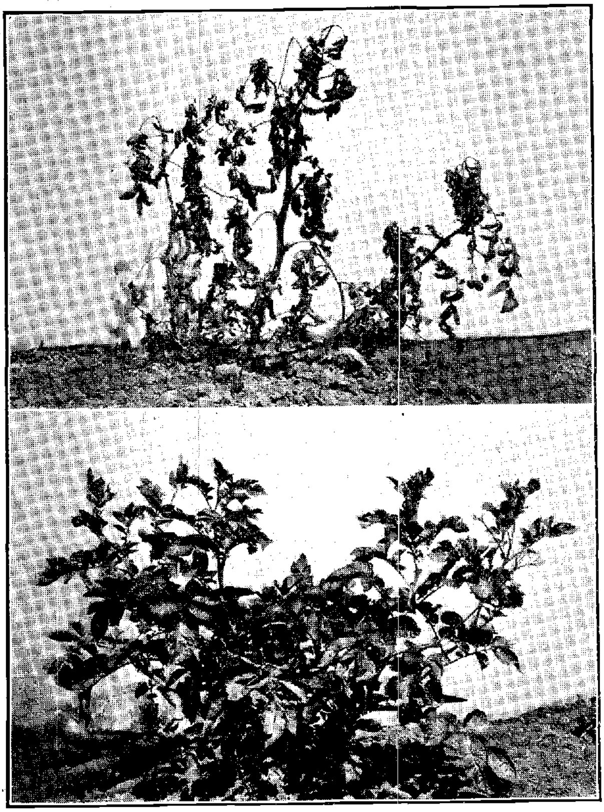
Station Circular 96 February, 1930

Potato Diseases in Oregon and Their Control



Two plants, same age, from halves of the same tuber, cut lengthwise; upper one grown on soil infested with Verticillium wilt from the previous crop, lower one on soil which had not grown potatoes for five years. Infection of potato plants by wilt from the soil can be avoided only by proper rotation of the crops.

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CONTENTS

IMPORTANT PRACTICES FOR CONTROLLING POTATO DISEASES

Success in potato culture depends to a large extent on the control of potato diseases. Most of the potato diseases occurring in Oregon can be controlled or prevented. The methods which are considered best for accomplishing this are described in this Circular.

1. Practice a four- to six-year rotation of crops so as to free the soil as much as possible from parasites which may attack the potato.

2. Treat all potatoes for tuber-borne diseases before planting, using only those treatments which have proved to be effective. Mercuric chloride and hot formaldehyde are now considered to be the most efficient.

3. Cut seed pieces, if not planted immediately, should be stored under humid conditions at a temperature of 55° to 65° F. for 24 to 48 hours. These conditions are favorable for the corking over of the cut surfaces, which will largely prevent seed-piece rot in the field.

4. Maintain a seed-plot, isolated at least 300 feet from other potatoes, for your own seed supply. In this seed-plot use only high-grade or certified potatoes and plant them in tuber units. Remove promptly all diseased units as soon as any systemic disease such as mosaic is detected.

5. The most nearly ideal method to control virus diseases is by tuber indexing, but this method is not generally practicable. Under proper conditions the seed-plot planted in tuber units will give results that are almost as effective as indexing.

6. To control insect injury and foliage diseases such as early and late blight, spraying or dusting should be more generally practiced.

7. Good storage conditions are important and can be maintained by keeping the temperature low, at from 35° to 40° F., and by providing adequate ventilation. This is particularly desirable for seed stock to prevent rot and to preserve the tubers in good vigorous condition.

Potato Diseases in Oregon and Their Control

By M. B. McKay and T. P. Dykstra*

INTRODUCTION

A comparatively few years ago, only three potato diseases were considered serious in the United States. Now there are recognized a half dozen generally serious diseases and a score of less important ones of very common occurrence, which occasionally are themselves quite serious. This comparatively rapid increase in the number of diseases affecting potatoes has been due in part to the continuous culture of potatoes on the same land for a period of several years. This unfortunate practice furnishes excellent conditions for the propagation of the common diseases and for the establishment of new ones.

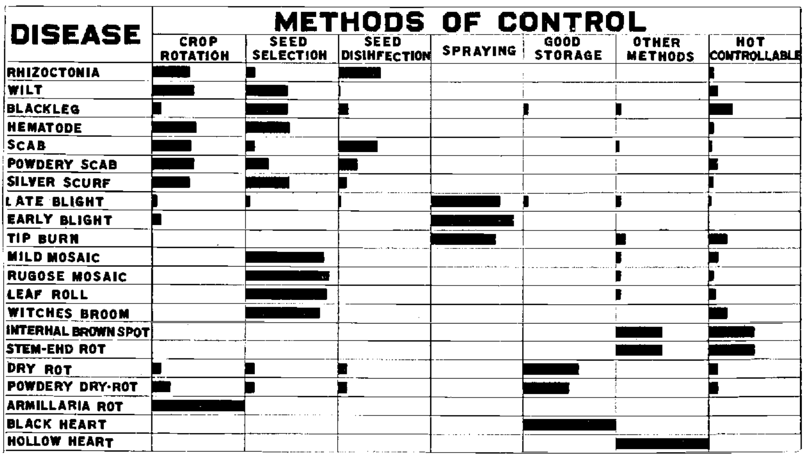


Fig. 1. Graph showing how potato diseases are controlled. The length of the bars shows the relative value of the different methods used. Seed selection as used here includes the practice of careful roguing in a seed-plot as explained in the text.

Potato growing is an important industry in Oregon and is generally a profitable one. Observations extending over several years have shown, however, that potatoes are too commonly affected by diseases that seriously reduce the size or quality of the crop. Experiments and experience have proved that much of this loss can be prevented by the practice of intelligent care.

*A part of the experimental work on which some of the conclusions included herein are based was conducted cooperatively by the office of Horticultural Crops and Diseases, Bureau of Plant Industry, and the Oregon Agricultural Experiment Station.

To enable the growers to recognize and apply the proper control measures to the different diseases that may be attacking their potatoes and causing undue losses therein, it has been deemed advisable to prepare this circular briefly describing most of the potato diseases that occur in the state and giving the essential facts known concerning their control. The nematode or eelworm disease is described even though it has a very limited distribution in the state. Because of the damage it causes in some other states special attention is called to it so that growers in Oregon may be on the lookout to protect themselves against it.

GENERAL CONTROL MEASURES

Control depends on prevention and not on cure. It is fortunate that practically all of the diseases affecting the potato can be successfully controlled by comparatively simple and inexpensive measures. It should be borne in mind that the control of these diseases depends entirely on prevention and not on cure. If, for instance, a potato leaf is infected with late blight, it can not be cured of the disease, although the spread of this disease to other leaves or other plants can be prevented by thorough and timely applications of spray. And if the soil becomes contaminated with a disease-producing organism, disease prevention in this case consists in the proper rotation of non-susceptible crops for a sufficient length of time to starve out the parasite in the soil.

Five important control factors and their relative value. There are at least five important factors to be considered in the prevention and control of potato diseases; namely, crop rotation, seed selection, seed disinfection, spraying, and good storage conditions. There are other factors that have an influence on disease control, among which may be mentioned kind of fertilizers used, cultural methods, controlling insects which aid in the spread of disease, the use of irrigation water, green manure crops, etc.; but the five factors mentioned first are the most important ones and will be discussed more in detail. All of these factors must be carefully considered if the grower is aiming at the production of potatoes high in yield and practically free from disease.

The relative value of each of these five measures for the control of the different potato diseases is shown graphically in Fig. 1. This set of graphs should be taken not as an absolutely accurate evaluation of the different control measures, though they are charted here on the basis of percentage, but should be taken as an approximation of the value of these measures for disease control based on present information and our best judgment. When taken from this standpoint they are chiefly of value in indicating at a glance the measures which may be used to best advantage and which promise to give the best results for controlling the different diseases.

More than one measure generally necessary. The graphs show also that most of the diseases cannot be controlled by the use of one measure alone but that usually two or more measures must be employed before the most successful control can be expected or obtained. A few cases will be mentioned briefly here.

Rhizoctonia lives over the winter both in the soil and on the seed potatoes. For the control of this disease it is necessary therefore to use care in the rotation of the crops and in seed potato treatment. Failure properly to handle either of these factors would make the crop susceptible to damage from the disease. Seed selection has only minor value in the control of this disease because of the fact that it is next to impossible to sort out disease-free tubers and furthermore infested tubers are rendered harmless by proper treatment. And because the fungus attacks so many different hosts including some wild plants, the fact should be borne in mind that it is practically impossible to obtain perfect control of this disease.

Again, the fungi which cause wilt are held over in the soil from one season to the next. They are also carried on in the inside of tubers from diseased hills. No seed treatment yet devised is effective in freeing these tubers of this internal infection. Consequently control of this disease must be effected by rotation and seed selection, which in this case is best accomplished by the use of a seed-plot where all diseased plants may be removed during the growing season while most easily detected. Since the standard seed treatment will kill only the organisms that are on the exterior of the tuber, this treatment is of very minor importance for wilt control. One of the organisms causing wilt of potatoes in Oregon occurs to some extent in the soil without any obvious relation to the crops grown thereon, making it difficult to obtain always complete control of the disease; though with good care in the use of the control measures mentioned this source of the disease will remain of minor consequence. These and other diseases will be discussed more fully under the headings of separate diseases. A brief presentation will now be made of the chief general control measures as enumerated above.

CROP ROTATION

Parasites live on potato refuse in soil. Inasmuch as a number of the organisms which cause diseases of the potato live for part of the time in the old tops and other refuse left in the soil after harvest, the practice of crop rotation is imperative where these diseases are present and a disease-free product is desired (see cover page). Not all fields grown continuously to potatoes for several years develop disease to a serious extent, because the seed used may have been free from disease, but such cases are very rare. In every section of the United States and of the world, in fact, where potatoes have been grown continuously or very frequently on the same piece of ground over a considerable area for a period of years, the result has always been the same; namely, that diseases eventually became so severe that profitable yields could no longer be obtained and large acreages had to be abandoned temporarily for potato culture.

Some parasites live also on wild plants. Investigation and experience have shown in a number of instances that some organisms which are parasitic on potatoes occur on wild plants or in virgin soil never previously planted with any cultivated crop. Land recently cleared of timber or brush and placed under cultivation may serve as an illustration. In case such soil is immediately planted to potatoes an appreciable amount of disease including at least Rhizoctonia, scab, dry-rot, and Armillaria tuber-rot may result. Such soil, though it may be highly productive and may produce a satisfactory crop of potatoes for table use, is nevertheless undesirable and should not be utilized the first year for growing a crop of potatoes to be used for seed. A better practice would be to grow other crops for two or three years before planting potatoes. Some potatoes grown in reclaimed dry land in Eastern Oregon, moreover, the first year under cultivation gave an appreciable amount of powdery dry-rot in storage even though stored in a newly constructed, well-ventilated cellar. Investigational work in Idaho has indicated that the organism which causes powdery dry-rot is at present apparently well distributed throughout western desert soils. Where some experiments were conducted on such reclaimed soils much better results were obtained by growing potatoes after alfalfa and grain rather than by placing potatoes on the land the first year in cultivation. From this standpoint, therefore, crop rotation means not merely that potatoes should not follow potatoes too closely but also that potatoes should not be planted on soil immediately following any other plants of whatever kind that harbor potato parasites. Before potatoes are grown the land should be planted with non-susceptible crops long enough thoroughly to rid it of these parasites.

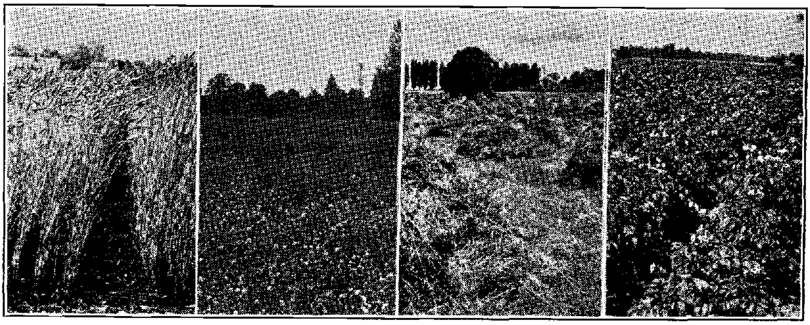


Fig. 2. A four-year rotation is desirable for potatoes. Proper rotation of crops is one necessary practice for avoiding the holding over of potato diseases in the soil. For potato disease control at least a four-year rotation should be used. The best basic crop rotation for Western Oregon is grain, clover seed, clover hay, and a cultivated crop. A variety of materials including potatoes, corn, kale, etc., may be used for the cultivated crop. This may, of course, be varied to suit local needs.

Three-year rotation inadequate for successful disease control. It is known that some of the organisms producing disease in potatoes remain alive in the soil for at least three years, even though no potatoes are grown on the land during that time. Consequently, it becomes necessary to practice longer rotations than this in order that the organisms may die out of the soil before potatoes are again planted on such land. It is best that potatoes be not grown on the same land oftener than once every four or five years, the ground in the meantime being planted to other crops not affected by the potato parasites. Since the length of the rotation and the kind of crops grown in rotation with potatoes will of course vary with each region and with the individual needs of each farm, no general plan to follow can be given. The chief considerations are to build up the soil by the use of legumes, to keep it in good working condition by the use of some cultivated crops, to avoid holding over disease-producing organisms in the soil by the use of nonsusceptible crops, and, of course, to utilize the crops that will give profitable returns for the region.

One good six-year rotation that may be used in a great many localities is grain, clover, corn, grain, clover, and potatoes. Where especially good quality seed potatoes are used, this rotation may be shortened materially to corn, grain, clover, and potatoes (Fig. 2) or even reduced half. A three-year rotation, however, is not to be relied upon for anything like complete disease control if used over a considerable period of years. This is especially true if ordinary, poor potato-seed stock is planted. A longer rotation, as for instance corn, grain, clover and timothy two years, and potatoes is much more trustworthy. The department of Farm Management considers the best basic rotation for Western Oregon to be grain, clover seed, clover hay, and a cultivated crop. A variety of products including potatoes, corn, kale, etc., may be used for the cultivated crop. Much of the farming of Western Oregon could with great advantage be carried on after this plan or a modification of it, to suit individual needs. For other sections of the state, a comparable plan can be worked out that is suited to local conditions in the particular area. Common practice has demonstrated that the most reliable plan to follow is the adoption of some such well-designed crop-rotation system that is well suited to local needs, following it as a more or less regular practice. As a general agricultural practice, crop rotation has everywhere proved a necessity to successful farming.

SEED SELECTION

Seed selection helps to improve quality and avoid disease. One of the most important means for avoiding disease in potatoes consists in seed selection, as indicated in Fig. 1. This is true because wilt, blackleg, mosaic, leaf roll, and a number of other serious diseases are carried over from one season to the next on the inside of the tubers and cannot be eliminated by seed disinfection. It is generally accepted that there is a limit beyond which improvement in type or increase in yield in potatoes cannot be secured by mere selection. Apparently the most that can be expected or accomplished in this direction is to maintain the normal performance of the lot under selection. The control of diseases is by far the largest element involved in this maintenance of the normal yield. The seed-selection methods are, therefore, designed and conducted to give the greatest measure of disease control. The methods that are being accepted as standard because they are effective and give the most returns for the efforts expended involve a combination of three practices—namely, hill selection, tuber-unit planting, and field roguing by which is meant the pulling up and removal of all diseased or abnormal plants (rogues) and any tubers they may have formed. Generally this is what is meant by the term "seed-selection" when used in this Circular. In the case of a few diseases, however, selection is based on an examination of the tubers. By the use of these seed-selection methods the yield and vigor of the crop can be improved in quantity and quality to such an extent as much more than to offset any added expense for labor involved in the selection process.

Seed selection best accomplished by use of seed-plot. Experience has shown that disease control can be accomplished with the least trouble and labor by the use of the seed-plot. In a seed-plot one can afford to take the time and pains for performing the essential tasks necessary for controlling the seed-borne diseases here, while it would be much more difficult and less practicable to accomplish the same thing if applied to the whole field. If proper care is used in growing the potatoes in the seed-plot, it will not be necessary to do much if any roguing in the main field the following year.

For this reason the importance of the seed-plot in the maintenance of a source of relatively disease-free seed potatoes on each farm wherever practicable cannot be overestimated. If selection has not been made in the field before harvest, it is good practice to start the improvement of the potato crop by selecting from the bin for planting in units the following season tubers which are smooth, uniform, free from blemishes, and apparently free from disease, and which weigh between two and eight ounces. The field selection of individual hills to be planted in tuber units, however, is by far the most reliable and satisfactory method. One convenient way for accomplishing this is to set aside each year a seed-plot of about one-tenth the total acreage, which will be large enough to produce all the seed potatoes that will be required for planting the general field the following year (Fig. 3). All plants that are diseased, weak, degenerate, or off type,

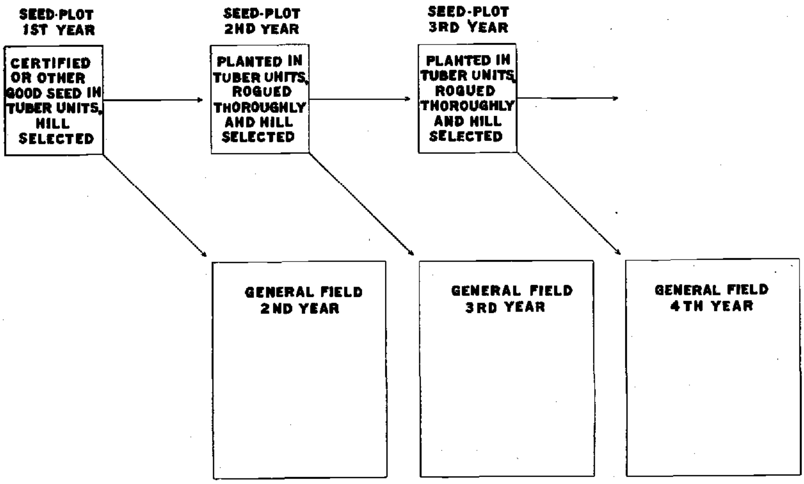


Fig. 3. Diagram of a plan for using a seed-plot to avoid disease and improve the quality of seed potatoes. For a beginning the first seed-plot may be planted with certified seed potatoes, with hill-selected seed potatoes from the previous year, or with bin-selected tubers if no better potatoes are available. Each succeeding seed-plot should be planted in tuber units to permit of more accurate and effective roguing. The seed-plot should consist of about one-tenth of the total acreage of potatoes to be planted the following year.

that belong to another variety, or are undesirable in any way, should be rogued out during the growing season when the diseases, weaknesses, or varietal mixtures can be readily and accurately determined by inspection. In the case of the wilt disease it seems advisable to pull out at the same time not only the wilted hill but also the next healthy hill on either side of the wilted one in the same row in order to avoid the spread of the disease from one plant to another down the row. In this way only the more desirable plants will be left to mature and furnish tubers for seed. Out of these remaining plants in the seed-plot enough of the high-yielding and most uniform, typical hills preferably from places in the field where there is a full stand should be selected at harvest time to be used for planting the seed-plot the following year; the remainder can be planted in the general field. This simple but effective plan, of which a diagram is given in Fig. 3, furnishes a method of continuous improvement of the seed potatoes which in a few years, if combined with proper crop rotation and seed disinfection, will reduce most of the tuber-borne diseases to a negligible quantity and will greatly increase the average yield of potatoes.

Tuber units may be planted either by hand or by machine. There are several satisfactory ways of planting the tubers in units. The essential thing is to plant all the sets from each tuber together in the row and so separated from the sets of the next tuber or marked as to permit ready and accurate recognition of the different units. A common practice is to use medium-sized tubers, cut into four pieces and set with the pieces about 15 inches apart in the row leaving one space unplanted, or 30 inches between units. Another plan is to place a stake between units in the row (Fig. 4). This is more trouble but it is a very accurate method. When thus spaced or marked the units can be accurately identified during growth and all the sets removed if the unit is affected by a virus disease. If one set gives a plant affected by a virus disease, it is best to remove all the sets of that unit even though some of them may not be up yet, for usually all the sets of a unit are affected alike. The ability to rogue at once all the plants from one diseased tuber is one of the big advantages of tuber-unit planting.

A convenient way to plant tuber units by hand is worthy of mention. Cut each tuber partly but not completely through with two cuts at right-angles to each other, leaving a small but definite part of the tissues uncut so that the four sets will hang together. These partly cut tubers are then laid in boxes that can be dragged or carried along the furrows that have been made for planting. The tuber is picked up, easily broken apart, and the four sets are spaced about 15 inches apart in the furrow. A 30-inch space may be left between units to permit proper identification of the units later when the plants come up.

The Montana Experiment Station has made use of an Iron Age planter for planting in units. The seed tubers were cut individually and the sets from each tuber were placed in a suitable sized can with the top removed. Several cans, each containing the sets from one tuber, were mounted on a special rack built to be set on the planting machine over the regular hopper. In planting, the operator picks up a can, pours the sets on to the revolving plate, and places one set in each of four consecutive openings. The empty can is returned to the rack, and the operation is repeated with another tuber. One extra space on the plate is left vacant between units to give proper separation of the units in the ground. Extra racks and cans are provided so that the only delay occasioned in reloading the machine is the time necessary to exchange racks. By operating with a slow, steady team, the planting can be done with few extra stops or delays.

Another machine method was developed by a grower in New York. In this method the selected whole tubers are placed in the regular hopper but with the attachment for dropping the tubers from the hopper removed. An extra operator sitting on the machine, facing backwards, picks up a tuber from the hopper, cuts it into the four sets and places them one tuber at a time in the reservoir at the side of the revolving spacing and dropping wheel. He places the cut tubers first on one side and then on the other so as always to have one tuber cut and ready for the planter. The operator sitting regularly on the back picks up these sets from one tuber at a time and places them in four consecutive openings of the revolving planter plate. Again one extra space is left between units.

A special automatic machine has been developed by one manufacturing company for taking the selected whole tubers, cutting them each into four pieces and planting them in the row with suitable spacing between sets and extra spacing between units. This machine operates best with the blocky round tubers. It is not designed to work well with long tubers. This machine is not recommended for use at this time, but if it becomes further

Fig. 4. A seed-plot planted in tuber-units separated by stakes in the row. Such a planting allows early and accurate roguings which are essential to control of the potato virus diseases. The upper illustration shows the stage of development when the first roguing was made in 1926 and the lower one shows the same plot at the second roguing one week later. Some tuber-perpetuated rugose mosaic was found and removed at each of these two roguings but none was found at the later roguings. Some plants, however, were found during the season, that became diseased by current-season infection as a result of spread. The early thorough roguings kept this to a minimum and resulted in reducing the disease from 5 to 2.5 percent in the one year.

perfected it may eventually be made into a very satisfactory implement. A machine that is successful for cutting and planting tubers in units would be a great help to the potato industry.

All potatoes grown for seed should be thoroughly rogued. Ordinarily no particular advantage commensurate with the cost would be gained from roguing fields of potatoes which are grown only for table use. The presence of blackleg under some conditions when the danger of excessive tuber-rot in storage is too great might serve as an exception to this statement. The much-needed improvement of table potatoes should be accomplished mainly through the improvement of the seed potatoes used in producing these crops. The desirability of using great care in the production of the seed potatoes, therefore, can hardly be overestimated. Every field of potatoes grown for seed should be thoroughly and completely rogued. Every potato grower should pay more attention to this most important matter of seed selection. In every locality where home-grown seed can be maintained in good productive condition from year to year the use of a well-rogued seed-plot should become a part of the general practice of every farm.

Rogued plants should be properly removed and disposed of. In roguing it is desirable that all parts of the plant that might grow again, including especially the old seed-piece, be removed. Also in roguing out the virus diseases care should be used to remove the rogued plant from the field in such a way that insects present on it are not allowed to scatter to other potatoes where they might carry disease. If diseased plants are merely pulled up and left on the ground any insects present on them will be likely to leave, go to healthy plants, and may infect them. One good way to take care of rogued plants is to place the plant directly into a sound gunny sack or some such container as soon as it is removed from the soil. When full or when the end of the row is reached the sacks can be left for disposal when convenient later in the day. Negligence in this detail may detract appreciably from the effectiveness of the other work or even almost nullify it. Proper disposal of rogued plants is a point indispensable to success in the control of the virus diseases.

Roguing virus diseases in mass-planted plots is difficult. One of the objects of a seed-plot is to provide conditions favorable for the effective roguing of diseased plants. Accuracy in the detection of diseased plants and earliness of removal are particularly essential to success in the control of the potato virus diseases, which are the most difficult of all potato diseases to control. When the seed-plot is planted in mass—that is, not in tuber units—each plant has to be judged on its own merits. Because the symptoms of some of the virus diseases are now and then obscure it is often not possible to detect all diseased plants until they have attained considerable size. Consequently, some of the diseased plants may not be discovered and removed from the plot before there has been appreciable opportunity for spread of the disease. To hold the spread of these diseases as near as possible to the minimum the first roguing should be done as soon as the diseases can be accurately determined, and preferably when the plants are an average of not more than three inches in height (Fig. 5).

Each plant rogued should be taken out completely, including all stalks, the seed piece, and the tubers if any are formed. The plot should be rogued once a week thereafter. Ordinarily all the tuber-perpetuated rugose mosaic may be removed in the third or at most the fourth roguing. Mild mosaic generally requires a longer time on account of the difficulty of detecting the symptoms in all of the young plants. Roguing in mass plots under nearly ideal conditions is effective for reducing the virus diseases from year to year; but because these ideal conditions are so seldom found in ordinary practice, this method of roguing is not the most effective one and is not recommended as the most desirable one to use.

Fig. 5. A seed-plot planted in mass, that is, each seed piece was planted without regard to the tuber it came from. Thus each plant has to be judged as to disease or health on its own merits. Roguing under such circumstances is more difficult and does not give the best control of the diseases. These illustrations show the stage of development in 1926 at the first, second, and third roguings, which were made at weekly intervals. Some tuber-perpetuated disease was found and removed at each of these three roguings, but none was found at the later roguings. During the last half of the season, however, some plants were found that were diseased by current-season infection. Thus, in contrast to the results mentioned in Fig. 3, it took more roguing and a longer time to remove the tuber-perpetuated disease from the mass-planted plot than it did from the tuber-unit plot. The disease in the mass plot was reduced, however, by very careful roguing, as is shown by the following figures of the percentage of disease rogued each year obtained from a continuation of this plot over a period of five years; namely, 4.5, 3.2, 1.7, 0.6, and 0.8 percent. To accomplish by mass roguing results as good as this has required very careful and consistent work.

Seed-plot should be planted in tuber units. The planting of the seed-plot in tuber units—that is, planting all the seed pieces cut from a single tuber one after another in the row—enables the roguing to be done more accurately and earlier than is possible with other methods and thus gives conditions that are the most favorable to the control of the virus diseases by field-plot methods (Fig. 4). There are three main advantages from tuber-unit planting in a seed-plot: (1) Diseased plants are more easily and accurately detected when the seed pieces from each tuber are grouped together. (2) Late growing sets that are not yet large enough to show symptoms may be classed as probably diseased if their more advanced sister hills in the same tuber unit show symptoms; these may therefore be rogued earlier than would be possible where each plant has to be judged on its own performance, as is true in mass plantings. (3) Fewer centers exist for the dissemination of disease because of the grouping of hills from each individual tuber. Tuber-unit planting is very practical and should be used invariably in the seed-plot.

The superiority of tuber-unit roguing over mass roguing is indicated by records from experimental plots. In one case 18 percent leaf roll in the seed stock was reduced to 8 percent in the progeny in one year by mass roguing and to 2.4 percent by tuber-unit roguing. In another case 17 percent rugose mosaic was reduced to 4.1 and 2.4 percent, respectively, by mass and tuber-unit roguing.

The advantage of early and repeated roguings is illustrated by the following results. Triplicated seed-plots planted with identical seed containing 12 percent rugose mosaic were rogued by different methods. The plot rogued early and at weekly intervals gave 1.6 percent current-season symptoms—that is, symptoms from infection contracted during the current season—and 5.4 percent disease in the progeny; the plot rogued once about midseason and once late gave 2.4 percent current-season symptoms and 16.4 percent disease in the progeny; the plot that was not rogued but had the diseased hills noted during growth and eliminated at harvest time, gave 9.2 percent current-season symptoms and 15 percent disease in the progeny. Thus two roguings, one at midseason and the other late, were not sufficient to avoid an increase in the amount of disease in the stock, whereas early and repeated roguings decreased the disease from 12 to 5.4 percent in one season.

Tuber-indexing nearly ideal but not generally practicable. In recent years a tuber-index method has been developed for determining the health of seed stock and eliminating diseased tubers before planting in the seed-plot. This involves the growing of one eye from each tuber well in advance of field planting to determine whether the tuber is healthy (Figs. 6, 7, and 8). All tubers detected as diseased are discarded and only the healthy ones are kept for planting in the seed-plot. Where facilities are available for doing the work effectively this is undoubtedly the most nearly ideal method now known for controlling the potato-virus diseases. Where this method can be used it should be employed. It is too complicated, however, and requires too many facilities not available to most growers to be generally practicable even on those farms where special attention is given to potato seed improvement. The careful operator can accomplish nearly as good results, moreover, by the proper handling of a seed-plot planted in tuber units, a type of plot which is much more practicable for most farm conditions.

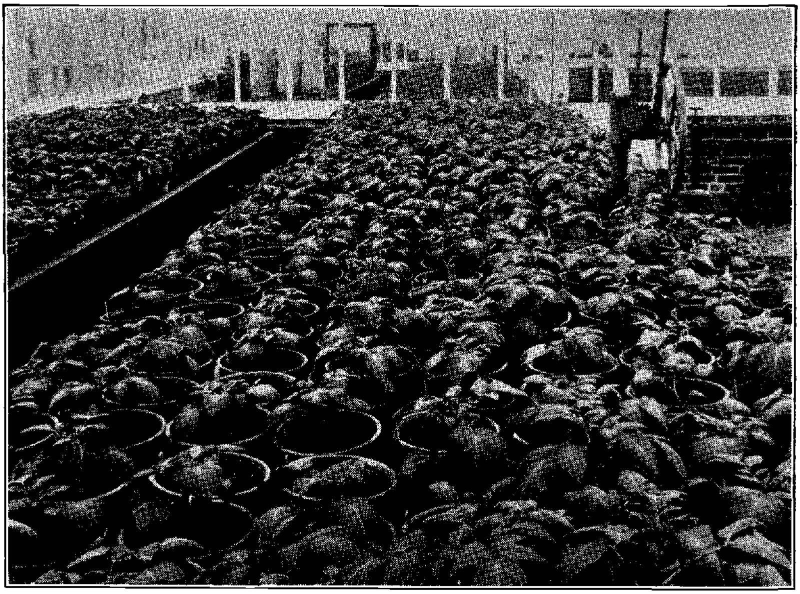


Fig. 6. Portion of greenhouse devoted to the tuber indexing of seed potatoes for the control of mosaic and other virus diseases. Each pot contains a plant grown from one eye cut from a separate potato and numbered to correspond. If the test plant, grown here in advance of the field planting, shows disease the tuber from which it came is discarded for seed. If the test plant is healthy, then the tuber is kept for planting in the seed-plot. Seed-plots planted with indexed seed are best planted in tuber units, isolated from other potatoes, and rogued for any undesirable condition. This is the most nearly ideal method for controlling the potato virus diseases that has been designed but it is practicable only for exceptional cases. The careful grower can accomplish nearly if not quite as good results by the right kind of roguing in tuber-unit planted seed-plots without tuber indexing.

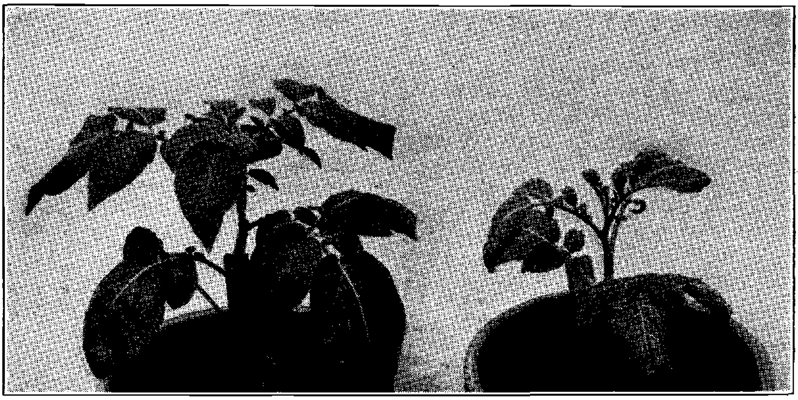


Fig. 7. Two index plants from lot shown in Fig. 6 each grown from one eye of a separate tuber; left healthy, right rugose mosaic. The tuber from which the plant at the right came will be discarded and not used for seed.

Seed-plot should be isolated. The seed-plot should if possible be in a patch by itself separated from the rest of the potatoes on the farm by at least 300 feet in order to avoid the danger of having some of the diseases spread from the general field to the seed-plot. Isolation of the seed-plot is essential particularly to prevent spread from one potato field to another of the mosaic and other virus diseases which are commonly carried by insects, notably aphids. When aphids feed on a diseased plant then on healthy plants, the virus diseases may be transmitted to the healthy plants. Any diseased plants located near the seed-plot and left without roguing thus serve as a source of contamination to the healthy plants in the seed-plot. If healthy plants are infected by the virus disease late in the season they may show no symptoms of disease that year, though some of the tubers would give rise to diseased plants if used for seed the following year. Consequently, plants in the seed-plot that are infected late cannot be rogued out because the disease cannot be detected that season. To avoid the chance of appreciable insect migration and consequent disease transmission from adjoining potatoes which are not rogued as carefully or as thoroughly as those in the seed-plot, a certain degree of separation between the seed-plot and any other potatoes is necessary. Isolation of the seed-plot by a distance of at least 300 feet from other potatoes is now regarded as adequate and essential to success in controlling these virus diseases.

To offer concrete suggestions for the maintenance of a seed-plot for the control of potato diseases, a farm plan has been made showing the location of the potato seed-plot separate from the main field and its relation to the other crops in each year of one four-year crop-rotation period (Fig. 9). These plans, made in cooperation with the department of Farm Management, show what is regarded as the best basic crop rotation for Western Oregon, consisting of grain, clover seed, clover hay, and a cultivated crop. A variety of materials including potatoes, corn, kale, etc., may be used for the cultivated crop.

Hill indexing unreliable for controlling the virus diseases. The growing of one tuber from a hill in advance of field planting as an index to the value of the hill lot for seed purposes has been tested and used to some extent for eliminating the virus diseases. An appreciable amount of disease can be removed from the seed stock by this practice, but the method is entirely inadequate as an effective means of controlling these troubles. In one case tested, 15 percent of the hill lots were taken out of the seed stock because of rugose mosaic in the index plants and yet 8.5 percent of the plants grown from the hills indexing as healthy gave rugose mosaic. This lack of control comes from the occurrence of hill lots in which only a part of the tubers are diseased. Our experience as well as that of others has shown that when a plant is infected late in the season, or after the disintegration of the seed-tuber has removed the union between the plants grown from one set, the hill lot will contain some tubers that are diseased and some that are healthy. Under such circumstances the value of the tuber taken from the hill for index becomes purely a matter of chance. Consequently, this method cannot be used with any degree of confidence.

Only standard market varieties should be grown. Seed selection, however, can not and should not be expected to overcome the paramount shortcomings or undesirable features of any particular variety. In other words, the efforts of growers toward improvement of the seed stock should be confined to the variety or varieties that are best suited to the local growing and market conditions. It is not advisable to spend time and energy on a second-rate variety of potatoes when much better financial returns could be obtained by growing only the standard types. A grower, or still better a whole community, should aim to confine selection of potato varieties to only one or two standard market varieties rather than to a large number of non-standard varieties. The advantages to be gained from offering to the market large quantities, even several car-load lots, of well grown, high-quality, and uniform potatoes would soon become apparent.

Seed certification an official movement that recognizes value of selection, etc., for potato improvement. The State of Oregon, through the Extension Service of Oregon State Agricultural College, is now giving

Fig. 8. The tuber indexing of potatoes for the improvement of foundation seed stock has been engaged in by some of the commercial seed companies in Oregon. The plants in the greenhouse illustrated here are grown for this purpose. Two and sometimes three successive lots of plants were grown in the winter and early spring before planting time out-of-doors. This allowed the indexing of from 20,000 to 30,000 tubers in a single season. A continuation of such high type of work as this will mean much to the future of agriculture in the Northwest.

official sanction to the movement for improving seed potatoes by selection, etc., by providing official inspection and certification of fields being grown for seed. The requirements for certification are such as to insure a product that may reasonably be expected to produce well. The requirements, on the other hand, are quite practical and are not too difficult for the careful grower to meet. The potatoes from fields which fulfill the requirements may be sold as certified seed under special official tags labeled "Oregon Certified Seed Potatoes." The practice is apparently firmly establishing itself because of the ability of the certified potatoes to produce so satisfactorily and so well as compared to the average lot of seed potatoes and because it furnishes a grower who wishes to obtain a good lot of seed potatoes an opportunity to buy potatoes of a more or less standard quality. If seed-potato improvement work has not been carried on for at least a year or two on one's own farm or if one's own seed potatoes are not of particularly good quality, the obtaining of an amount of certified seed potatoes sufficient to plant at least the seed-plot may well serve as the starting point for obtaining good-quality seed potatoes. Then if the seed-plot is maintained each year not only will the losses from disease be reduced to a minimum but the average yield of the potatoes grown will be greatly increased.

SEED DISINFECTION

Some diseases carried on surface of tuber. Owing to the fact that a number of skin diseases, such as scab, Rhizoctonia, etc., are so often present on the potatoes in this state, it is desirable that all potatoes, whether they show evidences of disease or not, be treated with a disinfecting solution before they are planted. Provided of course that the potatoes are not planted in soil already infected with disease-producing organisms, seed treatment not only will control these diseases mentioned but will also aid in controlling others, such as wilt, blackleg, dry-rot, etc. This is effected by killing the spores that may be on the surface of the potatoes and that, if not killed, might produce disease later on. Before treating any seed potatoes, however, it is always best to run them over a slat-work sorting table or rack and discard all tubers which are definitely diseased, bruised, cracked, or show evidence of decay. This will also remove much of the dirt, which interferes with the disinfecting solutions.

Four methods for treating potatoes are worthy of mention. To overcome these diseases on the tuber, a number of disinfecting solutions have been developed. Our knowledge about disinfecting methods is continually changing owing to the experimental work that is being done in different places. At present, mention should be made of four methods and their relative merits for treating seed potatoes. These are organic mercury, hot formaldehyde, acidulated mercuric chloride, and mercuric chloride. For general farm use mercuric-chloride (corrosive-sublimate) remains in the lead as our first choice at this time (1930). This is because it is more effective than the other methods and less special equipment is required for its use. The new acidulated-mercuric-chloride method may be excepted from this statement, but this method has not been tested or demonstrated thoroughly enough as yet to justify its general recommendation. It seems worthy of use, but what place it will finally occupy in potato culture remains largely to be determined. The details of these four methods are given here for the benefit of those who may wish to use any one of them.

Organic mercury not as effective as mercuric chloride but convenient to apply. Semesan Bel is the leading product now on the market in which organic mercury is used for potato treatment. This material is prepared and used by making a 10-percent solution in water and giving the potatoes an instantaneous dip. In treating, it is necessary only to insert the potatoes into the solution, souse them up and down a few times, and place them on a board to drain, after which they should be dried before cutting for planting. In our tests this material has sometimes given nearly as good control as mercuric chloride (Table III), but it is the general experience that from one year to another the results are variable and not as reliable as those obtained from mercuric chloride.

Hot formaldehyde not as effective as mercuric chloride but may be used where equipment is available. Hot solutions for treating potatoes are widely used in some places. Hot formaldehyde is the one most generally employed. This treatment is made as follows:

Use formaldehyde (commercial 40 percent) at the rate of two pints to thirty gallons of water. Dip potatoes for three to four minutes at 124° to 126° F. Pile treated potatoes six to eight inches deep, cover with wet sacks or canvas for one hour, and then allow to dry. The solution should not be warmer than 126° F. because this would injure the germination of the potatoes, nor should it be cooler than 124° F. as it would then not control the diseases if the tubers are dipped for only the four-minute period. Where the right equipment is available this is a very quick and a practical method

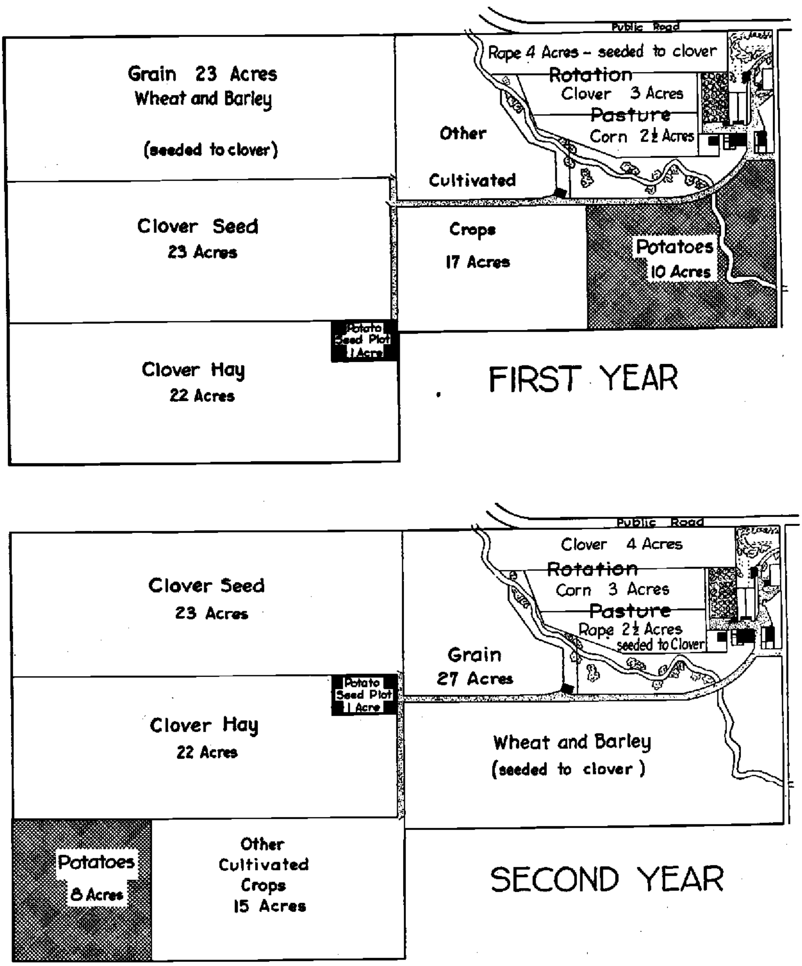
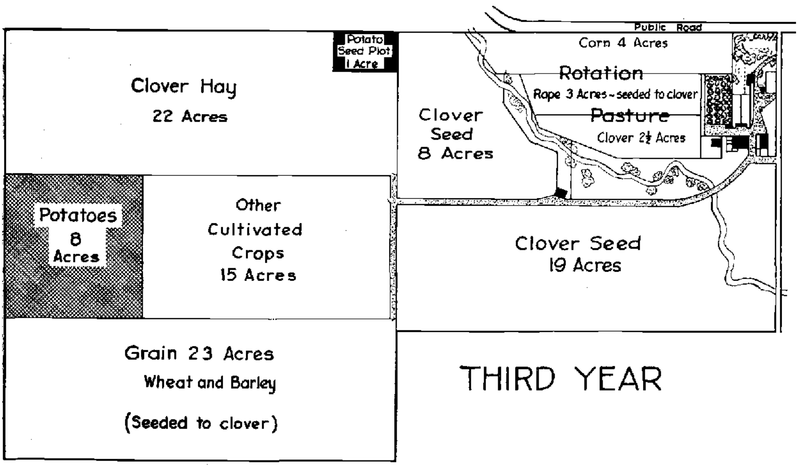


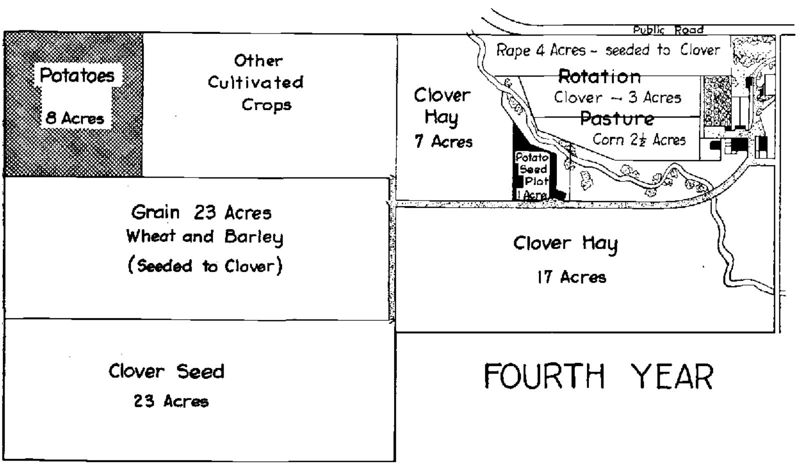
Fig. 9. Plan of a Western Oregon farm showing suggested locations for the potato seed-plot and the main potato field each year in a four-year rotation period for potato disease control. In these plans the seed-plot is separated from the main field of potatoes by at least 300 feet in order to guard against spread from one potato field to another of the mosaic and other virus diseases which are commonly insect carried. These plans, made in cooperation

of treatment (Fig. 10). Bulb-treating tanks, making use of a large tank for the solution, an agitator to provide for circulation of the solution, and a steam boiler for heat control, are very convenient for treating potatoes.

Hot formaldehyde will not control the Rhizoctonia disease quite as well as mercuric chloride and the yield will be a little less; the results, however, on the average, are considered satisfactory.

Some trouble has been experienced in using hot solutions on potatoes treated soon after being taken from cold storage. Such treated potatoes





with the department of Farm Management, make use of what is regarded as the best basic crop rotation for Western Oregon, consisting of grain, clover seed, clover hay, and a cultivated crop. Potatoes would generally occupy only a part of the space devoted to cultivated crops. Much of the farming of Western Oregon could, with great advantage, be carried on after this plan or a modification of it to suit individual needs.

will sometimes show circular, brownish, dead areas on the skin from $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter surrounding the lenticels and extending a short distance, perhaps $\frac{1}{8}$ inch, into the tuber. If these spots are numerous they come together and give large areas of dead skin. The exact cause of this injury has not been determined. Apparently no damage is experienced if the potatoes are left in common storage a week or two, depending on conditions before they are treated. No such injury has been noted when potatoes receiving only common storage are treated in hot solutions. It would seem best, however, not to treat potatoes in hot solutions at a time when the tubers are quite cold.

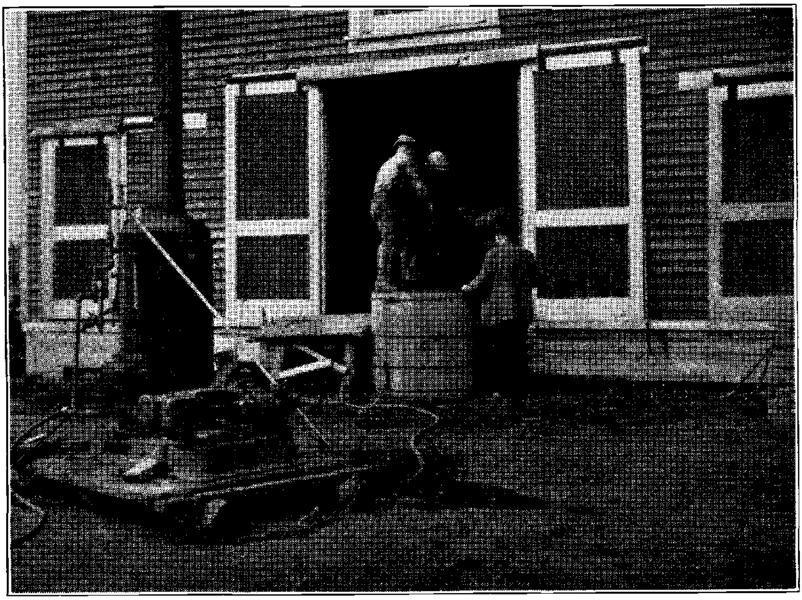


Fig. 10. Handy equipment for treating seed potatoes with hot formaldehyde available on some farms is a small boiler and a tank large enough to hold from four to six sacks of potatoes at one time. This permits rapid treating and is quite satisfactory for a considerable quantity of potatoes. When steam is added direct to the solution to provide the proper temperature it is necessary to add more formaldehyde occasionally to maintain the solution at the proper strength. The amount required can be calculated readily.

If it is desired to use cold formaldehyde for scab control alone or to avoid rot by treating the potatoes before placing them in storage in the fall, the formaldehyde may be employed at the rate of 1 pint (40 percent commercial formaldehyde solution) in 30 gallons of water, soaking the uncut potatoes for two hours and spreading them out at once to dry. This treatment is not at all effective for controlling Rhizoctonia.

Acidulated mercuric chloride promises to be very good but has not been thoroughly demonstrated. Work in New Zealand and in Minnesota has called attention to a very promising method for treating potatoes with mercuric chloride to which has been added some hydrochloric acid. This method has the advantages of being very quick, without requiring special equipment not available to the average farm, and yet of retaining approximately the effectiveness of the long-soak treatments with standard mercuric chloride. The data published in 1929 by the Minnesota Agricultural Experiment Station "show that by using the acidulated solution as a five-minute cold soak better results are obtained than those obtained by the hot-formaldehyde method and virtually as good as those secured by the standard mercuric chloride two-hour soak." The solution is made and used as follows: Dissolve 4 ounces of mercuric chloride (corrosive sublimate) in 15 gallons of water to which has been added 1 percent by volume or 1⅕ pints of commercial hydrochloric (muriatic) acid. The mercuric chloride dissolves quickly in this solution whereas it is slow to dissolve in ordinary cold water. Wooden, earthenware, or cement but not metal vessels should be used. Soak the potatoes in this solution for five minutes and dry before cutting for planting. The solution weakens slowly from use and apparently can be used as many as seven times before discarding or strengthening by the addition of more chemicals. This treatment has not been tested in Oregon up to 1930 but it appears worthy of trial. It is not recommended for general use unless first tried on a small scale and found satisfactory.

Mercuric chloride most effective material for treatment. Experimental work on potato-seed treatment in a number of states has shown definitely that Rhizoctonia, which is the commonest and most destructive potato disease in Oregon, is quite effectively controlled by the standard 1½- to 2-hour soak in mercuric chloride. Mercuric chloride is also equally as effective as formaldehyde for scab control; consequently mercuric chloride might well be adopted under most conditions as the standard material for all potato-seed treatment in the state.

Mercuric chloride used in 1-to-1000 solution. The mercuric chloride solution is prepared and used as follows:

Mercuric chloride (corrosive sublimate)	4 ounces
Water	30 gallons

Soak the uncut or whole potatoes in this solution from one and one-half to two hours and dry before planting.

Dissolve the mercuric chloride crystals or powder in about a gallon of hot water in glass jars, stone crocks, or a wooden bucket before dilution. This formula makes a 1-to-1000 solution. It decreases in strength with use. To correct this, add ½ ounce of chemical for every 4 bushels of potatoes treated for two hours. If a shorter treatment is used, reduce proportionately the amount of chemical added. For instance, if treated one and one-half hours add ⅜ ounce; if one hour, add ¼ ounce. Time and convenience are conserved if the chemical added is handled in a stock solution, one ounce dissolved in two quarts of water. Keep the water in the tank up to its original volume. The solution can be utilized as long as it remains clear, usually for not more than seven or eight times. Wetting the potatoes for twelve to twenty-four hours before treatment helps to remove dirt, softens the sclerotia of Rhizoctonia, and makes the disinfection more effective.

Caution. In using this mercuric-chloride solution it should be borne in mind that this material is very poisonous, and if potatoes are once treated with it they should never be used for human consumption or for feeding to animals.

If the planting is not to be done immediately after disinfection, the potatoes should be dried thoroughly before being placed in storage again. Care should be taken not to reinfect the potatoes by placing them back in the same bags or storage places unless they too are disinfected. (For disinfection of storage bin see page 32 under "Storage Conditions"). The bags may be disinfected by soaking for one hour in formaldehyde, 1 pint to 15 gallons of water.

Treatment conveniently done in barrels. Mercuric chloride corrodes metals and must be used in wooden barrels or tubs, asphaltum-painted iron, cement, or wooden tanks. One convenient way is to have about three barrels (Fig. 11) with a hole and plug at the bottom of each for convenience in draining the solution off after treatment. Two of the barrels can be kept

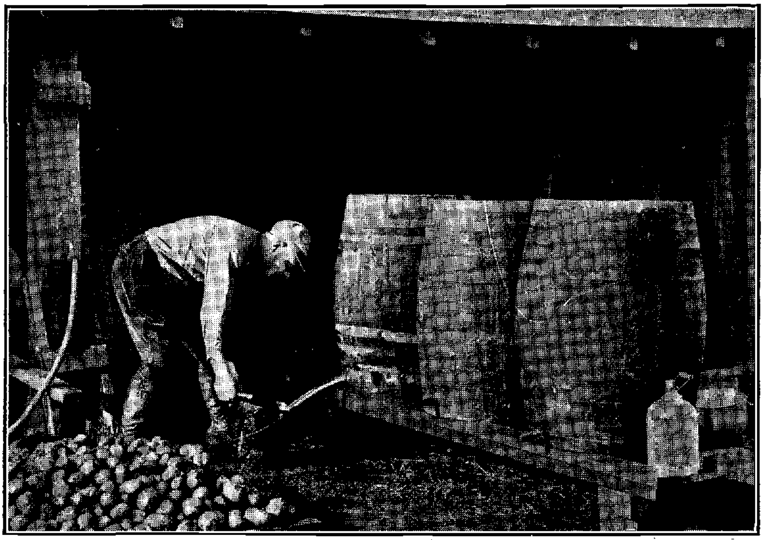


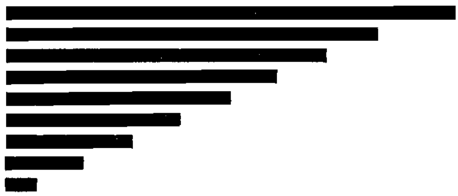
Fig. 11. One convenient arrangement for the treatment of potatoes is the use of three barrels mounted on a platform. The solution can then be transferred readily from one barrel to another.

constantly in use treating potatoes and the third one may be filled with fresh potatoes while the others are soaking. The better practice is to treat the potatoes loose in the solution rather than to have them in sacks. It has been shown that gunny sacks take more mercuric chloride out of the solution and thus weaken the solution faster than the potatoes themselves do.

Solution weakens with use and must be kept up to strength. The mercuric chloride reacts with the organic matter of the outer portion of the tuber and so becomes weaker with each successive treatment. Table I shows the result of tests to determine the rate of weakening following several successive treatments. After the first treatment the solution was only 75 percent of standard strength, after the fourth it was only 46 percent, and after the twelfth consecutive treatment it was only 6.5 percent of standard strength. This shows well the need for taking steps to maintain the solution at a strength that will be efficient for disease control. A convenient method for doing this has been mentioned in a preceding paragraph. Other work has shown too that dirt and refuse that may be carried into the solution with potatoes that are not well cleaned will weaken the solution much more than the potatoes themselves do. This emphasizes the desirability of at least using the precaution to run the potatoes over a slat-work sorting table to get out all of the dirt and trash possible. If this is not done the solution may be weakened excessively, become inefficient for further use, and give unsatisfactory results.

TABLE I. LOSS OF STRENGTH OF MERCURIC CHLORIDE WITH TREATMENT OF 12 CONSECUTIVE LOTS OF POTATOES[1]

Treatment	Percentage of standard strength[2]
	%
Original solution	91.0
After 1st treatment	75.0
After 2d treatment	66.0
After 3d treatment	57.0
After 4th treatment	46.0
After 5th treatment	35.0
After 7th treatment	26.0
After 9th treatment	16.0
After 12th treatment	6.5



[1]From Bulletin 331, Wisconsin Agricultural Experiment Station.
[2]Standard strength solution of mercuric chloride is 4 ounces to 30 gallons of water, or 1 part of the chemical to 1000 parts of water.

Seven and one-half gallons of solution required to cover one bushel of potatoes. Thirty gallons of solution will treat about four bushels of loose potatoes at one time, and so if used eight times will treat about thirty-two bushels. If, however, the potatoes are placed in sacks while treating, which is not so desirable a method because of the more rapid weakening effect on the solution, then thirty gallons used eight times will treat on the average only about twenty-six bushels of potatoes.

Potatoes should be treated before cutting. It is the safer and better practice always to treat the potatoes before cutting, and not after they are cut, as occasionally the seed pieces are apparently considerably injured by the solution if treated after being cut. This has been shown both by experimental work and by the general experience of growers. In cutting potatoes, is is advisable to have for each cutter two knives, which, when not in use, are to be kept with their blades immersed in about a ten-percent solution of formaldehyde. When cutting, reject every tuber which shows any signs of disease or discoloration of the interior, especially near the stem end. Not all tubers which show discoloration are affected by a disease-producing organism, but since many of them are it is safer to discard all such tubers and not to run any undue risk in the matter. Drop the knife used in cutting the discolored tuber into the formaldehyde at once to prevent infecting other seed with it and take out the other knife to use until another suspicious-looking potato is cut.

Much seed-piece rot can be prevented by proper suberization. When seed potatoes are cut and exposed to the drying action of the air before planting a high percentage of the sets will sometimes rot before the young plants are produced or have become established. This result is generally due to incomplete transformation of the cell walls in the tissues below the cut surface into suberin or cork, a reaction called suberization. Suberization is hindered by dry air and cool temperatures. When sets after cutting are exposed excessively to dry air, the suberin layer is not complete, cork formation is patchy, and rot generally destroys much of the set after planting. Instead of suberizing, the cut surface merely dries down to a hard layer, which later cracks. These cracks furnish an ideal opening for soil organisms to invade the tissues and rot the sets. Poor stands are often noted due to this condition. This can be quite effectively prevented by surrounding the cut seed with conditions favoring suberization before planting. This is readily provided by maintaining a temperature not lower than 55° to 65° F. and a high humidity. Under most conditions it is sufficient, without special treatment, to hold the cut seed for a day or two in bulk in sacks or boxes not unduly exposed to the air. If the cutting is done when the air is warm and quite dry it is advisable to pour a bucket of water over the sacks of cut seed to keep them moist for the first 24 to 48 hours. Under these conditions of a warm, moist air the cut surface will suberize so perfectly that it protects the set as thoroughly as does the unbroken epidermis of whole seed. These well-suberized sets will remain sound in the soil long after the plants are established. When proper attention is given to this item much of the seed-piece rot may be avoided and cut seed may be used with as good results as whole seed.

Some use has been made of land-plaster, sulfur dust, etc., applied to the cut seed immediately after cutting to protect it from decay. These materials no doubt afford considerable protection to cut seed. It seems likely that sulfur, being the stronger fungicide, might give greater protection than plaster. It is believed, however, that better protection for the cut seed can be obtained from proper suberization, discussed in the preceding paragraph, than can be obtained from the use of any of these dusts.

SPRAYING

Bordeaux mixture used for spraying potatoes. In order to control certain of the leaf diseases such as late blight or early blight, spraying of the potato plants must frequently be resorted to. For this purpose bordeaux mixture has proved to be the most efficient spray mixture used. The following formula is frequently employed for potatoes:

Copper sulfate (Bluestone)	5 pounds
Lump lime	5 pounds
Water	50 gallons

This is briefly and commonly expressed as 5-5-50 bordeaux. A weaker solution, such as 3-4-50, may often be used with good results if it is thoroughly applied.

Bordeaux mixture should be used as soon as made or else preserved with sugar. A convenient and satisfactory method of making up this spray mixture is to dissolve the 5 pounds of copper sulfate in 25 gallons of water either by suspending it in a sack near the top of the water over night, or in a small quantity of hot water, as it dissolves slowly; slake the 5 pounds of lime gradually in a small amount of water and dilute the milk of lime to 25 gallons, then pour the two solutions together into a third barrel or through a strainer directly into the spray tank and stir vigorously. The resulting mixture is bordeaux and is of a milky blue color. The mixture may also be prepared by pouring the diluted milk of lime directly into the spray tank and adding the copper sulfate solution gradually to it while it is being agitated. The spray mixture should be strained as it is put into the spray tank, since otherwise the small particles held in suspension are very apt to clog the spray nozzles and cause considerable trouble. The spray mixture is then ready for use and should be applied at once. If it is impossible to spray at once owing to bad weather or other unfavorable conditions, ¾ ounce (a heaping tablespoonful) of sugar dissolved in a small amount of water should be added to each barrel of 50 gallons of spray mixture. This will keep the spray mixture in good condition for a long time, even two or three months, though without the sugar added the mixture would have lost most of its value and become practically worthless in even one day's time.

Bordeaux mixture may be conveniently made from stock solutions. In case large quantities of bordeaux mixture are to be used, it will be found convenient to make up stock solutions of the copper sulfate and lime at the rate of one pound in one gallon. To prevent undue evaporation these stock solutions should be kept well covered when not in use and should always be well stirred up before any is removed for making bordeaux mixture. Then when 5-5-50 bordeaux is desired, 5 gallons of the copper-sulfate stock solution and 5 gallons of the milk-of-lime stock solution may each be diluted with 20 gallons of water and then poured together with thorough stirring, making 50 gallons of the desired spray mixture. These solutions should not be mixed to make the dilute bordeaux, however, until it is to be used as it loses value if left standing for more than a few hours, unless sugar is added as mentioned above. Further details in regard to the making of bordeaux according to any desired formula may be obtained from the Oregon Agricultural Experiment Station bulletin on Preparation of Spray Materials.

Spray should be applied from three to five times during season. In the East, the largest increases in yields as the result of spraying have been obtained when the spraying was begun while the plants were from six to eight inches in height and continued at intervals of about every two weeks. Much benefit has been derived, however, by commencing later in the season and spraying only three times. In Oregon probably the only disease for which spraying should be done regularly is late blight, though both early blight and tip burn can also be successfully controlled by this means. The first application of spray should be made at least by the time the disease first appears.

When the plants are from six to eight inches in height it will require approximately 75 gallons of spray mixture per acre to cover the plants well and give good control. Later when the plants are larger from 100 to 125 gallons of spray will be needed.

Spraying must be thoroughly done to be effective. A convenient and satisfactory spray machine is one that will maintain at least 100 pounds of pressure, that will spray thoroughly four rows of potatoes at a time, and that is geared to the truck or run by an engine. The spraying should be thoroughly done, using preferably three nozzles to each row, one from above and one on each side (Fig. 12), since the plants must be completely covered with the fine mist in order to be effectively protected. The spray machines which are equipped with only one nozzle for each row of potatoes are not adequate for covering the entire foliage of the plants with the spray and will not effectively protect them from infection. Such machines are better than nothing but should be used only when it is impossible to obtain the more efficient three-nozzle attachments. For small home-garden plantings the hand barrel spray outfit which requires one person at the pump and one to handle the nozzle is sufficient for good blight control, provided the work is thoroughly and carefully done.

Lime-sulfur not satisfactory for potato disease control. It should perhaps be stated that lime-sulfur should not be used for spraying potatoes. This material does not give as good results in controlling the late-blight disease, and furthermore when used on potatoes it causes an actual stunting of the plants and a reduced yield as compared to unsprayed plants. Bordeaux mixture, on the other hand, will often give increased yields even though no appreciable amount of disease is present on the plants.

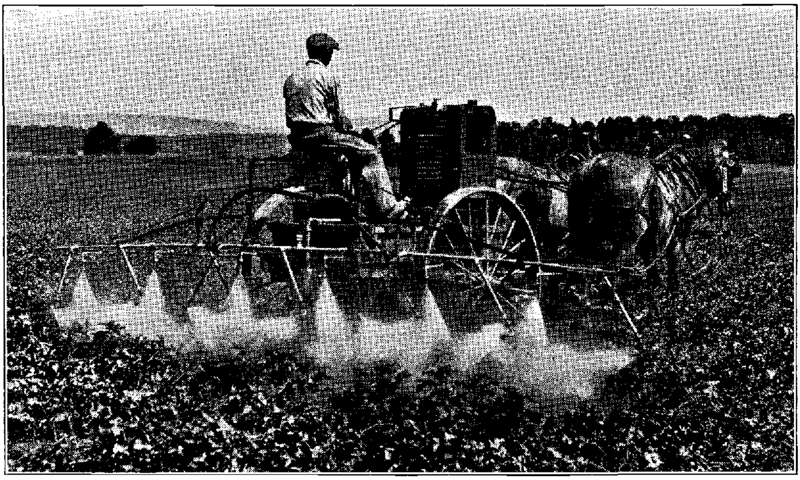


Fig. 12. Spray machine showing a good arrangement for the use of three nozzles to each row of potatoes. *(Illustration by courtesy of Bateman Manufacturing Company.)*

Dusting is a desirable method for late blight control. That spraying for late blight control is effective and profitable in many sections has been demonstrated over and over again, yet the practice has not been as universally adopted by growers as the practicability of the method would justify. One reason for this is that spraying is a rather inconvenient task to perform. Dusting, on the other hand, as compared to spraying, is much more conveniently done and requires less expensive and complicated machinery for applying. This has led to a very great interest in the possibility of the substitution of dusts in place of liquid sprays wherever possible. Much experimental work conducted in a number of states indicates that dust properly applied will give approximately as good blight control as the spray.

Copper-lime dust best for potatoes. The dust used for potato blight control consists of a mixture of partly dehydrated copper sulfate and hydrated lime. A mixture frequently used contains 15 pounds of the dehydrated copper sulfate and 85 pounds of the hydrated lime. Where there are insects to be killed too, some calcium arsenate, usually about 8 pounds, is put into the mixture in place of an equal weight of the hydrated lime. This gives a 15-8-77 formula. About 50 pounds of this dust mixture is required per acre for each application in order to equal in amount the metallic copper contained in the 100 gallons of bordeaux mixture necessary to give good control of blight on full-grown plants. Proportionately less than this amount would be required when the plants are smaller. The schedule as to the number and frequency of dust applications required for blight control will not differ materially from that of spraying. For best results dusting should be done very early in the morning while the air is quiet and dew is present on the foliage. Dusting plants with copper-lime dust when they are dry results in reduced effectiveness. These dusts may be readily mixed at home or they may be obtained commercially mixed from different companies. To get effective results, the hydrated lime must be fresh when used.

Fig. 13. The dusting of potatoes with copper-lime dust for late blight control is nearly as effective as spraying. Hand dusters can be used successfully on acreages up to five acres. Machines for hand dusting are not expensive.

Dusting is more convenient but costs more than spraying. The materials required for dusting an acre of potatoes cost more than those necessary for spraying an acre, but the dust can be applied more quickly and with cheaper equipment. When all items of the cost are computed it costs more to dust potatoes than to spray them.

On the basis of equipment necessary for application, dusting has the advantage over spraying, particularly for the small grower, for a hand duster may be used with good results on acreages up to three to five acres (Fig. 13), whereas no hand sprayer is satisfactory for this size of field. Dusting appears to be worthy of considerable use in Western Oregon where late blight is often a serious factor in potato production.

STORAGE CONDITIONS

Storage losses held down by low temperatures and good ventilation. A considerable part of the loss of potatoes due to disease is brought about by various tuber-rots in storage. There are a number of distinct rots of potato tubers caused by different organisms, and without exception they are most severe when the storage temperatures are high and when the air becomes heavily laden with moisture owing to lack of proper ventilation. For instance, neither the powdery dry-rot which is so prevalent and serious in the eastern part of the state, nor the dry-rot which is apparently widely distributed all over the state, will develop seriously in storage if the temperature is kept from 35° to 40° F., and the storage place is kept well ventilated. It is also well known that the shrinkage in weight of potatoes in storage is much greater when the temperatures are allowed to remain high than when they are kept down to 35° to 40° F. These facts show the necessity of surrounding stored potatoes with the proper storage conditions in order that the serious losses from storage rots and from shrinkage in weight may be reduced.

In warm weather the potatoes should not be placed in storage until they have cooled down to the night temperature. This will tend to prevent overheating and sweating conditions which are favorable to infection.

Good storage places are necessary for trustworthy storage. A good storage place embodies the following requirements: ease and thoroughness of ventilation, ability to prevent rapid changes in temperature inside in response to rapid changes in the temperature of the atmosphere outside, convenience in cleaning, conveniently arranged for use, ample in size, and durable. In many sections of the United States where potatoes are an important cash crop these essentials are most efficiently obtained in the cellars constructed mainly underground and partly above, with three or more ample-sized ventilators in the top, and with large doors and a driveway at one end large enough to accommodate a wagon for loading and unloading the potatoes.

Another type of storage place used with much satisfaction in this state is the double-walled, well-insulated bin with the walls about six inches thick and with ventilators to let air in beneath the potatoes and out at the top; these ventilators, when the days are warm, may be left open at night and kept closed in the daytime, with the result that the whole bin is kept reasonably cool all the time. All storage places should be provided with a thermometer, so that the temperatures may be regulated intelligently. Injury is produced when the temperatures are too low as well as when they are too high. With the dry-rot it appears that the critical time, the time when many of the infections and when much of the loss from this disease results, is during the first two months after digging, when the temperatures are likely to be higher than during any other part of the storage period. It is at this time that our potatoes need especially to be surrounded by the favorable storage conditions that are best obtained only in a good storage place. Whenever possible the storage place should be located in a dry, well-drained place, and preferably away from a sunny slope, so as to avoid unduly high temperatures.

Bins are best made up with false slatted walls and floors. As an aid to thorough ventilation, the lack of which is now responsible for much of the poor storage in the state, all permanent potato storage places should be equipped with bins made of slatted floors, slatted walls, and double slatted bin partitions. For convenience in taking down the bins when emptied of potatoes, these should be made in sections. They may be constructed after plans shown in Fig. 14, or to suit particular needs. In any event the division

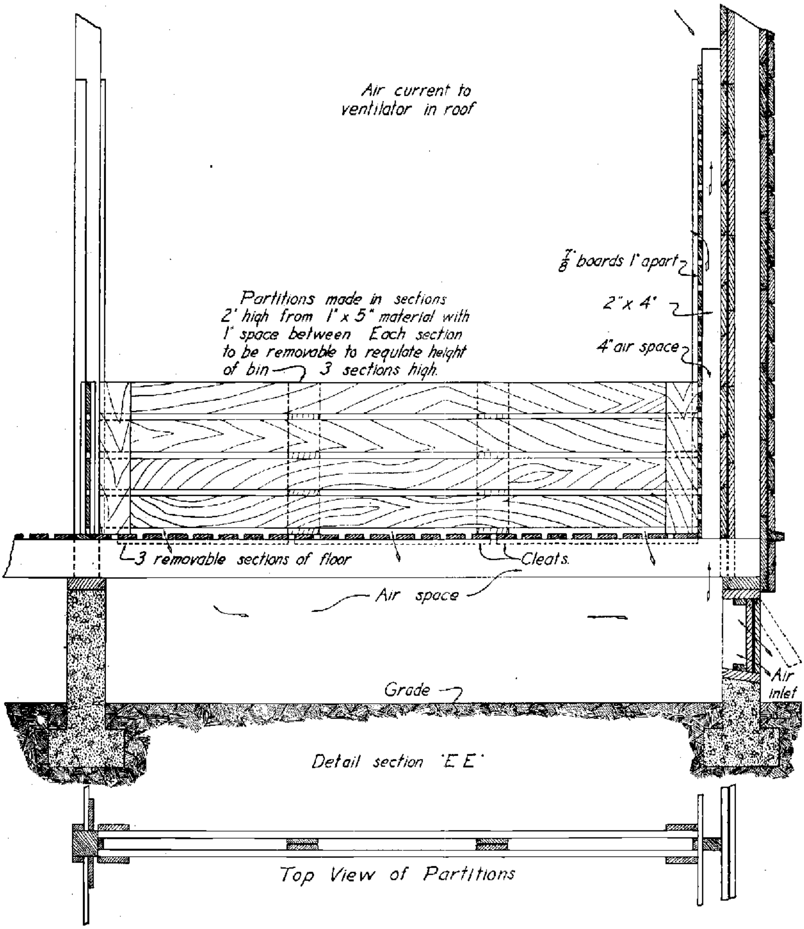


Fig. 14. Section of potato bin showing one plan for the construction of the slatted walls, floors, and bin partitions to give good ventilation, which is so much desired in potato storage.

walls should be double, with an air space between them. The ventilated wall and floor may be constructed of three-inch board strips, allowing a one-inch space between boards, and separated from the main floor and wall by joists and studding. This type of bin construction provides a conduit for air on the side wall and, connecting with the bottom, affords an air passage-way completely around the stored tubers, materially lessening the danger from tuber heating and from tuber-rots in storage and providing a convenient and sanitary bin which can be taken down easily, cleaned, and disinfected when desired.

Bins should be cleaned and disinfected before potatoes are stored. In order to kill all the rot-producing organisms already present, storage places, particularly those in which rotting of the potatoes was bad the previous year, should be thoroughly cleaned and disinfected before potatoes are again placed in storage. To accomplish this, the storage places may be swabbed or sprayed with either of the following solutions:

Copper sulfate (Bluestone)	1 pound	*or*	Formaldehyde	1 pint
Water	10 gallons		Water	10 gallons

After being disinfected the storage place should be well aired and dried out before potatoes are again placed in it.

POTATO DISEASES

Accurate recognition is the first step to successful control of any disease. The first step in the successful control of any disease is the accurate recognition of the symptoms or appearances of the particular disease under consideration. Before one can progress far toward the accurate identification of most of the potato diseases it is necessary to give a careful and complete examination of the entire plant, noting specifically the color, shape, size and condition of the leaves; the soundness and condition of the stems, such as rotting or cankerous areas, discolorations of both the inner and outer tissues, above and below ground; the condition of the seed piece, and the presence of any abnormalities on the roots and the new tubers. At times a microscopic or cultural examination of affected tissues must be resorted to before a reliable determination can be made. It is of course not expected that the general grower will do this. The practice is mentioned here only to show that when the diseased plants have an appearance other than that which is average or typical, some difficulty may be experienced in the identification of the disease. One may occasionally encounter a disease which is not included in this Circular.

Key designed to aid in identification of potato diseases. As an aid to growers in determining what diseases may be affecting their potato crops the following brief "Key for Identifying Potato Diseases" has been prepared. Having found a plant or tuber affected by a common disease in the typical way and having accurately noted the symptoms, this key will no doubt be of assistance to the grower in the recognition of the disease. Following the key will be found a more complete though necessarily condensed description of the different specific diseases, together with the definite measures that are recommended for their control.

Though of course some diseases affect both plants and tubers, the key is divided for convenience into two parts: (1) Diseases Affecting Plants and (2) Diseases Affecting Tubers. Some diseases are therefore listed under both groups. For those who are not familiar with the use of such a key it may be explained that it is arranged in "steps" of equal rank, as A, B, and C, and under each of these 1, 2, and 3; and in steps of unequal rank, as A, 1, and a. The correct procedure is to read the steps of equal rank, as A, B, C, etc., until one is found to fit the specimen under examination; then drop down to the next unequal step below and read the steps of equal rank with this one, as 1, 2, 3, etc., until the specimen is properly located, or if a further subdivision is made drop down to the final rank and select the description which fits the specimen. Then, having the name of the disease, turn to the more complete description and the illustration of the disease as given on later pages for checking up on the accuracy of the determination and for the information desired on the nature and control of the disease.

As an illustration of the method for using the key let us suppose we have a plant with no conspicuous spots on the leaves but with leaves rolling or drooping and yellowing, stunted in size, with lower end of stem affected by black rot, and the seed piece entirely rotted. Under "I. Diseases Affecting Plants," A does not fit, B fits; as a precaution we may look at C but it does not fit. Under B, 1 fits, 2 and 3 do not fit. Under 1, "a, Lower part of stalk especially below ground inky black and rotten. Plant easily pulled up. Seed piece rotten, usually in pulp. Occasionally soft rot in some of the tubers. Blackleg." This appears to fit our specimen exactly, and we look at the more complete description of the disease on pages 37-38 for a confirmation of our determination and for the information that is desired on its nature and control.

KEY FOR IDENTIFYING POTATO DISEASES

I. Diseases affecting plants.

A. Foliage showing prominent circular or irregular dead areas not confined to lower leaves.

1. Dead areas at first circular or irregular spots within leaf-blade or on part of margin. May finally involve whole leaf.

a. Spots brittle, light to dark brown, small (one-eighth to one-half inch in diameter), more or less circular.

2. Dead areas quite irregular extending along veins and spreading into leaf-blade or confined at first to tips and margins of most exposed leaves and working inward.

a. Dark brown or black discolored areas extending along veins and spreading irregularly out into leaf-blade usually most prominent on lower surface. Leaves in upper middle of plant generally worst affected. These may die and drop off, leaving portion of stem with no normal leaves attached. Usually not prevalent until after midseason.
Current-Season Rugose Mosaic. Pages 71-73.

b. Brown, dead areas confined at first to tips and margins of most exposed leaves and working inward. May finally involve whole leaf. Dead spots harsh, dry, and curling up, and leaves inclined to roll on midrib. Appears mostly after very warm, sunny weather and often following insect injury.
Tip Burn. Page 79.

B. Foliage showing evidence of disease in wilting, rolling, mottling, crinkling, dwarfing of, or loss of color in leaves with no prominent dead areas or if present confined to lower leaves, or to veins on lower surface of leaves.

1. Leaves wilting or rolling or both, usually accompanied with change of color from green to yellow or brown. Plants usually stunted and dying prematurely.

   a. Lower part of stalk especially below ground inky black and rotten. Plant easily pulled up. Seed piece rotten, usually in pulp. Occasionally soft rot in some tubers.
   Blackleg. Pages 37-38.

   b. Stalk firm and apparently normal on exterior but with inner tissues stained brown in streaks at least as far up as surface of ground. Seed piece often sound. Brown discoloration in vascular region at stem end of some tubers.
   Wilt. Pages 46-53.

   c. Stalk firm and without discoloration either on exterior or interior. Roots showing small swellings or knots varying up to ¼ inch in diameter scattered irregularly over entire root system. Some tubers in hill slightly to distinctly pimply on surface with small circular brown spots with pearly white center as small as pinheads in tissue about ¼ inch below surface.
   Nematode. Pages 53-56.

2. Leaves more or less rolled without wilting or extensive loss of color.

   a. Plants often normal in size. Rolling most conspicuous on upper leaves, which may show yellowish or brownish tints but usually no general yellowing. Aerial tubers and enlarged nodes on stems common. Dry reddish brown scars on stem below ground, on stolons or roots. Slight whitish growth appearing like salt deposit on green stems a short distance above soii line. Many small potatoes common with some tubers usually showing black sclerotia scattered irregularly over surface.
   Rhizoctonia. Pages 38-46.

   b. Plants more or less dwarfed. Lower leaves always rolled, leathery or brittle, often dying from tips backwards. Other leaves may roll also. Plants have stiff upright habit or are bushy and are almost always pale in color. Yield small and tubers usually attached close to stem.
   Leaf Roll. Pages 73-75.

3. Leaves mottled with irregular yellowish-green or cream-colored areas and often crinkled or corrugated but not rolled or wilted. Sometimes veins on lower surface of leaves discolored brown to black.

   a. Leaves slightly crinkled or corrugated and mottled with faint yellowish-green areas. Plants tending at first to be more erect than normal, not conspicuously dwarfed, except in severe cases, but drooping and dying prematurely.
   Mild Mosaic. Pages 69-71.

b. Leaves strongly crinkled or corrugated, may be dark green or may often have numerous small yellow mottled areas along or near veins. Veins on under side of leaves frequently black. Plants noticeably to extremely dwarfed and somewhat resembling curly kale.

Rugose Mosaic. Pages 71-73.

c. Leaves showing large irregular yellow to cream colored spots or blotches usually distributed freely over the plant. Leaves flat not crinkled. Plant slightly to moderately stunted.

Calico. Page 77.

C. Foliage normal or nearly so to slightly yellowish in color, leaves small, rounded, and yellow-green at margins; stalks numerous, small and spindling, often considerably branched and showing no external or internal discoloration; tubers small and occasionally very numerous, sometimes showing thread-like discoloration of vascular bundles.

Witches'-Broom. Pages 76-77.

II. **Diseases affecting tubers.**

A. Tubers exhibiting abnormalities, such as spots, discolorations, rots, etc.

1. Tubers showing abnormalities other than rot on exterior.

a. Rough, more or less round, corky, scabby, brown spots from $\frac{1}{4}$ to $\frac{1}{2}$ inch or more in diameter scattered irregularly over surface of tuber.

Scab. Pages 61-62.

b. Small, roundish, slightly raised spots usually less than $\frac{1}{4}$ inch in diameter, epidermis around margin of spot torn and rolled back exposing brown, powdery mass of spores.

Powdery Scab. Page 62.

c. Irregular brownish stained areas on skin of tuber, which turn silvery and show many fine black points when moistened. Spots $\frac{1}{4}$ to 1 inch or more in diameter, usually most abundant on stem-end half of tuber.

Silver Scurf. Page 62.

d. Black sclerotia from size of pin head up to $\frac{1}{4}$ inch in diameter, scattered irregularly over surface and attached to skin tubers, particularly noticeable when wet, looking like dirt but will not wash off though may be scraped off with finger-nail, leaving skin smooth.

Rhizoctonia. Pages 38-46.

e. Small slightly-raised pimple-like elevations on surface of tuber about $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter which when abundant produce a very irregular, roughened and warty appearance. At varying distances usually not more than $\frac{1}{4}$ inch in tissue beneath such elevations are small circular brown spots usually less than $^1/_{16}$ inch in diameter with pearly white center.

Nematode. Pages 53-56.

f. Slightly raised enlarged openings in skin filled with light or cream-colored growths of cells appearing as though pushed out from below and which assume a corky appearance in older stages or when exposed to air for a few hours after digging.
Enlarged Lenticels. Page 82.

2. Tubers showing abnormalities on interior; exterior normal.

a. Discolored strands or ring varying from light yellow to brown or black extending for varying distances into tuber at stem end from point of stolon attachment and confined to vascular tissues which when normal appear as faint layer located about ¼ inch beneath skin.
Wilt. Pages 46-53.

b. Irregular brown spots varying in size up to ½ inch or more in diameter occurring in scattered and irregular places in interior of tuber.
Internal Brown Spot. Pages 79-80.

c. Extensive network of small brown strands of discolored tissue extending throughout interior of tuber though occurring more abundantly in tissues near surface.
Net Necrosis. Pages 77-79.

d. Gray blotches prominent in tissues near surface of tuber, or strands of brownish discoloration through interior but distributed mostly in vascular region about ¼ inch below surface. Found after exposure to low temperature before or after digging or in storage.
Frost Necrosis. Page 81.

e. Irregular area of dead black tissue in interior of tuber.
Black Heart. Pages 80-81.

f. Hollow areas occasionally surrounded by brown corky cells in center of tuber.
Hollow Heart. Page 81-82.

3. Tubers affected by rot.

a. Slightly sunken dark-colored rotted areas of irregular size varying from very small spots to areas involving whole surface of tuber and extending into tissues usually not deeper than half an inch at harvest time, though finally (particularly in storage) whole tuber may become affected.
Late Blight and Rot. Pages 56-59.

b. Large sunken areas of brown firm rot occurring on any part of tuber and frequently starting at wounds, often involving large part of tuber. Surface of affected portion of tuber much wrinkled and often bearing numerous bluish or white protuberances.
Dry-rot. Pages 63-64.

c. Large sunken areas of brownish dry-rot extending into tuber in irregular way, and often containing pockets or cavities partly filled with a pink powdery mass of fungous growth. Surface of affected portion of tuber much wrinkled and often bearing pinkish or whitish tufts of fungous growth.

Powdery Dry-rot. Page 64.

d. Small to large rotting areas slightly sunken and light brown with few long black string-like strands attached to surface, interior rotted portion composed of alternating layers or flakes of yellowish and white tissues.

Armillaria Rot. Page 65.

e. Soft slimy rot frequently starting at stem end or at wounds and eventually affecting whole tuber.

Blackleg. Pages 37-38.

f. Rot of tuber at stem end varying from slightly sunken and withered condition to soft and jelly-like light brown colored rot extending back at times 1½ inches from stem end. Rot affects only long tubers.

Stem-end Rot. Pages 65-66.

B. Tubers exhibiting no evidence of disease either externally or internally. Inspection must be made of growing plants for trustworthy determination of presence of these diseases in tubers.

Mild Mosaic. Pages 69-71.
Rugose Mosaic. Page 71-73.
Leaf Roll. Pages 73-75.
Witches'-Broom, Pages 76-77.
(Occasionally) *Wilt.* Pages 46-53.

DISEASES DUE TO PARASITES

The diseases are here grouped quite arbitrarily according to cause. Under parasitic diseases are listed the diseases of the potato known to be due to living organisms on or within the tissues of the potato.

BLACKLEG, *Baccillus phytophthorus* Appel. The common name of this disease is taken from the appearance of attacked plants. In typical cases the diseased plants die in the early part of the season owing to an inky black, relatively dry decay of the main stalk progressing up from the point where it is attached to the parent tuber (Fig. 15). The seed piece is invariably rotten, usually in a pulp. Plants less severely attacked or not affected till later in the season produce potatoes which if harvested and planted are very apt to carry the disease over to the next season. Sometimes as high as 30 percent disease has been obtained by this means. In the field before digging or later in storage, some of these tubers may develop a soft slimy rot due to the blackleg organism (Fig. 16). From such tubers the organism may be spread by contact to healthy tubers in the bin, which if planted untreated may give rise to disease in the field. It is believed that this is one of the chief means by which the disease is transmitted from one season to the next. Recent work has showed that contrary to former conclusions the organism stays alive in the soil over winter. In Minnesota it has been demonstrated also that the seed-corn maggot is active in spreading the disease among plants. If the fly has access to seed potatoes before planting, eggs may be deposited which on hatching are often contaminated with the blackleg organism. As these maggots migrate through the tissues of the tuber they break down the ability of the seed piece to wall off the disease with cork and consequently a diseased plant is frequently the result. Eggs laid in stems of healthy growing plants may also be the cause of initiating the disease. Up to the present time the possible relation of the seed-corn maggot to blackleg of potatoes in Oregon has not been determined. All of the ways in which the disease spreads here are not fully known.

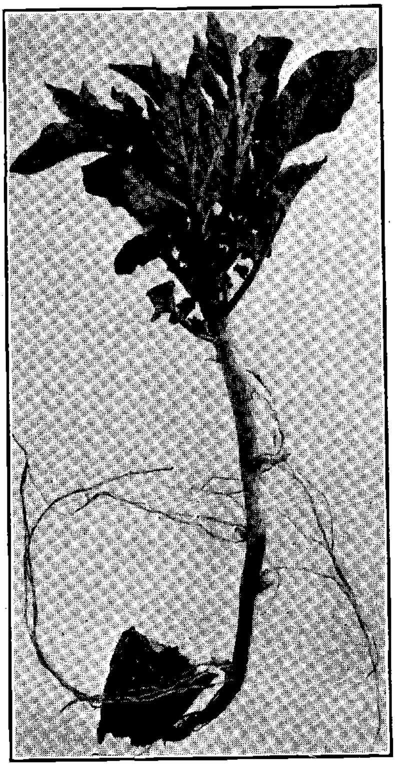


Fig. 15. Blackleg. Plant showing the black rot progressing up from the lower end of the stem. (*Photograph by W. C. Whitaker.*)

The disease can be prevented in part by planting treated seed from healthy hills. Disease-free seed is best obtained by thorough roguing in a seed-plot. All partly rotted potatoes in the seed lot should be sorted out and the remainder treated according to the suggestions given under "Seed Disinfection." If the seed-corn maggot proves to be a factor in spread of the disease here, protection of the seed from the fly before planting would be advisable. The crops should be rotated. The practices in common use in Oregon for the control of this disease are not fully effective in holding it in check. Further investigations are needed.

RHIZOCTONIA OR BLACK SCURF, *Corticium vagum* B. & C. This disease, which frequently goes by the name of black scurf owing to the presence of black sclerotia or resting bodies of the fungus on the potato tubers at harvest time (Fig. 17), is apparently the commonest and most serious potato disease in the state, being present in every potato-growing locality. The disease manifests itself in a variety of ways, the most important of which are the following:

Often the young sprouts are attacked and are "burnt off" by the fungus even before they reach the surface of the ground. This may lead to the production of other new sprouts which in turn are also burnt off with the result that a rosette or cluster of sprouts is formed with their tips killed, none of which reach the surface of the ground and are able to produce plants (Fig. 18). This is often the cause of poor stands.

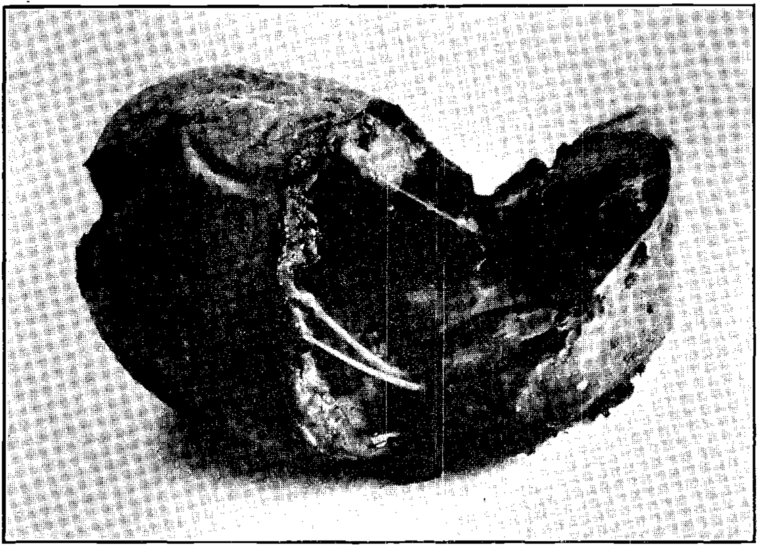


Fig. 16. Soft, slimy field-rot of tuber produced by a plant affected with blackleg.

Plants attacked less severely or later in the season may develop lesions or dead areas on the underground stems (Fig. 19) and upon the stolons, which so interfere with the normal growth and functions of the plant that the leaves may roll up considerably, small potatoes may form in the axils of the leaves or other convenient places in the top of the plant (Fig. 20), or

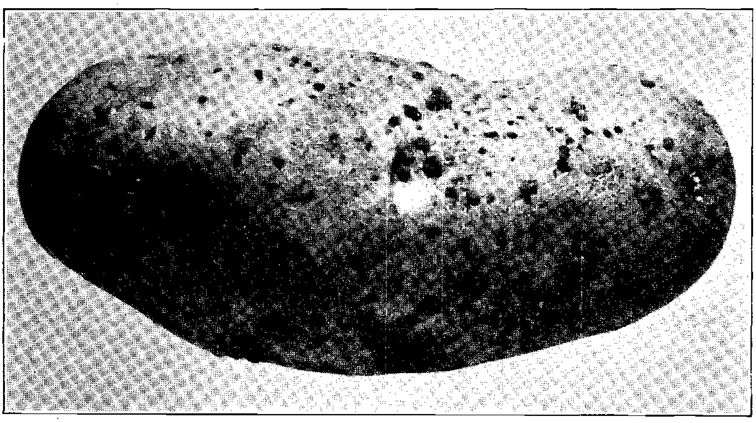


Fig. 17. Sclerotia or resting bodies of Rhizoctonia on surface of tuber. This is one of Oregon's most destructive potato diseases.

the nodes of the stems may become considerably enlarged and knobby because the starch cannot be properly transported downward, and a large number of small potatoes and a few large knotty ones may be developed underground. This result often gives rise to the term "little potato" disease. The yields in such badly attacked hills are practically worthless for commerce as well as for seed.

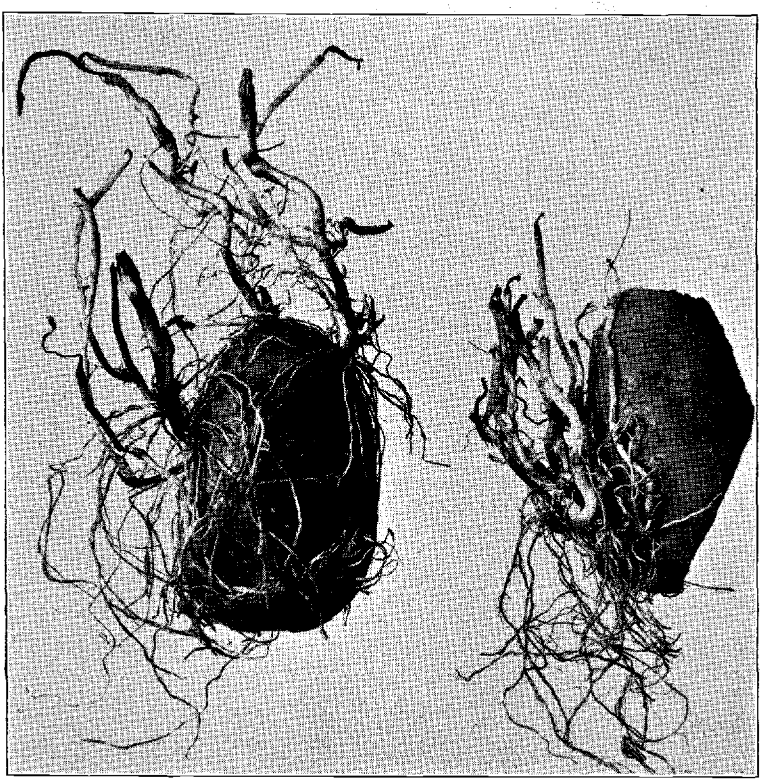


Fig. 18. Burning off of young sprouts due to Rhizoctonia. This is often a cause of poor stands.

Near the base of attacked plants and extending up varying distances from the ground surface, a gray or white mold-like growth on the surface of the stalks (Fig. 21), may frequently be found from late June to the last of August. This is the fruiting stage of the fungus in which numerous spores are produced and often has the appearance of salts collected on the stalks from the soil. The tops of such plants generally show distinct evidences of abnormalities due to the attacks of the fungus.

Fungus occurs on plants other than potatoes. The fungus often attacks plants other than the potato, though generally much less severely; therefore long rotations are essential to hold the disease in check when it is once well established in the soil. The experience of many growers has shown that a three-year rotation will not free the soil of this fungus and that rather heavy losses may be expected from this disease under such conditions. A five-year rotation is much superior and should be used wherever practicable. Because the fungus attacks so many plants even including some wild ones in virgin soil, perfect control of the disease cannot be secured. If reasonable care is taken in the application of the control measures presented in this Circular, however, the losses from this disease will on the average not be large.

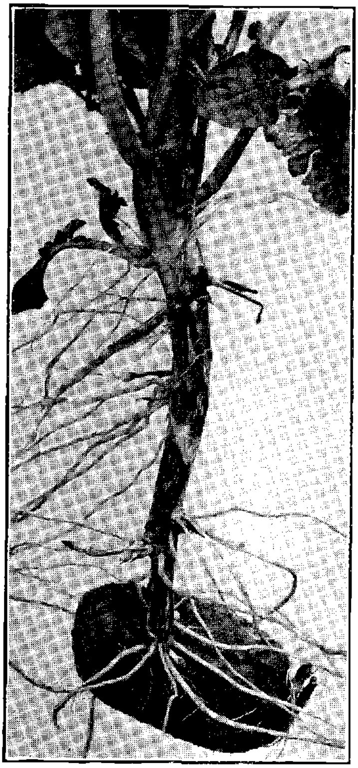


Fig. 19. Brown dead cankerous areas on stalk and on stolons due to Rhizoctonia. The stalks are occasionally completely girdled. (*Photograph by W. C. Whitaker.*)

Fig. 20. Small potato-like growths (aerial potatoes) in top of plant due to severe attacks by Rhizoctonia on the underground portions of stalks. (*After Bailey.*)

Seed treatment with mercuric chloride effective in freeing tubers of disease. In order to kill the Rhizoctonia sclerotia and mycelium on the surface of the tubers and thus avoid the introduction of the disease into the field with the seed potatoes, potato seed treatment is necessary. Because of the effectiveness of formaldehyde for scab control and the general familiarity of the growers with this method of treatment, and because for some time no better method of treatment was known, formaldehyde used to be employed rather extensively for treatment of seed potatoes against Rhizoctonia. Experiments conducted during the past ten years in many different states and under different conditions have clearly demonstrated, however, the ineffectiveness of cold formaldehyde for Rhizoctonia control and the superiority of mercuric chloride over all other methods yet devised for this purpose. The general effectiveness of mercuric chloride treatment for the control of Rhizoctonia has been so clearly and so well shown that no one should hesitate now to use this treatment in preference to all others.

Fig 21. Rhizoctonia. White moldy growth, the fruiting stage of the fungus, on a stalk above the ground surface. (*Photograph by Corsaut.*)

Comparative seed treatment tests. It remains true, however, that a few growers in Oregon are still using formaldehyde for potato seed treatment. This is so probably because they do not fully appreciate the superiority of the mercuric chloride treatment. On account of this fact seed treatment tests were conducted by the Oregon Agricultural Experiment Station at Corvallis in 1920 and at Milwaukie in 1926 to obtain records under Oregon conditions.

In each case two lots of seed potatoes selected out of the same bin were used. One lot of tubers was selected as being practically free of any Rhizoctonia. No doubt they did have some Rhizoctonia present, but to all ordinary appearances they were free from this fungus. All of the tubers selected for the other lot had Rhizoctonia sclerotia present on the surface.

These two lots of potatoes were divided, treated by several different methods, and planted on well-rotated land to avoid contaminations from the soil so far as possible. The cold formaldehyde solution for treatment was used at the strength of 1 pint of the commercial 40-percent formaldehyde in 30 gallons of water, which is the standard strength for scab control. The mercuric chloride was used at the standard strength of 4 ounces in 30 gallons of water. Wooden barrels were used in making the treatments, since the mercuric chloride reacts with metal containers. Semesan Bel, which contains organic mercury compounds, was used both as a dust at the rate of three ounces per bushel mixed with the seed and as a liquid in which the potatoes were given an instantaneous dip in a 10-percent solution in water. The hot formaldehyde was used at the rate of 1 pint in 15 gallons of water at 122° to 125° F., for four minutes. After treatment the potatoes were covered for a while and then spread out to dry.

When the plants averaged about 5 inches in height a part of the 1926 plots were dug so that readings could be made on the amount of injury from Rhizoctonia on the stalks.

At harvest all the different lots of potatoes in both tests were dug separately and the percentage of the tubers bearing sclerotia of Rhizoctonia was determined by counting all the tubers which were apparently free from Rhizoctonia and those which had sclerotia present. A summary of the results from this work is given in Table II and the accompanying graph. These show several interesting facts, among which the following may be emphasized.

Cold formaldehyde not effective for Rhizoctonia control. Where Rhizoctonia was present on the seed potatoes, treatment with cold formaldehyde for 1½ and ½ hours gave crops that were not very much freer of the disease than where the infested seed was planted untreated, the percentages of tubers bearing Rhizoctonia in the crops being 53, 62, and 85 respectively. Cold formaldehyde is thus shown to be far from effective in controlling Rhizoctonia.

TABLE II. RESULTS OF SEED TREATMENT TESTS FOR CONTROL OF RHIZOCTONIA ON POTATOES

Season of 1920. Burbank Variety. Corvallis.

Condition of seed	Treatment	Time	Percentage of tubers bearing Rhizoctonia in yield
		hrs.	%
Apparently clean	Untreated	0	34
Apparently clean	Mercuric chloride 1-1000	1½	14
Rhizoctonia on surface	Untreated	0	85
Rhizoctonia on surface	Formaldehyde Cold 1 pt. to 30 gals.	½	62
Rhizoctonia on surface	Formaldehyde Cold 1 pt to 30 gals.	1½	53
Rhizoctonia on surface	Mercuric chloride 1-1000	½	32
Rhizoctonia on surface	Mercuric chloride 1-1000	1½	17

TABLE II. RESULTS OF SEED TREATMENT TESTS FOR RHIZOCTONIA CONTROL (*continued*)

Season of 1926—Earliest of All Variety. Milwaukie.
(All plots replicated three times)

Condition of seed	Treatment	Time	Percentage of stalks with stem lesions
		hrs.	%
Apparently clean	Untreated	....	12.2
Apparently clean	Mercuric chloride 1-1000	2	3.2
Rhizoctonia on surface	Untreated	....	51.4
Rhizoctonia on surface	Semesan Bel Dust 3 oz. per bu.	Instant	23.8
Rhizoctonia on surface	Formaldehyde Hot 122°-124° F.	3-4 Minutes	13.1
Rhizoctonia on surface	Semesan Bel 10 percent solution	Instant dip	6.2
Rhizoctonia on surface	Mercuric chloride 1-1000	2	2.3
			Percentage of tubers bearing Rhizoctonia in yield
Apparently clean	Untreated	....	12.2
Apparently clean	Mercuric chloride 1-1000	2	.1
Rhizoctonia on surface	Untreated	....	45.5
Rhizoctonia on surface	Semesan Bel Dust 3 oz. per bu.	Instant	37.1
Rhizoctonia on surface	Formaldehyde Hot 122°-124° F.	3-4 Minutes	9.5
Rhizoctonia on surface	Semesan Bel 10 percent solution	Instant dip	3.1
Rhizoctonia on surface	Mercuric chloride 1-1000	2	.8
			Yield in grams per plant
			grams
Apparently clean	Untreated	....	525.4
Apparently clean	Mercuric chloride 1-1000	2	659.5

TABLE II. RESULTS OF SEED TREATMENT TESTS FOR RHIZOCTONIA CONTROL (*continued*)

Condition of seed	Treatment	Time	Percentage of stalks with stem lesions
Rhizoctonia on surface	Untreated		544.3
Rhizoctonia on surface	Semesan Bel Dust 3 oz. per bu.	Instant	504.5
Rhizoctonia on surface	Formaldehyde Hot 122°-124° F.	3-4 Minutes	488.5
Rhizoctonia on surface	Semesan Bel 10 percent solution	Instant dip	692.6
Rhizoctonia on surface	Mercuric chloride 1-1000	2	692.6

Hot formaldehyde gave fair control but a low yield. The results as judged both by disease control and by crop yield were not as good with hot formaldehyde as with the long soak in mercuric chloride. Since these tests were run, however, it has been shown that where hot formaldehyde is used somewhat better results than are indicated here can be obtained at a slightly higher temperature—namely, at 124° to 126° F. for three to four minutes. The general experience from many sources is that hot formaldehyde does give satisfactory control of Rhizoctonia but that generally the yield is a little less than where mercuric chloride is employed. The rapidity with which the treatment can be conducted is the chief item in favor of the use of hot formaldehyde.

Semesan Bel dip gave satisfactory control but performance is variable. Good control of the disease and good yields were obtained in these particular tests by dipping the seed in a solution of Semesan Bel, an organic combination of mercury. Much poorer results were obtained, however, in tests conducted later under conditions apparently as favorable as existed in this case. Other workers have had similar experiences. The prevalent opinion is that this material cannot be recommended generally for potato seed treatment because the results obtained from its use are too variable.

Semesan Bel used as a dust gave poor disease control and is not recommended for use.

Mercuric chloride long-soak treatment gave best results. The best results were obtained from the 1½- and 2-hour treatments with mercuric chloride. This material gave almost perfect control. The diseased seed treated gave almost as clean a crop as the apparently clean seed treated and cleaner crops than the apparently clean seed untreated. These figures would indicate that the longer treatment—that is, from 1½ to 2 hours—with mercuric chloride should be used wherever possible. There are circumstances under which one might be justified in using the shorter ½-hour treatment, as for instance when the seed is only lightly infested or when the seed is badly sprouted and the injury to the sprouts from long treatment might be excessive. But it must be borne in mind that less perfect control of the disease will be obtained from the shorter treatment. Seed potatoes should be treated while still dormant for then no injury to the tubers will result even when soaked for from 1½ to 2 hours, which is the standard length of time for treatment with mercuric chloride.

Apparently clean seed not entirely free of Rhizoctonia. In each case where apparently clean seed was planted untreated considerable amounts, 34 and 12.2 percent, of the tubers in the two crops were diseased. This is largely accounted for by the fact that the Rhizoctonia fungus was no doubt present, as it is frequently known to be, in the form of indistinct thread-like filaments on the surface of the tubers not easily visible to the naked eye. These filaments, though small and indistinct, are capable of remaining alive on the surface of the tubers and introducing the disease into the new crop provided the seed is planted untreated. This fact illustrates the necessity for the recommendation which the Oregon Agricultural Experiment Station is urging upon all potato growers in the state; namely, that all seed potatoes regardless of whether they appear to be diseased or not ought to be given the standard mercuric chloride treatment before planting.

The "apparently clean" seed when treated with mercuric chloride for 1½ and 2 hours gave in the tests only 14 and 0.1 percent disease respectively, in the two crops, which was only slightly less than that obtained in the crops from the diseased seed treated in the same way (17 and 0.8 percent respectively). To some the amounts of disease in these two crops grown from treated seed may appear to be excessively high. It should be remembered, however, that Rhizoctonia is a more or less constant inhabitant in our soils and affects a wide range of plants besides potatoes, making it next to impossible to grow a crop of potatoes free from this fungus. No doubt the organism responsible for the disease on these crops came largely if not entirely from the soil. It is evident also that more disease came from the soil in the first test than in the second. This only emphasizes the necessity for carefully conducting the cropping systems so as to avoid undue accumulation of this as well as other diseases in the soil, as has already been outlined in previous paragraphs.

WILT, *Fusarium oxysporum* Schlecht, and *Verticillium albo-atrum* Reinke and Bert. Potato wilt is caused by the growth of organisms in the tissues of the stem and roots of the plant. This results in a plugging of the water-conducting vessels, the production of poisonous substances, or the destruction of the tissues to such an extent that normal functions cannot be performed. Under such circumstances the leaves lose their color, wilt, and the whole plant finally dies. Several different organisms have been encountered which produce wilting of potatoes. There are two serious wilt diseases in the state caused by distinctly different organisms, but the two diseases are so similar in appearance and effect that they may both be treated together. Attacked plants may wilt rather suddenly and die in a comparatively short time or they may and usually do show the effects slowly and succumb very gradually. Plants produced from infected tubers may be stunted from the beginning and die without attaining average size. Those contracting the disease from neighboring plants or from the soil show their first indication of the disease in the yellowing and drooping of the lower older leaves, followed by the gradual yellowing, browning, and wilting usually of the entire plant (Fig. 26 and cover page). The stems of affected plants are invariably discolored in the interior. The vascular or woody tissues of the interior of the stem are yellow to brown in color (Fig. 22), this discoloration often extending from the base well into the top. The exterior of such stems commonly appears normal. The tubers in wilt-affected hills often, though less regularly, show a browning of the water vessels (Fig. 23). These discolored tissues show as yellow to brown or black strands, or a ring extending for varying distances into the tuber at the stem end from the point of stolon attachment. The discoloration is confined to the vascular tissues, which when normal appear as a faint layer located about ¼ inch beneath the skin.

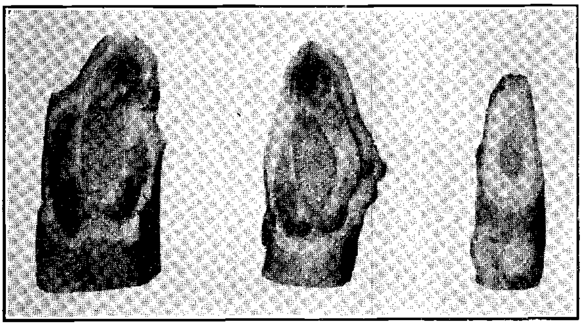


Fig. 22. Oblique sections of potato stalks, at left from Verticillium wilt-diseased plants, showing the browning of the vascular (woody) tissues caused by the wilt fungus, and at right from healthy plant.

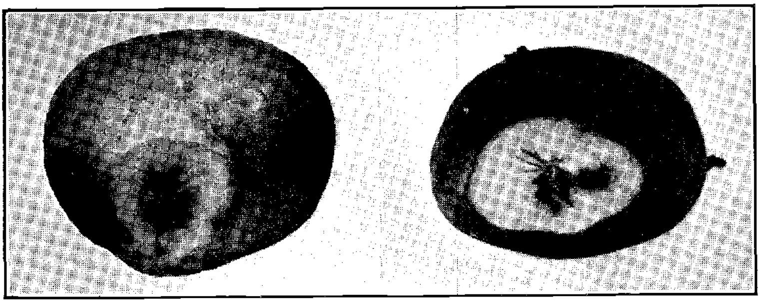


Fig. 23. Discolored vascular tissue at stem end of potato tubers affected with the two wilt-producing organisms which are common in Oregon. Up-to-date tuber affected with Verticillium at left, Early Rose tuber affected with Fusarium at right.

This type of discoloration in the vascular ring is sometimes confused with Internal Brown Spot (Fig. 55), but is a very different trouble and is readily distinguished from it. Such discolored tissues associated with wilt indicate the presence in the interior of the potato of the organism that caused the wilting. Not all discolored tubers, however, are carriers of wilt fungi.

Unfortunately, discoloration of the vascular tissues of the stems and tubers, indistinguishable from that caused by the presence of a wilt fungus, may be induced at times by trying conditions during growth such as high soil and air temperatures, dry soil, early frost, the presence of unimportant fungi, etc., and cannot, therefore, be relied on as a sure symptom of wilt. Under such circumstances accurate diagnosis of the disease in the field or in the bin is impossible without resorting to cultures to determine the presence of wilt-producing fungi. In general, however, wilt can be quite accurately recognized in the field when any considerable number of diseased plants are present.

Tuber discoloration unreliable for wilt determination. That the presence or absence of discoloration is an unreliable guide to the presence or absence of wilt-producing fungi in potato tubers has been clearly shown on a number of occasions. Pethybridge in Ireland pointed out that this is far from being an infallible sign. Edison working in Colorado and Wisconsin stated: "In the materials studied, vascular discoloration of the stem-end tissues of Irish potato tubers was not found to be proof of the presence of parasitic fungi. Discolored bundles were often sterile, and fungi were frequently isolated from tissues which appeared normal."

In the work at the Oregon Agricultural Experiment Station extending over several years and dealing with several lots of tubers grown under different conditions, it was found that the presence of discoloration in the stem-end vascular region of potato tubers is not a trustworthy index of the presence of disease-producing organisms therein and ought not to be relied upon exclusively as a guide for the separation of diseased from healthy tubers for planting purposes. For instance, a summary of results from more than 12,000 tubers examined in detail in the laboratory showed that only 45 percent of the tubers which were browned in the stem-end vascular region when cultured gave organisms which cause disease in potatoes; 55 percent gave either no organisms or miscellaneous fungi of no apparent importance. Twenty-two percent of the tubers which were distinctly yellowed in the stem-end vascular region and 5 percent of those which showed no discoloration gave organisms parasitic on potatoes, while the others of these lots gave nothing of consequence.

A similar condition for Verticillium is shown (Fig. 24) in a comparison of results from two lots of tubers grown from the two longitudinal halves of 272 tested wilt-free tubers, one lot on soil infested by scattering Verticillium-diseased tops the previous fall and the other lot on adjacent clean, well-rotated soil as a control. The discolored tubers grown by the wilt-infested plants on the contaminated soil gave a high percentage of infection with *V. Albo-atrum,* whereas the discolored tubers grown by the wilt-free plants on the clean soil showed no infection with this fungus. To make specific comparisons: 45.3 percent of the tubers grown on contaminated soil were definitely colored brown in the vascular region at the stem-end, and of these 55.3 percent gave *V. albo-atrum* and 7.2 percent gave no organism in culture; 17.8 percent of the tubers from the clean soil were stained brown, but none gave *V. albo-atrum* and 48.3 percent gave no organism in culture. A summary of all the discolored tubers from the two plots, listing the "end rot," "blackened," "browned," and "yellowed" tubers together as being discolored, shows that approximately 85 percent of the tubers from the wilt-infested plot were discolored and of these 46 percent were invaded by *V. albo-atrum;* approximately 65 percent from the wilt-free plot were discolored, but none of these were invaded by the wilt fungus. The only reasonable conclusions from these data are that the presence or absence of *V. albo-atrum* in potato tubers is determined by the plants that produced them rather than by the presence or absence of tuber stem-end discoloration, and that tuber discoloration cannot be relied on to any considerable extent for the separation of wilt-diseased from healthy tubers.

On the average only about half of the tubers in a wilted hill are invaded by the organism which caused the wilting. These, if used for seed, are very likely to give rise to the same disease the following year. Evidently the disease cannot be avoided with any degree of certainty by cutting off and discarding the stem end and planting only the eye end of affected tubers as has been formerly stated. This is due to the fact that the fungus responsible for the disease has apparently progressed farther into the tuber than the discoloration of the tissues would indicate. Then too, as mentioned above, it is not possible to determine all tubers affected with wilt merely from their appearance.

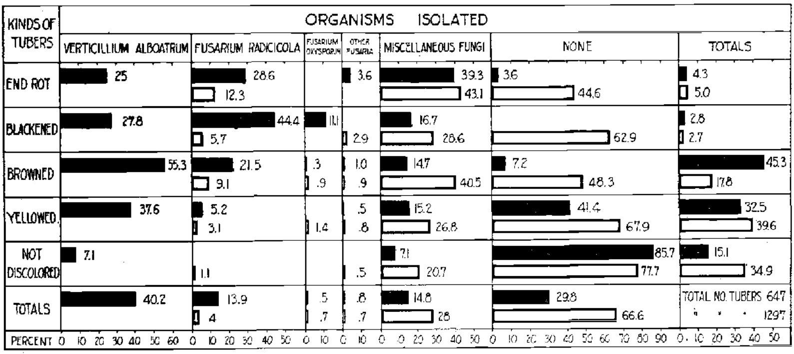


Fig. 24. Stem-end discoloration in potato tubers such as that shown in Fig. 23 is unreliable for the determination of the presence of wilt infection. This graph shows the relation between discoloration and the occurrence of various fungi in two lots of potato tubers. The tubers from which these results were obtained were grown from the two longitudinal halves of known wilt-free tubers, one lot, shown in solid black bars, on soil infested by scattering Verticillium-diseased tops the previous fall and the other lot, shown in outlined bars, on adjacent clean, well-rotated soil as a control. Some of the discolored tubers from the diseased soil always showed infection by Verticillium wilt, while none of the discolored tubers from the clean soil showed any infection by this disease.

Careful roguing in seed-plot effective for avoiding wilt infection in tubers. These facts just mentioned show that reliance for the control of wilt cannot with confidence be placed on a mere bin sorting of the tubers for seed. Seed treatment is similarly not dependable for wilt control since this will kill only the organisms on the exterior and is not effective in killing the fungus in the interior of the tubers. To avoid wilt in seed potatoes it is by far the best practice to maintain a seed-plot as outlined in a previous paragraph and rogue out all diseased plants as soon as they appear. In the case of wilt it is necessary to do this roguing more thoroughly than in the case of most other diseases. This is due to the fact that the disease has a tendency to spread from one plant to another in the row (Fig. 25), apparently by contact of the root systems. In one test conducted where the wilted plants were not removed during the growing season but were left in the field to the end of the season, thus giving the fungus an excellent opportunity to spread, the first, second, and third plants in the same row away from the original wilted plant carried on the average as high a percentage of wilt infection in the tubers as did the original wilted plant itself. In order to check this spread of wilt it seemed advisable to pull out promptly not only the wilted hill but also the next healthy hill on either side of the wilted one in the same row. To get information on different roguing methods for wilt control some field-plot tests were conducted.

In one plot notes were kept on the growth of the plants but no roguing was done. In the second plot all wilted plants were rogued promptly as soon as observed. In the third plot the wilted plants and in addition the next healthy plant on either side of the wilted one in the same row were rogued at the same time. For convenience this is termed the "three-plant method" of roguing. These plots were gone over five times from July 11 to August 22 or as long as wilt could be clearly enough distinguished from maturity to justify additional roguing. After harvest the tubers were tested by culturing in the laboratory for the presence of wilt infection.

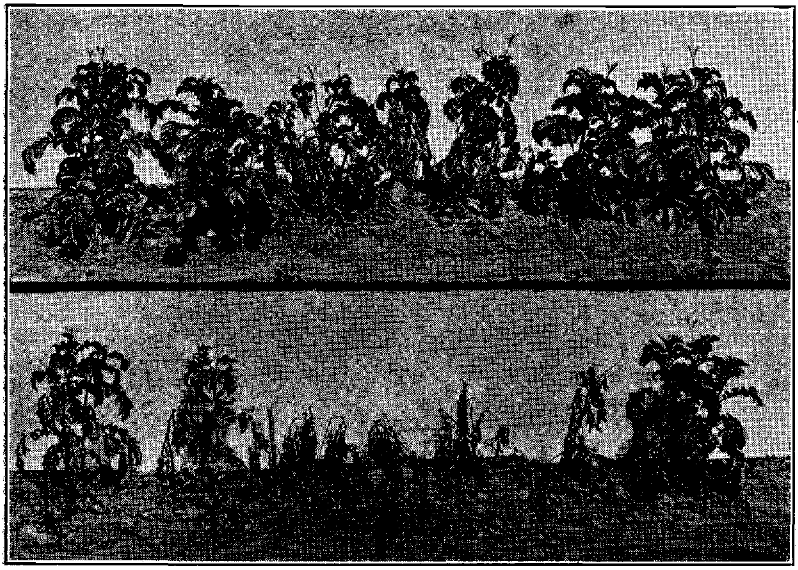


Fig. 25. Verticillium wilt of potatoes spreads from one plant to another in the row during the growing season. The upper illustration shows six plants photographed August 1 of which the two central ones were inoculated at planting time and these only are showing symptoms of wilt. The lower illustration shows the condition of the same six plants on August 31, at which time all the plants were showing wilt except the one at the extreme right. It is interesting to note that even this plant gave one Verticillium-infected tuber out of twelve produced. Thus spread of the disease to the second plant in the row from the one originally diseased is indicated. To control this disease, it is advisable to rogue not only the visibly wilt-affected hill but also the next healthy-looking hill on either side in the same row at the same time.

The figures obtained (Fig. 26) indicate a very decided advantage of the three-plant method of roguing over the ordinary roguing of only the plants which can be detected on appearance to be wilt-infected. This is evident from the high infection of the tubers in the plants adjoining visibly wilted plants and is also well shown by the percentages of Verticillium in the tubers remaining in the plots following the two methods of roguing. For instance, in the second plot, where only visibly wilt-affected plants were rogued, 24.2 percent of the tubers from the next adjoining hill were infected and a total of 8.4 percent Verticillium infection was obtained in the tubers harvested from the entire plot; whereas in the third plot, where the wilted and adjoining plants were rogued, only 3.2 percent Verticillium infection remained in the tubers harvested from the entire plot. In this latter case, following the three-plant method of roguing, this represents a reduction of from slightly more than 22 percent visible wilt infection in the plants to 3.2 percent infection in the tubers in one season's time.

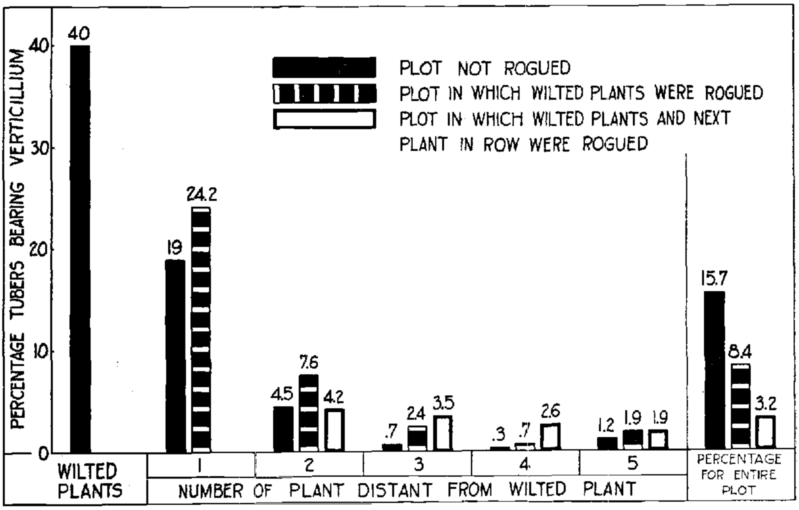


Fig. 26. Graph showing a summary of the results obtained from three plots for determining the spread of Verticillium wilt from plant to plant in the row and the influence of the one- and three-plant methods of roguing thereon. The inadequacy for Verticillium wilt control of roguing only visibly wilt-affected plants is shown here in the results from the second plot; for in this case the next plant in the row to a wilted plant, though itself not showing wilt symptoms in the field, gave an average of 24.2 percent Verticillium infection in the yield. In contrast the three-plant method of roguing is quite effective in eliminating this disease from the seed-plot.

From the foregoing data it is clearly apparent that not all plants that produce Verticillium-infected yields show visible symptoms of wilt infection in the field. A great many plants have been grown at different times that exhibited no detectable wilt in the field but which produced tubers containing a high percentage of Verticillium infection. This is doubtless to be explained on the basis that the effects of the disease on the plant itself were so slight as frequently to escape detection because infection resulting from spread in the row took place late in the season. Such late infection causes little or no change in the appearance of the plant and cannot be clearly distinguished from normal maturity of the vines. It is not known how late infection may gain entrance into plants and grow on into the tubers; it is believed, however, that this may take place quite late in the season, possibly almost up to harvest time. To make a common practice of the three-plant method of roguing would eliminate most of this type of infection and in a short time would undoubtely reduce damage from Verticillium to a negligible quantity. By this method the seed-plot can probably be freed of wilt in two years' time at most, whereas if only the wilted plants are pulled out three or more years would probably be necessary to free the seed stock of this disease.

Crop rotation must be practiced to avoid wilt infection from the soil. Since the organisms remain alive in the soil for a considerable time following the production of a diseased crop, it is necessary to practice long rotations in order to avoid undue infection from the soil. This is well shown by the results obtained from some field-rotation experiments conducted to determine how long the Verticillium wilt fungus will stay alive in the soil and still cause disease in healthy potatoes planted therein. The crops used in the rotations were as follows: one-year rotation, potatoes following potatoes; two-year rotation, grain and potatoes; three-year rotation, grain, clover, and potatoes; and four-year rotation, grain, clover, clover, and potatoes. The tests were run in duplicate to avoid variations in amount of disease due to differences in climatic conditions from year to year.

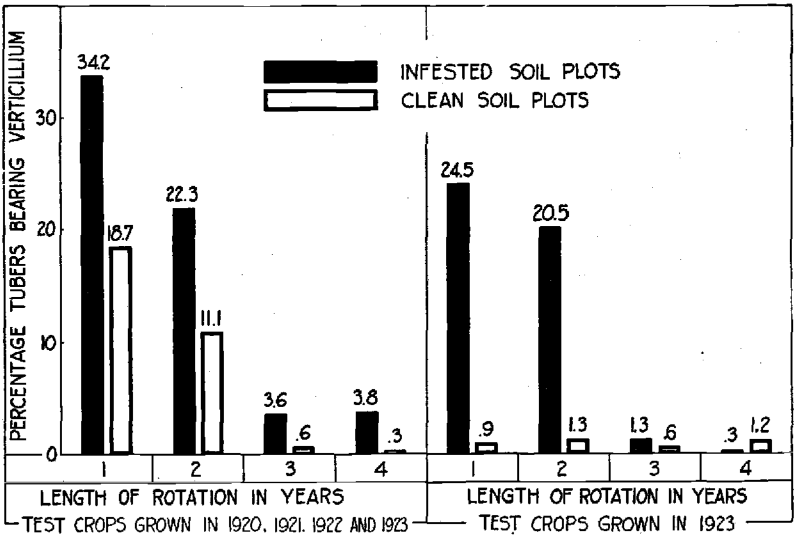


Fig. 27. Graph showing results secured from plots conducted for determining the length of rotation necessary for avoiding Verticillium wilt infection from the soil. The three- and four-year rotations can be considered to have given effective disease control. The longer rotation of four years is preferable for potatoes because it increases the margin of safety for Verticillium wilt control and because the three-year rotation is not effective in controlling some other diseases which affect potatoes.

As shown by the summarized results (Fig. 27), in both sets of tests the one- and two-year rotation plots gave a considerable amount of the wilt disease due to infection from the soil, and the three- and four-year rotations can be considered to have given practically complete control. The longer rotation of four years is preferable for potatoes because it increases the margin of safety for Verticillium wilt control and because the three-year rotation is not effective in controlling some other diseases which affect potatoes. For instance, Fusarium is not as readily eliminated from the soil by rotation as Verticillium. Other diseases such as Rhizoctonia persist in the soil rather commonly for three years. Consequently, nothing short of a four-year rotation is ordinarily advisable, particularly for the production of good seed potatoes. This does not mean that good crops cannot be grown with a shorter rotation, but it does mean that with a four-year rotation risks from damage from soil-borne diseases are very materially reduced. The growers of the state could with great advantage make more general use of well-planned crop rotations of sufficient length to lessen the danger of contamination of their potato crops from the soil.

NEMATODE, *Caconema radicicola* (Greef) Cobb. This nematode or root knot disease, as it is often called, has fortunately been found only a few times on potatoes in Oregon. Its seriousness in many other states makes it desirable that the attention of Oregon growers be called to it now in order that due precautions may be taken to prevent its introduction or spread and establishment on any farms. It is more likely to be met with in sandy, well-drained soil than in heavy and poorly drained soil.

On potatoes, as well as on other crops affected, the parasite invades the roots in many different places, giving rise to roundish or irregular enlargements of the roots often called root knots. These may be few or many, depending on the number of individual infections, and may vary in size from a pinhead to a quarter of an inch or more in diameter. As enlargements or swellings of a portion of the root, they are different from the spherical or lobed nodules produced by beneficial nitrogen-fixing bacteria on many leguminous plants, the latter nodules being small or medium in size and attached to the side of the rootlets. Plants rather severely attacked by the nematode on the roots show a general yellowing and stunting of the foliage, leading to a gradual wilting and premature death of the entire plants. Plants less severely attacked may show only slightly stunted growth. At least some of the tubers in a diseased hill are generally invaded by the nematode. Wherever affected, these usually show small, slightly-raised, pimple-like elevations of the surface of the tuber about $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, which when abundant produce a very irregular, roughened, and warty appearance (Fig. 28), though tubers only slightly attacked may not show any external evidences of disease. In the tuber tissues at varying distances, usually not more than $\frac{1}{4}$ inch, beneath such elevations are small circular brown spots usually less than $^{1}/_{16}$ inch in diameter with a pearly white center (Fig. 29). This pearly white center of such spots is the female nematode, which by planting time the following spring is the center of a thriving colony of numerous, newly produced minute nematodes. These, when such tubers are planted, work their way out into the soil and finally into the roots of the young plant again to cause disease.

Parasite attacks wide range of hosts besides potatoes. This parasite attacks a very wide range of commonly cultivated crops and is in general one of the most serious plant diseases known. The classified lists which follow and which with the two following paragraphs were taken from Farmers' Bulletin 648 of the United States Department of Agriculture, include the more important highly susceptible plants. These should never

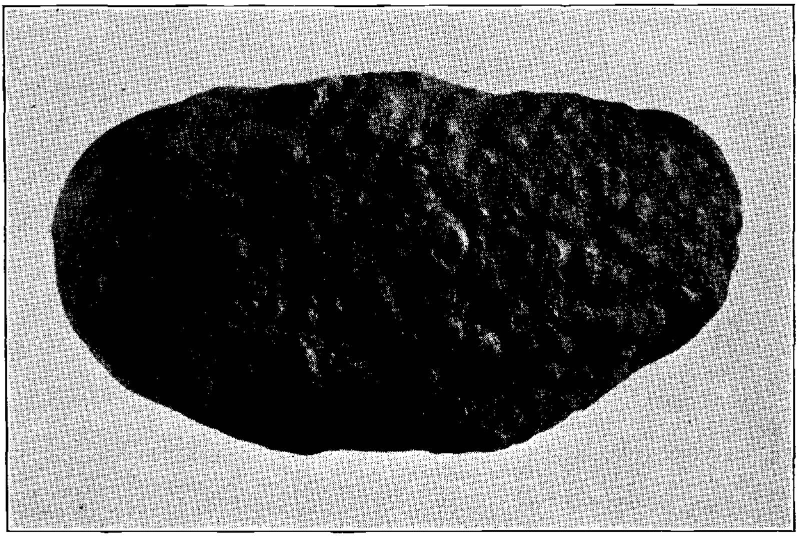


Fig. 28. Potato tuber affected with root-knot nematode, showing numerous small, slightly raised, pimple-like elevations of surface resulting in an irregular roughened and warty appearance.

be grown on infested fields or transplanted from any field that may possibly contain the parasite.

Field crops:
- Alfalfa
- Clover
- Cotton
- Cow-pea (except Iron, Brabham, and hybrids of Whippoorwill crossed on Iron)
- Field pea
- Flax
- Pumpkin
- Soy-bean
- Sugar-beet
- Sugar-cane
- Sweet potato
- Tobacco
- Vetch

Ornamental and drug plants:
- Begonia
- Cineraria
- Clematis
- Coleus
- Dahlia
- Hollyhock
- Ginseng
- Goldenseal
- Peony
- Rose
- Sweet pea
- Violet

Truck crops:
- Asparagus
- Bean
- Cantaloup
- Carrot
- Celery
- Cucumber
- Eggplant
- Garden beet
- Garden pea
- Irish potato
- Lettuce
- Muskmelon
- Okra
- Onion
- Pepper
- Salsify
- Spinach
- Strawberry
- Tomato

Woody plants:
- Almond
- Catalpa
- Cherry
- European elm
- Fig
- Old World grapevine
- Mulberry
- Peach
- Pecan
- Persian walnut
- Weeping willow

Besides the plants listed above, most of the common weeds are attacked by the nematodes, although usually not very severely. Such weeds, however, are a constant source of danger to the farmer, as they help to increase the number of nematodes in the soil. An abundance of weeds is a sign of poor agricultural practice anywhere, but weeds become doubly dangerous where they not only do harm by crowding out other plants and using up food intended for them, but also multiply a pest which may later destroy the crops planted.

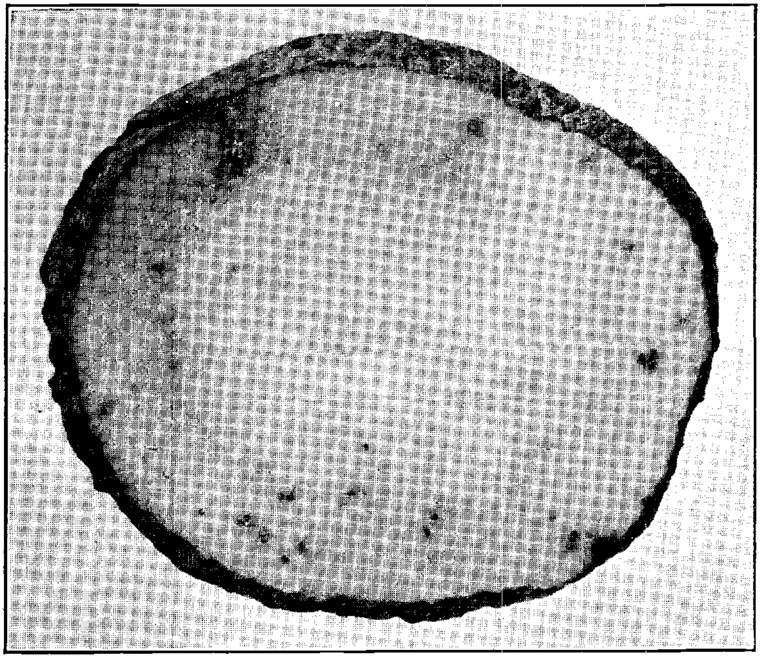


Fig. 29. Section of tuber affected with nematode much like that illustrated in Fig. 28, showing many small, circular, brown spots with a pearly white center distributed at irregular distances generally not deeper than a half inch in the tissues. This pearly white center of such a spot is the female nematode.

Many economic plants free from attacks of this pest. Fortunately, many plants of economic importance are free from the attacks of root-knot. At every opportunity, advantage should be taken of this fact in controlling the disease. The following list includes the more important cultivated plants which, so far as known, are seldom or only slightly affected by the nematodes and may be used in crop rotations with the expectation of greatly reducing the number of nematodes in the soil.

Barley	Corn	Pearl millet	Timothy
Beggarweed	Crab-grass	Red top	Velvet bean
Brabham cow-pea	Iron cow-pea	Rye	Wheat
Broom-corn millet	Peanut	Sorghum	Oats

Three-year rotation with non-susceptible crops necessary to free soil of infestation. Where the nematode has become established in the soil it can be starved out by a good three-year rotation with non-susceptible crops, provided weeds and volunteer plants of susceptible crops are rigidly excluded during this time. As an aid in accomplishing this it is well to have at least some of the rotation crops planted in rows and thoroughly cultivated. The utmost care should be used to insure that the pest is not introduced into the field in seed potatoes. If the seed potatoes come from an unknown source they should be carefully inspected, and if any infestation is found the entire lot should be rejected for seed. No potatoes from a field known to be infested should ever be used for seed; a mere inspection of the tubers will not reveal all cases of light infection and the introduction of the disease into the field might very readily be accomplished in this way. Care used in avoiding this very objectionable disease will be repaid many fold.

LATE BLIGHT AND ROT, *Phytophthora infestans* (Mont.) de Bary. This disease is known as late blight, because in most sections of the country it attacks the plants most severely comparatively late in the season. In some places, however, and this is true of the Coast Region of Oregon, the disease may appear early in some seasons, killing the young plants as early as July. The disease has been found a number of times along the Coast in June. The fungus invades the leaves, producing large, dark-brown to black dead areas (Fig. 30), and spreads rapidly through the leaf tissues without forming any distinct rings such as are produced in some leaf diseases. When the disease is severe, even the leaf stalks and tender tissues of the stems are invaded and killed. Under favorable warm and moist weather conditions the disease spreads rapidly both in the attacked leaves and on to other leaves not previously attacked, with the result that all the plants in an entire field may be killed in a very few days (Fig. 31). The diseased and decaying tissues give off a noticeable odor, which becomes quite pronounced in fields heavily attacked. The organism also readily attacks the tubers, producing on them slightly sunken, dark-colored, rotted areas of irregular size, varying from very small spots to areas involving the whole surface of the potato (Fig. 32). At harvest time the rot does not as a rule extend very far into the potato tissues, usually not deeper than half an inch (Fig. 33). In storage, however, it may and frequently does become complicated with other secondary rot organisms which finally involve the whole potato with disastrous results, particularly if the temperature is allowed to remain at 40° F. or above and the ventilation is poor.

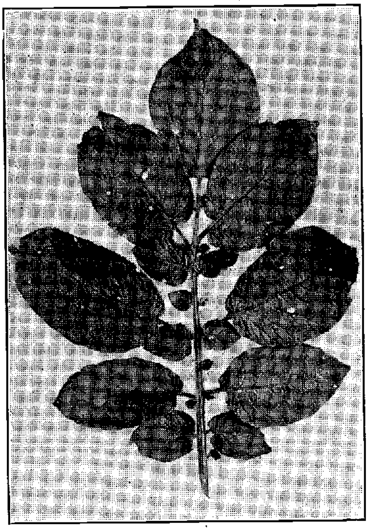


Fig. 30. Late Blight. Dead areas on leaves, showing the usual appearance of the leaves when the disease first attacks them.

Disease serious only in restricted areas in the state. The disease is not serious in all sections of the state, being most serious near the Coast, occasionally destructive in the Willamette Valley and other points west of the Cascades, and rarely, if ever, present to any serious extent east of the Cascades.

Excessive tuber rot frequently avoided by delayed digging. If late blight has been particularly prevalent in the field late in the season, killing much of the foliage of the potato plants, and rot of the tubers is threatened, it is much better to delay digging the potatoes till two weeks after the

Fig. 31. **Entire** potato **plants** in the field killed by late blight. (*After Boiley.*)

potato tops are fully dead, preferably until after a frost has killed the vines. This delay is necessary in order that the numberless spores of the fungus present on and about the old dead plants and on the surface of the soil may die to a large extent before the potatoes are dug. If the potatoes are dug without this two weeks' delay, a large number of them will almost surely become infected by the live spores with which they come in contact during the digging process. Experiments have shown that the smallest percentage of late-blight tuber-rot in storage follows the practice of delayed digging.

The large commercial grower must consider his labor supply and other conditions in relation to the time available, and yet delay his digging as

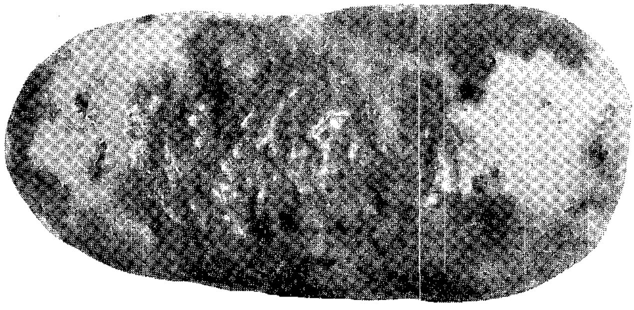


Fig. 32. Tuber showing slightly sunken dark-colored rotted areas due to the late-blight fungus. (*After Bailey.*)

much as is consistent with getting the crop out in advance of the rainy season or before frost injury. In the case of the farm home supply, which can be dug in a few days, the greatest advantage can be taken of this means of reducing field tuber infection and subsequent storage rot.

Spraying with copper sulfate sometimes advisable. In addition to delaying digging for two weeks after the plants are dead it is occasionally advisable also to spray the old vines and the entire soil surface soon after

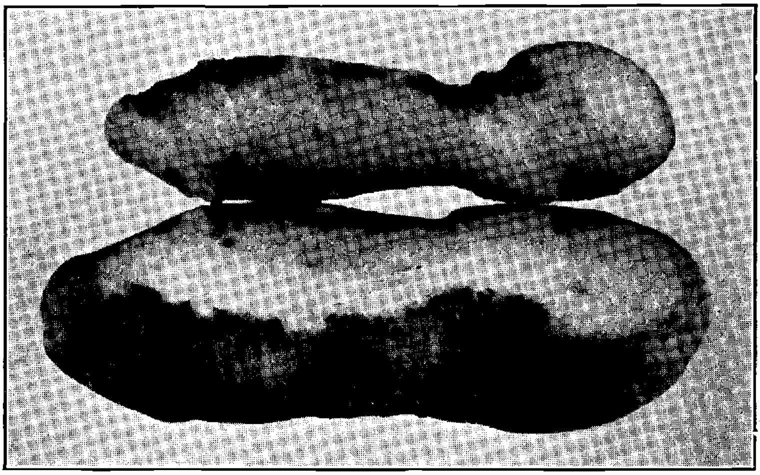


Fig. 33. Section of tuber showing late-blight rot as it usually appears at harvest time.

the heavy attack with a solution of copper sulfate (bluestone) at the rate of 10 pounds in 50 gallons of water in order to kill as many as possible of the spores. In case this is done, thorough spraying of the soil surface is necessary because the spores falling from the plant become very abundantly distributed over the entire soil surface. Whether the spraying of the dead plants and the soil surface before digging is profitable or not will depend mainly on conditions such as the value of the potatoes, the price of copper sulfate, labor, etc. Whether the soil is sprayed or not, however, the delay of two weeks before starting digging is always advisable under the conditions mentioned.

Mowing potato tops sometimes done. Occasionally some growers use the practice of mowing the potato tops during or following a heavy attack of blight. While no experiments on the value of this method have been conducted here it is conceivable that under some conditions it would help to hold down tuber-rot. A delay of about two weeks following mowing before digging would be necessary to allow the vines to dry completely and the mowing would have to be thoroughly done without disturbing the soil or the tubers to any appreciable extent; otherwise a large amount of rot infection would likely result. If the plants, however, could be left to dry thoroughly after dying without mowing, the results would probably be as satisfactory; or if the spraying with the copper sulfate as outlined above could be done, the results would then probably be more satisfactory than if the tops had been mowed.

Diseased tubers should be avoided for seed and the crops well rotated. Diseased potatoes should not be used for seed, as even a small rotting area not more than a quarter inch in diameter may carry the disease to the young plant, from which it can readily spread to surrounding healthy plants. In the same way volunteer plants from diseased tubers left in the soil the previous year may serve as a dangerous source for the introduction of the disease to the new crop. To avoid this, crop rotation should be practiced; and for the rotation to be effective volunteer plants must be completely eliminated by good cultivation, etc. Otherwise these volunteer potatoes might perpetuate themselves and also the disease for two or three years in the soil even though the crops were rotated.

Spraying with bordeaux mixture a thoroughly demonstrated, reliable method for control. If the disease does begin to develop in a field, however, it can be successfully controlled, if detected soon enough, by thorough spraying with bordeaux mixture. Where the disease is generally serious every year, one should commence spraying before the disease ordinarily appears, and continue at intervals of about two weeks during the rest of the season. Where the disease is not generally serious every year the first application of spray might be delayed until the first traces of the disease appear, and if moist weather conditions prevail or the disease takes a new start, the later sprayings may be continued.

That spraying with bordeaux mixture for the control of late blight is satisfactory, effective, and a paying proposition has been repeatedly demonstrated in a large number of eastern states. In New York State, for instance, an extensive series of experiments and demonstrations covering a period of ten consecutive years, during which there were seasons of severe blight epidemics and other seasons when blight did little or no damage, showed conclusively that three to five applications of bordeaux mixture as applied by the average farmer would give an average increased yield to the acre of twenty-five to fifty bushels, while the more thorough applications in experimental plots would give an increase of approximately double this amount. In Vermont the average increase in yield from spraying for 20 consecutive years was 105 bushels an acre. And everywhere that bordeaux mixture has been used on potatoes for blight control over a period of years, the results on the average have always been worth while, so that no one need hesitate to use this material on the ground of effectiveness and reliability. Furthermore it is at present the only thoroughly demonstrated, reliable method for controlling late blight. The practice of regularly spraying potatoes with bordeaux particularly in the bad blight areas should be more widely used in Oregon than it is at the present time.

Copper-lime dust is convenient and fairly effective. What has been said of spraying applies with practically equal force to the use of copper-lime dust. Dusting is merely a convenient way to apply in dry form practically the same materials that are used in the spray. The details on these methods are given in an earlier section under "Spraying."

EARLY BLIGHT, *Alternaria solani* (E. & M.) J. & G. Early blight attacks only the potato leaves, causing brown spots thereon, which as they enlarge develop concentric rings or markings, producing a "target-board" effect.

When the spots are numerous, they kill the leaves with a consequent reduction in the yield of the potatoes. In contrast to late blight this disease develops best in warm weather and earlier in the season. It is not serious in this state but where present can be successfully controlled by thorough and timely spraying with bordeaux mixture.

WART, *Synchytrium endobioticum* (Schilb.) Perc. This disease has never been found in Oregon. In fact it has only fairly recently invaded any part of the United States and is now known to occur only in rather limited districts in Pennsylvania, Maryland, and West Virginia. It is present in eastern Canada and has caused heavy damage for many years in Europe, notably England and Scotland. Because of its destructiveness and persist-

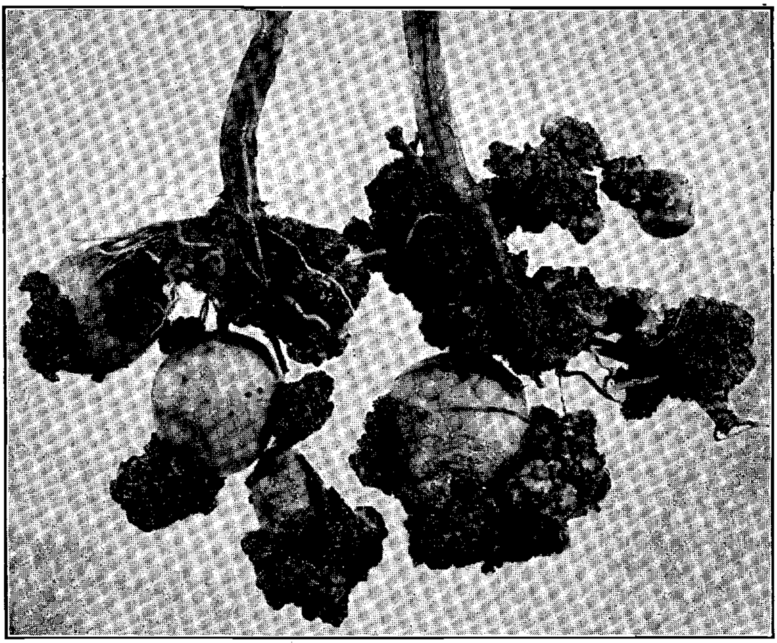


Fig. 34. Potato Wart showing brown to black, spongy, rough, warty outgrowths on tubers. (*Cut by courtesy of New Jersey Agr. Exp. Sta. from photograph by H. B. Kirk, Pennsylvania Bureau of Plant Industry.*)

ence in the soil it is one of the most feared of all potato diseases. It is for this reason that a description of the disease is given here, and it is very much desired that if any one encounters any suspicious specimens he send them without delay to the Oregon Agricultural Experiment Station for examination.

The disease known chiefly as "wart" or "canker" is one which attacks the tuber principally, though infection may take place in all the young tissues of the plant, the roots, stolons, stems, and even the leaves. Consequently it is generally not observed until harvest time. Attacked tubers show brown to black, spongy, rough, warty outgrowths starting usually at the eyes and varying greatly in size though frequently as large as a walnut or even the tuber itself (Fig. 34). In advanced stages the tubers may be wholly covered by this warty growth, having lost every resemblance to potatoes. When this wart-affected tissue is left in the soil it soon becomes broken up and liberates millions of spores, leaving the land badly infected for years. The results of many years of experience and tests conducted in Europe show that occasionally at least the organism remains alive as long as six years in the soil without in the meantime potatoes having been grown therein. The chief and most reliable means of control lies in the use of immune varieties of potatoes of which there are now several successful ones available. The Burbank variety grown so much in Oregon is immune to wart.

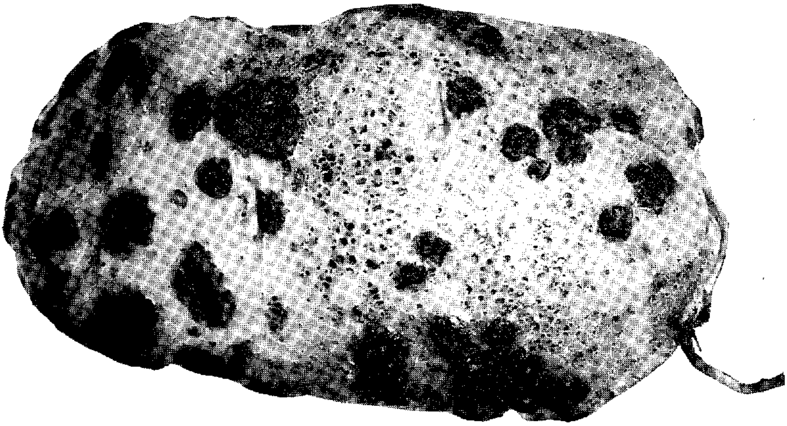


Fig. 35. Scab, showing typical large, irregular scabby areas. (*After Bailey.*)

SCAB, *Actinomyces scabies* (Thaxter) Güssow. Scab is confined in its attack on the potato entirely to the tubers. At first the spots are usually small and brownish but later enlarge into rough, corky, brownish patches (Fig. 35). A single scab spot is usually less than three-fourths inch in diameter, although a whole potato may occasionally be covered with scab owing to the abundance of individual spots. The organism may also affect other host plants such as turnips, garden beets, sugar-beets, etc., which ought therefore to be avoided as much as possible in rotation with potatoes. This disease is serious only in limited areas in Oregon probably owing to a soil reaction that is unfavorable to the causal organism. It is most frequently encountered in the lighter soils and in gardens where ashes are frequently deposited.

The disease thrives best on alkaline soils; consequently lime, ashes, and fresh manure tend to increase scab when they are placed on land just before potatoes are planted. These materials, therefore, should be avoided at that time but may often be used with profit with other crops following potatoes. On the other hand, sulfur applied to the soil is detrimental to the development of scab and is often used in places as a means of control of the disease. Since poorly drained or wet soils also favor the development of scab, an excess of moisture is to be avoided on potato land. To prevent the introduction of scab on seed potatoes, they should be treated with either formaldehyde or mercuric chloride, and then planted on land which has not grown potatoes for at least three or four years, for the organism remains alive in the soil for a considerable length of time following a crop of diseased potatoes.

POWDERY SCAB, *Spongospora subterranea* (Wallr.) Johns. This disease is quite different in nature from common scab but resembles it somewhat in appearance. On potato tubers in typical cases the spots are at first covered and blister-like, later they break open, forming roundish, raised pustules surrounded by the torn skin of the potato (Fig. 36) and exposing a brownish powdery mass of spores. The spots when mature are generally less than ¼ inch in diameter.

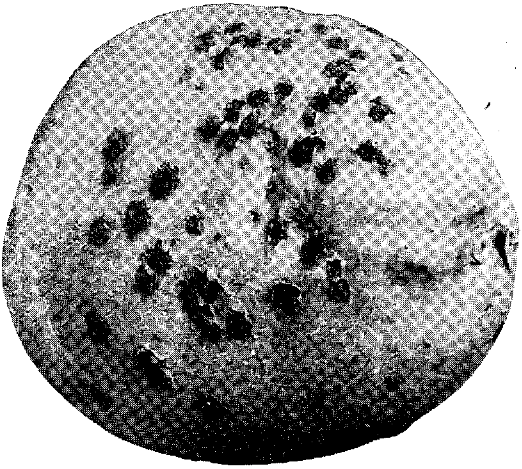


Fig. 36. Powdery Scab. Spots small, circular, and surrounded by the torn skin of the tuber. (*After Bailey.*)

This disease is quite serious in some parts of Europe and eastern Canada. It has recently been found in this country in a number of states from Maine to Minnesota and also in Oregon in Clatsop, Tillamook, and Lincoln counties. The disease occurs only in cooler, damper seasons and does not develop when the temperature is too high. So far it has not proved so serious in the United States as was at first feared. It may never become serious here, but precautions should be used to prevent its spread by not planting infected potatoes. It is not satisfactorily controlled by seed treatment. Long rotations are necessary to rid the soil of the organism when it once gets established.

SILVER SCURF, *Spondylocladium atrovirens* Hartz. This disease is distinguished by the occurrence of irregular brownish areas on the skin of the tubers, which turn silvery and show many fine black points when moistened (Fig. 37). These spots are from ¼ to 1 inch or more in diameter and are usually most abundant on the stem-end half of the tuber. Silver scurf causes some loss to potatoes in storage by injuring the skin, permitting considerable loss of water and consequent shriveling. It has been encountered in a number of places in the state only during recent years, though at the present time it probably occurs in most localities. It is not entirely controlled, though considerably reduced, by seed treatment with mercuric chloride. Diseased tubers should be sorted out and not planted, and long rotations should be regularly followed.

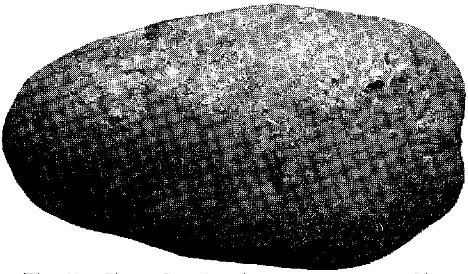


Fig. 37. Silver Scurf. Discolored areas on skin covered with fine black points. (*After Bailey.*)

DRY-ROT, *Fusarium coeruleum* (Lib.) Sacc. This is apparently the commonest, the most widely distributed, and the most destructive potato tuber-rot in Oregon. It enters the potato generally through wounds and produces large sunken pockets, if only one side of the potato is attacked; or a wrinkled decay, if a large part of the tuber is affected (Fig. 38). Numerous bluish or white points or protuberances are formed on the surface of the decayed parts. This decay often develops extensively during the first few months after harvest when the temperatures are high. It is not so serious in storage when the storage temperatures are kept low and the ventilation is good. Bruising of the potatoes at harvest time or during subsequent handling should be carefully guarded

Fig. 38. Dry-rot showing large sunken rotted areas with surface much wrinkled and bearing numerous whitish to bluish protuberances.

against. The disinfection of all storage places before storing in the fall is to be especially recommended.

Some growers in the state have had excellent results in avoiding this rot by treating the potatoes immediately after digging and before placing in storage, using formaldehyde at the usual strength of 1 pint in 30 gallons of water. On the same farms in other years the rot had been quite destructive. In localities where the average losses from this rot are rather heavy, this method of prevention would be worthy of thorough trial and perhaps regular applications.

POWDERY DRY-ROT, *Fusarium trichothecioides* Wollenw. This rot of potato tubers is in the main serious in Oregon only east of the Cascades. It appears to be limited chiefly to climates having warm dry summers. Affected tubers shrink considerably and often develop in the interior large hollow pockets partly filled with a pink powdery mass of fungous growth (Fig. 39). Pinkish or whitish tufts of fungous growth are occasionally produced freely on the surface of the sunken, rotted areas. In storage the rot develops at a somewhat lower temperature than many of the other common rots, though it is not serious if the temperature is kept at from 34° to 40° F. Injury to the potatoes during digging should be avoided, and they ought not to be allowed to remain exposed on the ground very long after they are dug. When dry they should be picked up at once and placed as soon as they have cooled, preferably at night or very early in the morning, in cool storage with good ventilation. Where it is necessary to store seed potatoes in a poorly ventilated or improperly cooled storage house, the disease may be effectively prevented by disinfecting the stock, prior to storage, with a solution of mercuric chloride or formaldehyde, provided the disinfecting is done immediately, or within twenty-four hours after digging.

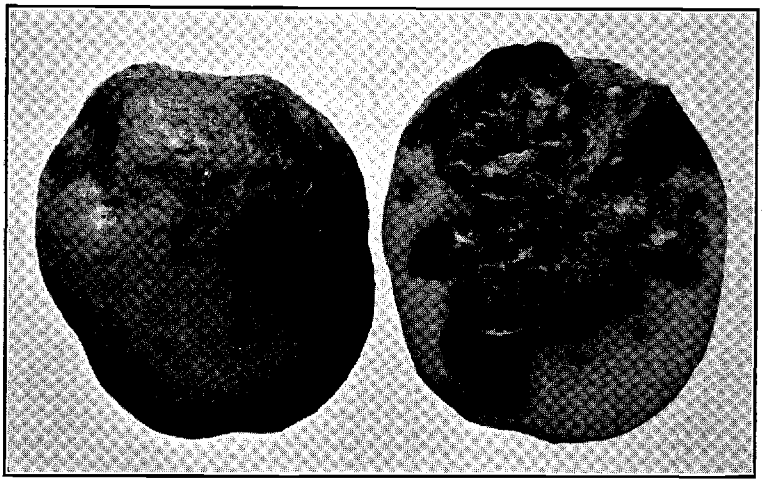


Fig. 39. Powdery Dry-rot, surface and section view of same tuber. Rot extends into tuber in irregular way and commonly hollow pockets partly filled with a pink powdery mass of fungous growth are formed.

ARMILLARIA ROT, *Armillaria mellea* Vahl. When potatoes are planted on newly cleared land containing much rotting wood or in prune or other orchards where Armillaria root rot is common, a number of the potato tubers are often attacked by the Armillaria rot. The rotting areas are light brownish, slightly sunken and generally have attached to them a few long black strands which are the rhizomorphs or root-like runners of the fungus (Fig. 40). The interior rotted portion of the attacked potato tuber is composed of alternating layers or flakes of yellowish and white tissue. This rot

Fig. 40. Armillaria Rot, characterized by black thread-like strands clinging to the surface of the tubers and by the presence of alternate layers or flakes of yellowish and whitish rotted tissue in the interior. (*After Bailey.*)

apparently does not continue to develop in storage, although other fungi commonly gain entrance and complete the destruction of the partly rotted tubers. While the rot is often encountered in the western part of the state the losses are not large. The largest individual loss that has come to our attention was three percent of the tubers grown in an old prune orchard. To avoid this disease potatoes should not be planted on newly cleared land the first year that it is in cultivation.

STEM-END ROT, *Fusarium radicicola* Wollenw., and other organisms. A stem-end rot, often called jelly-end rot, of potato tubers occurs not infrequently during some seasons in Western Oregon, and to some extent in the rest of the state, while in other seasons it is rarely encountered. It affects only the long tubers and varies widely in type and extent of rot at harvest time from a mere withering unaccompanied by discoloration of the stem end of the tuber as though a part of the water had been withdrawn from that portion, to a dry, wrinkled, sunken, rather tough, and light brown to black discolored condition of a half inch or more of the stem end of the tuber, or to a soft and rather jelly-like, light-brown-colored rot extending back at times 1½ inches from the stem end, the rest of the tuber being sound and unaffected (Fig. 41). In storage these diseased tubers often do not rot further, but the affected tissues frequently dry down, forming a sharp line of demarcation from the sound, unaffected tissues unless stored under conditions unfavorable to the tubers.

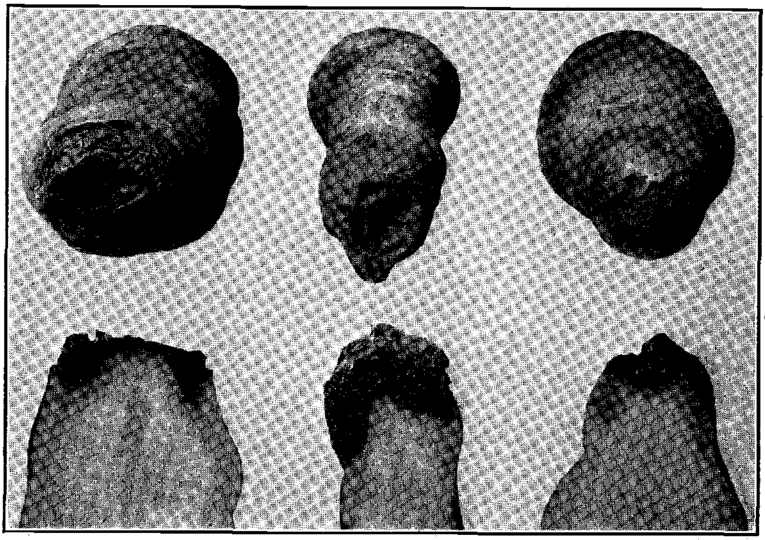


Fig. 41. Stem-end Rot of potato tubers as it usually occurs at harvest time.

The exact conditions which lead to the development of the rot are not known, though it seems possible that when moisture in the soil is deficient in the latter part of the growing season, as is frequently true in Western Oregon, the plant might actually withdraw water from the stem end of the tuber giving a sunken withered condition favorable to the entrance of various organisms both saprophytic and parasitic, which soon give rise to the rot. At any rate no one organism is found consistently associated with the disease and the rot develops in the crop without any apparent relation to the condition of the seed potatoes at planting time or to crop rotation. For the present no special measures for its control can be definitely recommended. The rot can no doubt be avoided to a considerable extent, however, by the maintenance of a uniform and adequate supply of moisture in the soil throughout the season.

DISEASES DUE TO FILTERABLE VIRUSES

During recent years a number of diseases of potatoes not due, so far as is known, to bacteria or parasitic fungi, or to nutritional or environmental disturbances, have been receiving increasing attention by growers and investigators alike. The cause of these diseases is obscure and up to the present time has baffled many careful investigations. The work that has been done shows that in many cases these diseases are due to so-called filterable viruses. From the evidence one may assume, though it has not been proved, that all the diseases listed here under this heading are caused by viruses. By a filterable virus is meant a causal agent in the juice of the plant that is not visible and has the ability to pass through filters which take out all ordinary bacteria and fungi. These diseases are systemic—that is, the causal agent becomes distributed to all parts of the plant—and are transmitted by vegetative propagations. Consequently all tubers from a diseased plant are practically invariably affected by the same disease.

In this group come such diseases as mild mosaic, rugose mosaic, leaf-roll, and witches'-broom. Some of these are widely distributed in America and are causing great reduction in yields. Most of them are present to a serious extent in this state. Other potato virus diseases in this group that are not now present in Oregon, or are so rare as to be of no immediate interest, are leaf-rolling mosaic, crinkle mosaic, and spindle tuber. Giant hill may belong to this group, but so little definite information is available concerning it that it cannot be classified with confidence. All of the potato virus diseases are transmitted from year to year in the tubers. Generally there are no reliable indications of such diseases in the tubers. With few exceptions, the presence of virus diseases can be determined only by an examination of the growing plants. The chief exceptions are net necrosis and early infections of spindle tuber and witches'-broom resulting in the production of discolored, small, or abnormally shaped tubers. Diseased plants give lower yields than normal. After a few years plants attacked by some of these diseases fail to produce any marketable potatoes. In addition to being carried in the tubers from diseased hills, the diseases may be spread to adjacent healthy plants in the field. If the spread takes place early the affected plants may show symptoms during the current season's growth. But if infection occurs late usually no symptoms are evident that year though the tubers carry the disease to the following year and produce plants that show the typical symptoms.

Spread of the potato virus diseases is frequently accomplished through the agency of sucking insects and possibly other means not now known, and is not always readily prevented. Aphids are the most effective carriers of these diseases known. When aphids feed on a diseased plant, then on healthy plants, the virus diseases are often transmitted to the healthy plants. Some kinds of aphids are more effective carriers than other species of aphids and some diseases are more readily transmitted by aphids than other diseases. As illustrating the many complications in nature and the innumerable factors that enter into the spread and control of potato diseases it is worthy of mention that the aphids which transmit these diseases are themselves subject to being parasitized by other insects (Fig. 42). During the course of some experimental work with the virus diseases several colonies of aphids were completely destroyed by parasites. While the work of these parasites is commonly overlooked or not fully appreciated it is unquestionably a large factor in making possible the control of these diseases by roguing.

The spread of virus diseases is prevented mostly by early and thorough roguing of the affected plants. If a field shows a large number of plants affected by any of these diseases, however, no potatoes should be used from it for planting the next year; roguing under such circumstances is not apt to give good results. The seed should be obtained from fields that are more nearly free from these inherited weaknesses. As mentioned in an earlier section, roguing for control of the virus diseases is most effective and will give the greatest returns for the effort if done in connection with a special plot set aside for seed purposes. A grower is justified in using the most rigid care to eliminate these diseases from the seed-plot. The ideal is to use only healthy potatoes from normal hills for seed purposes. This ideal can be accomplished most nearly by careful work with a seed-plot.

Fig. 42. Leaf of potato plant containing a colony of aphids completely parasitized by a small wasp (Family *Braconidae,* Genus *Aphidius*). The hole visible in the back of each aphid was made by the parasitic insect for emerging after it had killed the aphid and completed its own growth. The work of this parasite reduces the number of aphids available that might function as agents of spread of the potato virus diseases and makes easier the task of the grower in producing high-grade potatoes in Oregon.

MILD MOSAIC. This disease is characterized by a mottling in the green of the leaf, in which yellowish or light-colored areas alternate with the normal green, and is accompanied generally by a crinkling but not a rolling of the foliage (Fig. 43). These mottled areas are variable in size and shape without regard to the different tissues such as the veins of the leaf. This is in contrast to the loss of color occasioned by other factors

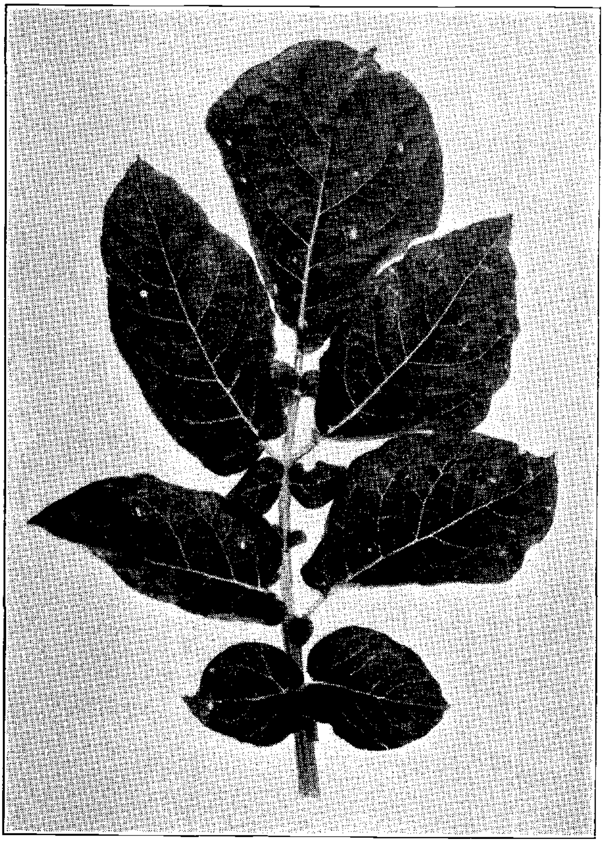


Fig. 43. Mild Mosaic. The leaves show mottled areas consisting of irregular patches of yellow green color distributed without symmetry throughout the blade. Typically the leaves are not smooth and flat but have an uneven crinkled surface. Often the margins of the leaflets are wavy or ruffled.

than mosaic which may give rise to yellowish, somewhat circular, island-like areas in the leaf tissues between the larger veins. This latter type of discoloration is not to be confused with mosaic for in the mosaic disease the lighter-colored areas are not bounded or stopped by leaf veins. Diseased plants tend to have a slightly erect appearance at first and are from slightly to considerably stunted depending on the severity of the attack. They droop and die prematurely. No symptoms are evident in affected tubers. The yield in the average affected hill is reduced about one-third as compared to normal hills.

The symptoms of mild mosaic are much less conspicuous in the growth of the plants that takes place during the warmer weather of summer than in growth taking place in cooler weather. This masking of the symptoms is sometimes so pronounced as to make it difficult to identify the disease in attacked plants. This is particularly true if only a single plant is available for judging. If four plants coming from different sets of a single tuber are growing side by side in the row as when planted in tuber units, it is much easier to determine accurately whether the disease is present. The virus is

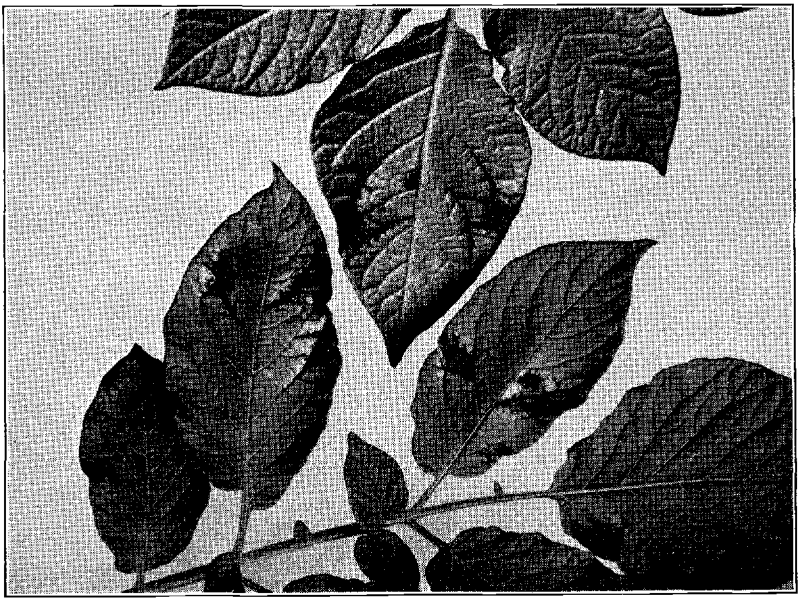


Fig. 44. Current-season rugose mosaic. This burning of the veins and leaf-blade is usually the first symptom shown when plants are infected during growth. This symptom is so characteristic that current-season infection by this disease can be accurately determined. If infection takes place late, however, no symptoms may be produced. The leaves illustrated here were photographed six weeks after inoculation in muslin-covered cages. For the performance of the tubers from this plant see Fig. 45.

always present, however, in diseased plants whether the particular plant shows the symptoms or not. Later, if cooler weather prevails, the symptoms will again become quite apparent in the new growth. Because of this difference in growth the roguing can be done more accurately in the cooler weather.

Mild mosaic is widely distributed in Oregon and has been seen severely attacking upwards of three-fourths of the plants in some fields. It is of such a nature that particularly in light cases many growers overlook it entirely and are not aware of its presence though it may be causing considerable reduction of the yield. The only way in which mild mosaic can be avoided is by the selection for seed purposes of tubers from healthy plants. This is best accomplished in the seed-plot, where during the growing season the disease can be recognized and should be removed by roguing promptly and rigidly to prevent its spread to other plants. This disease cannot be rogued accurately unless the seed-pieces are planted in tuber units. Early and thorough roguing is very essential to success in the control of this disease. It cannot be eliminated merely by a bin sorting of the tubers as there is no visible abnormality in the tubers; they are perfectly normal in appearance. It is due time that the growers pay more attention to this type of disease, learn to recognize it readily, and take the necessary steps to avoid the losses that are now occasioned by it.

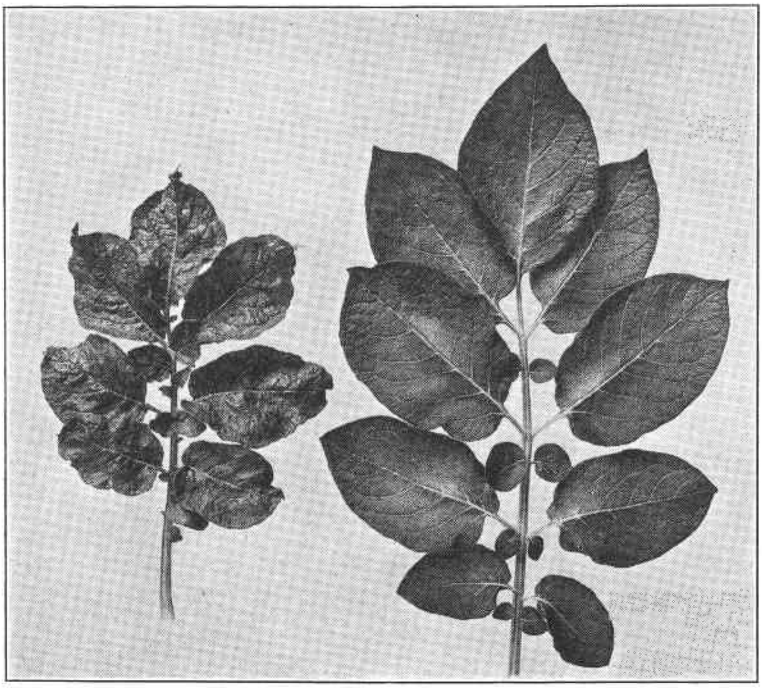


Fig. 45. Rugose mosaic and healthy leaves from sister plants, variety Burbank. The tubers which produced these leaves were grown by two sets of the same tuber. The difference in their performance is due to the fact that one set was inoculated with rugose mosaic and the other was kept as a healthy control. Crinkling of the leaf-blade and ruffling of the margin are very prominent here. Mottling is not distinct in this specimen. Under some circumstances the mottling is quite plain. Typically the mottled areas are small and located more abundantly near the main veins. The tuber which produced the diseased leaf was grown by the plant illustrated in Fig. 44.

RUGOSE MOSAIC. This is a more severe disease than mild mosaic and is entirely distinct from it. In most cases it can be readily differentiated from mild mosaic by appearances. The mottled areas are smaller, more numerous and typically distributed closer to the main veins. These symptoms are often masked so much by warm temperatures as to be quite inconspicuous. But even if the mottling is masked the crinkling of the leaves which is so prominent a feature of this disease makes identification rather certain. Leaves of affected plants have quite an uneven surface showing many elevations and hollows in noticeable contrast to the more nearly flat conditions of healthy leaves (Figs. 7, 45, and 46). Also the veins on the under side of the leaves, particularly the lower ones, often show necrotic areas as black, pencil-like lines. These blackened veins often make possible an accurate diagnosis of the disease. The affected plants are appreciably stunted and die much earlier than the healthy ones. Consequently the tubers tend to be less numerous and smaller than the normal. The yield is only from one-third to one-half normal.

Rugose mosaic spreads readily to other plants in the field. If infection of a healthy plant occurs before midseason, current-season symptoms are apt to be exhibited before the plant dies. If infection occurs late, however, no symptoms will be apparent that season though the tubers will carry the disease. The rapidity with which symptoms appear after infection depends much on temperature and other growth conditions. Sometimes these show up in three weeks but more often they do not become evident before five or six weeks. Almost always the first symptom to appear is a distinct and characteristic burning and discoloration of the leaf veins and leaf-blades (Fig. 44). The death of the tissues proceeds most rapidly in the veins and appears to extend into the leaf-blades from the veins. This gives rise to quite irregular dead areas. These spots may be scattered anywhere in the leaves or plant, but they occur most commonly and first in the leaves about three-fourths of the distance up the plant. Soon after this symptom is evident the mosaic mottling typical of this disease may occur in the newer leaves at the top of the plant. At that time usually the lower half of the plant may still present a normal appearance. Soon afterward, however, the burning of the leaves is so extensive that many of the leaves die and droop, hanging by a thread of tissue to the stem, or drop off entirely. In typical extreme cases this results in the plant having a few normal-appearing leaves at the bottom, no live leaves in the middle, and a tuft or cluster of mottled and crinkled leaves at the top. The response of the plant to current-season infection may vary from the condition related to very mild leaf burning or to no symptoms at all, particularly if infection occurs during the last three or four weeks' growth. But even if symptoms do not become apparent, a part or all of the tubers from the late-infected hill may carry the disease to the following year. This factor tends to make the control of the disease more difficult and emphasizes the desirability of early roguing to hold current-season infection to a low amount.

Rugose mosaic appears to spread more rapidly than any other potato virus disease if allowed to go unchecked. Cases have been observed where 3 percent tuber-perpetuated disease increased to 27 percent current-season infection showing symptoms by the last of August in one season's time. If to this is added the late infections which would not show symptoms, it is easily possible that this lot of potatoes by the end of the year carried a total of thirty-five percent or more rugose mosaic. Such extensive spread, however, can be avoided because the disease is subject to control by rigid roguing. Careful roguing even in mass-planted plots can be relied on to reduce the amount of disease in the seed stock from year to year. Tuber-unit roguing, however, will give control and practical elimination of the disease much more easily and in a shorter time. To be effective the roguing must be started early, at least by the time the plants average three inches in height; it must be repeated often, preferably about once a week in the early part of the season, and done thoroughly, so that all parts of the plant likely to grow again and including the original seed-piece are removed from the field in such a way that insects present on the plant at the time of roguing are not allowed to migrate to other plants. One good way to dispose of rogued plants is to place them in a sack as soon as removed. The

Fig. 46. Rugose mosaic and healthy plants, variety Burbank. The chief symptoms are pronounced crinkling of the leaves, mottling of the leaf-blades which is sometimes prominent but often masked, burning of some veins on the under side of leaves frequently, noticeable stunting, and commonly early death of the plant.

sack can be carried to the end of the field and left for hauling away when convenient later in the day. This disease need cause no serious difficulty if it is properly handled.

LEAF ROLL. The establishment of this disease in Oregon is apparently a recent occurrence. Seven years ago it was unknown to us; now it is frequently encountered. Unless it is generally recognized and steps are taken to control it, the prospects are that it will spread materially and cause appreciable damage. Leaf roll causes serious losses in many potato-growing areas of the United States and Europe. Diseased plants have an upward rolling of the leaflets on the midrib giving them a tubular form (Fig. 47) and the plant a stiff, erect appearance. The lower leaves of attacked plants are always rolled and leathery or brittle, often dying from the tips backward in advanced stages. Other leaves may roll also. The plants are almost always pale, being yellow green instead of dark green in color, and are considerably dwarfed (Fig. 48). The yields are generally small, and the tubers are often attached close to the stem. Plants affected by current-season infection show leaf rolling and loss of color in the topmost leaves first. At this stage it is difficult to distinguish this disease from injury due to Rhizoctonia. Aphids carry the disease readily. Roguing in tuber-unit planted plots gives good control.

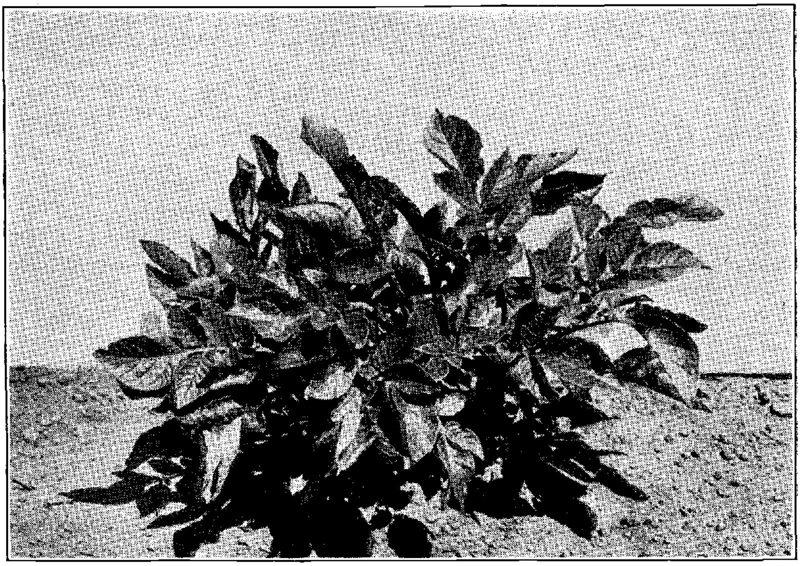


Fig. 47. Leaf roll, variety Burbank. Rolling is particularly prominent in the lower leaves though it is evident also in the upper ones. The foliage tends to be rigid and leathery and not soft and flexible as in normal plants. Diseased plants are noticeably stunted and lighter in color than the healthy plants.

Fig. 48. Two adjoining rows showing hill lots, leaf-roll diseased on left and healthy on right. The disease here was the result of spread of infection the previous season. Current-season infection may often result in the production of plants high in yield though badly diseased. When such hills are used for seed, however, only low yields are obtained the following year. The diseased plants shown here are decidedly stunted.

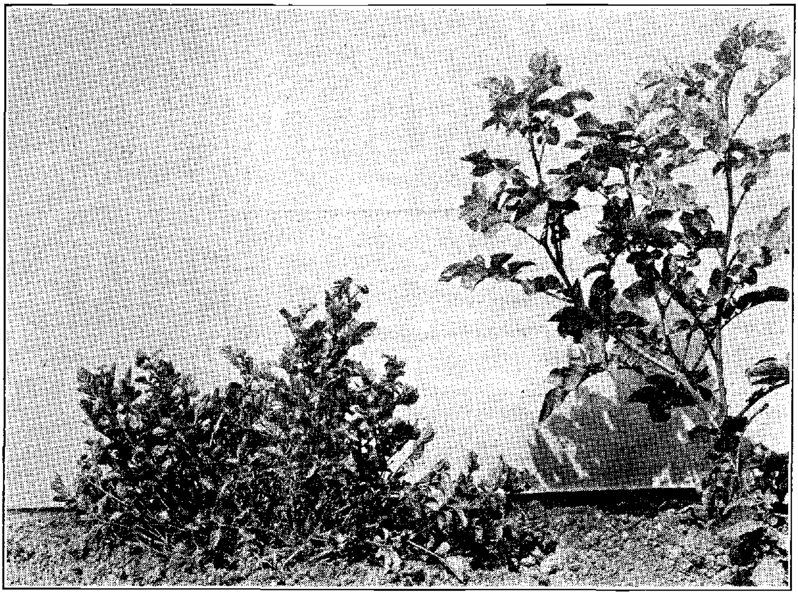


Fig. 49. Witches'-broom and part of healthy plant, variety Bliss Triumph. This plant shows the typical performance obtained from badly diseased tubers. Sometimes hundreds of sprouts or branches are produced and none of the tubers set acquire much size. The leaves are often somewhat rounded and velvety in appearance.

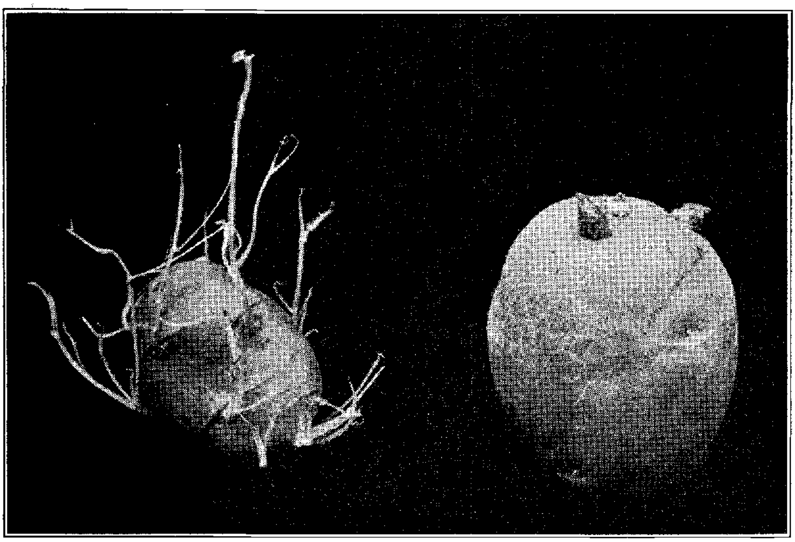


Fig. 50. Spindling sprouts caused by witches'-broom disease in tuber held in storage till late, in comparison with sprouts of normal potato, variety Up-to-Date.

WITCHES'-BROOM. In this disease numerous slender spindling sprouts are produced by the affected tuber when planted, none of which succeed in producing a large plant or any appreciable yield (Fig. 49). The effect is sometimes so extreme as to cause the plant to lose resemblance to a potato. The leaves may be quite small and somewhat velvety in appearance owing in part to the prominence of the leaf hairs. This is one virus disease that appears to get progressively worse as time passes after infection. Sometimes diseased plants are noted giving nearly normal growth and yields; the second year no normal potatoes are produced by the progeny, and the third year the plants may not grow taller than nine inches and may give no potatoes as large as a marble. That this progressive severity of the disease is typical is indicated by the fact that the different sets of a tuber unit will often give identical performances. When affected tubers germinate, they often give numerous spindling sprouts (Fig. 50). This sometimes enables an identification to be made of the disease before planting. Wher-

Fig. 51. Hill of Burbank potatoes from which one potato had been removed and grown as an index that resulted in revealing the presence of the witches'-broom disease. Some of the eyes here can be seen giving rise to weak, spindling sprouts which are so characteristic of this disease. None of the tubers from this hill lot gave normal plants. It is presumed that the plant which produced these tubers became infected during growth. Current-season infection has never been obtained, however, from inoculations in our experimental plots and the agent of spread of the disease is not known. This hill lot is a striking illustration of the fact that good seed cannot be obtained on the basis of appearance of the tubers or by hill selection alone.

ever possible these tubers should always be sorted out. That good seed cannot be picked out and this disease avoided merely by selecting hills having good yields of tubers with a good appearance is illustrated by the hill lot in Fig. 51. On appearances this hill would easily be selected for seed. When one tuber was grown from it as an index, however, it showed the typical weak condition of witches'-broom. When examined closely it will be seen that several eyes on these tubers are sending out weak, slender sprouts. This hill lot is very undesirable for seed purposes.

Witches'-broom is much more prevalent and troublesome in the northwest states than in other parts of the United States. It is widely distributed in Oregon, occurring in all areas of the state. It is quite variable in its abundance, both from section to section and from one season to another. Apparently it is spread more rapidly in some locations and in some seasons than others. It seems to be more abundant in sections and seasons having warm, dry summers. Generally the percentage of affected plants is quite small though sometimes a majority of the plants are affected in some fields.

The way in which this disease is spread from plant to plant in the field is not known. In our experimental plots direct spread to healthy plants in the row did not seem to occur even when alternate plants were diseased. Presumably the agent of spread was not present in these cases. It is assumed that spread of the disease may be effected by some insect, but all tests to determine this point have given only negative results. Tested many times, aphids have never given any infection in the trials. The disease can be controlled in part by roguing and selection for strong normal sprouts. In our experience roguing is of value perhaps only in eliminating the known diseased hills and therefore the tubers that would be valueless for seed purposes. Apparently it can not be relied on for preventing or avoiding infection in healthy plants. No appreciable reduction of spread of the disease has thus far been noted from roguing. The disease cannot be controlled completely until the agent of spread and the sources of the disease are discovered.

CALICO. This is a peculiar trouble of potatoes that is characterized by the occurrence of large irregular yellow to cream-colored spots or splotches on the leaves (Fig. 52) and by a stunting of the plants. Many of these spots are devoid of chlorophyl, the green coloring matter. These spots may be few or numerous. Occasionally only a few leaves on a plant will show this condition. Generally, however, the spots are numerous and well distributed over the plant. It appears to be systemic since generally all the tubers from an affected hill will give rise to the same condition if used for seed. Tuber perpetuation of this disease is not as inevitable, however, as it is with the virus diseases already described. Some evidence indicates that this is a virus disease though final proof has not been determined. In one test calico was apparently transmitted by inoculations, but this needs confirming. The fact that calico is becoming gradually more prevalent in some areas suggests that it may be infectious. No agent of spread is known. The trouble can be avoided quite effectively by roguing affected plants during the growing season.

NET NECROSIS. This disease is characterized by the production of an extensive network of small brown strands of discolored tissue extend-

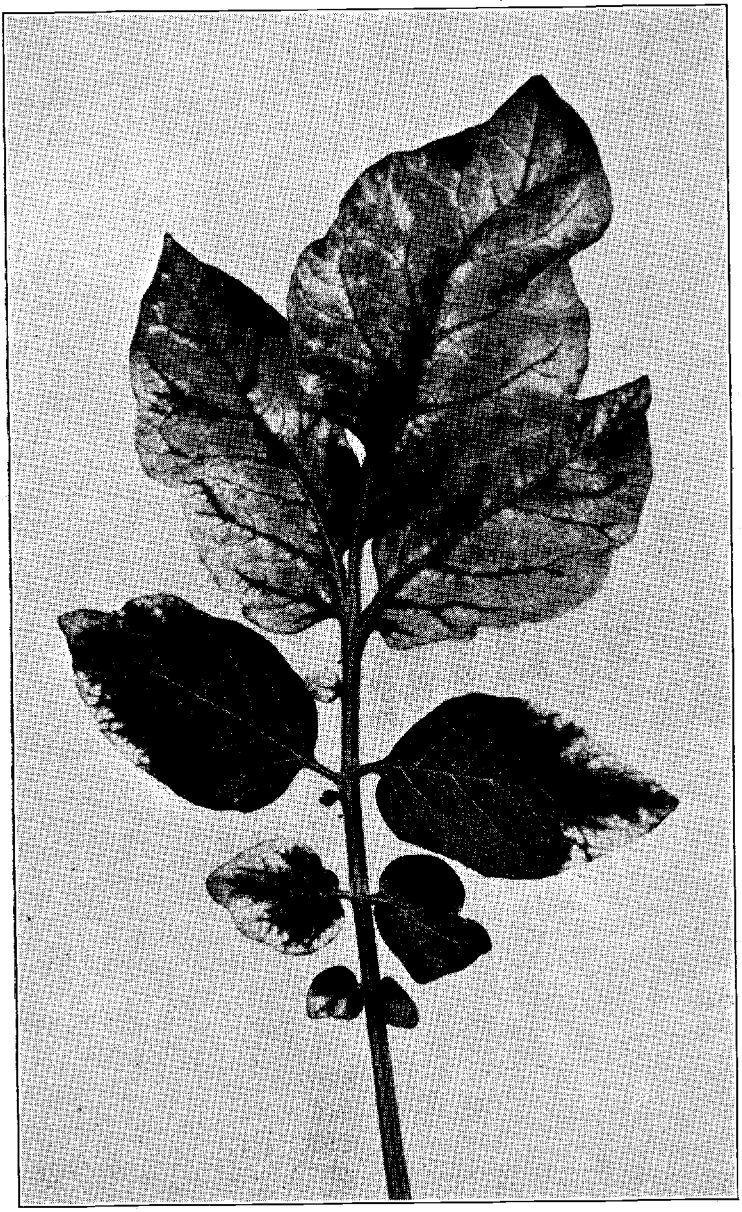


Fig. 52. Calico. This disease is distinguished by the occurrence of large irregular yellow to cream-colored splotches on the leaves and by a stunting of the plant. Tubers from affected plants will perpetuate the disease. There are some reasons for believing it may be due to infection by a virus but definite proof of this point has not been obtained.

ing throughout the interior of the potato tuber tissue though occurring more abundantly in the tissues near the surface of the tubers (Fig. 53). Experimental work in the East shows that it is closely associated with leaf roll and is apparently a symptom of it. This type of symptom has been found also in tubers affected with witches'-broom. It is apparently one symptom that is common to two or more diseases. It may not be a distinct disease. Tubers showing net necrosis should be avoided for seed. In some cases a condition indistinguishable from this hereditary net necrosis is brought about by chilling or frosting of the tubers. Such condition should be called frost necrosis. (See page 81.)

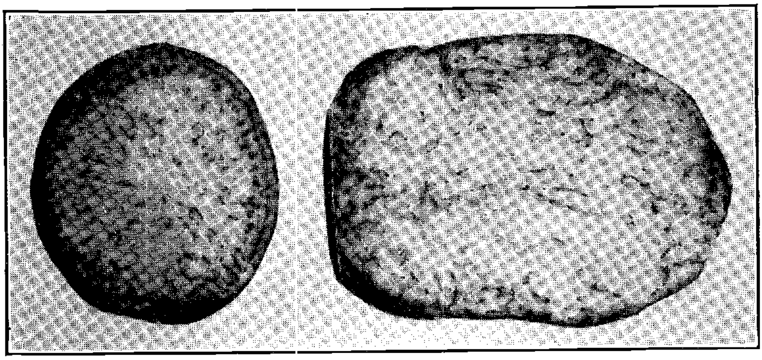


Fig. 53. Net Necrosis. The netting is typically more abundant in the tissues near the surface than in those deeper in the tuber. (*Photograph by courtesy of U. S. Department of Agriculture, Bureau of Plant Industry.*)

DISEASES DUE TO CLIMATIC OR ENVIRONMENTAL CONDITIONS

This group includes tip burn, internal brown spot, black heart, hollow heart, enlarged lenticels, and potatoes with no tops. These diseases or abnormalities are not inherited but depend for their development on unfavorable conditions.

TIP BURN. Tip burn is a drying and dying of the leaves, beginning at the tips and margins and working inward. The leaves often roll; becoming brown, they present a scorched appearance (Fig. 54). The feeding of certain leaf hoppers on potato foliage will give rise to a similar condition which is then known as hopper burn. Tip burn is usually most pronounced on light soils and during hot, dry periods, often following insect injury. If possible, an adequate soil-moisture supply should be maintained by irrigation or careful cultivation. This disease can be largely prevented by timely spraying with bordeaux mixture, owing probably to the shading effect which this spray has on the foliage of the potato plant and to the repellent action it has on the insects, causing them to feed less on sprayed foliage.

INTERNAL BROWN SPOT. The development of irregular brown spots in scattered and irregular places in the interior of potato tubers (Fig. 55) is known as internal brown spot. These brown spots are free from bac-

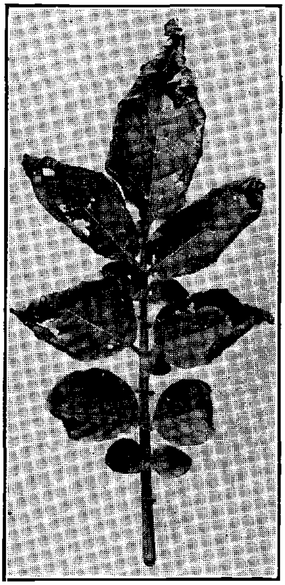


Fig. 54. Tip-burn. A drying and dying of the margins from the tips backwards accompanied by an upward and inward rolling of the leaflets.

teria or fungi and represent merely groups of cells which have died from some cause or other. This disease is generally believed to be due to excessive evaporation from the foliage or to lack of water at some period during the growth of the plants, perhaps as the result of poor soil or merely insufficient soil moisture. The trouble is not transmissible in the tubers. Affected potatoes are, however, generally avoided for seed on account of the chance for predisposition of the affected potatoes to this disease and because badly affected tubers may give rise to weak plants.

BLACK HEART. The disorder of potato tubers known as black heart is distinguished by the occurrence in the center of the tuber of an irregular area of jet black, quite moist and flabby tissue (Fig. 56). Occasionally the discoloration may occur as a black ring near the center inclosing a gray or darkened area. In advanced stages, the tubers show hollow, black-bordered cavities in the center. The discoloration progresses outward and whenever it reaches the outside, as occasionally happens, a rapid decay sets in.

Black heart is produced when potatoes are heated to 100° to 110° F. for a few hours or stored at lower temperatures in piles deeper than six feet without ventilation from the sides or bottom. This type of trouble is

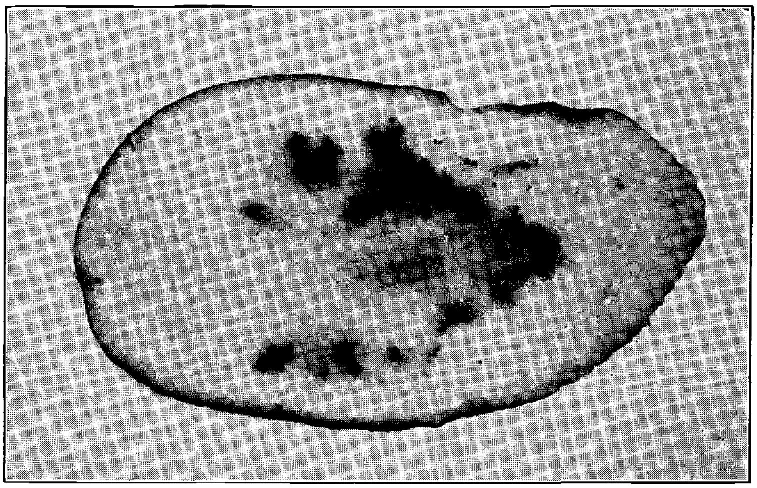


Fig. 55. Internal Brown Spot. Irregular brown spots or groups of cells which may occur at any place within the tuber.

more frequently encountered in shipments of potatoes which have been overheated in transit, in bins where the ventilation is unusually poor, and in seed potatoes that are taken out of storage and exposed to too high temperatures in the sun for too long a period while they are being prepared for planting.

FROST NECROSIS. Injury to potato tubers is sometimes occasioned by light chilling or frosting. Chilling or long storage at 30° to 35° F. causes the tubers to "turn sweet." Actual frosting, which occurs at 28° F. or below, may produce a grayish color in blotches in some of the tissues near the surface of the tubers. Often, however, the discoloration shows as brownish strands through the tuber but distributed more abundantly in the vascular region about ¼ inch below the surface. This may sometimes be quite similar

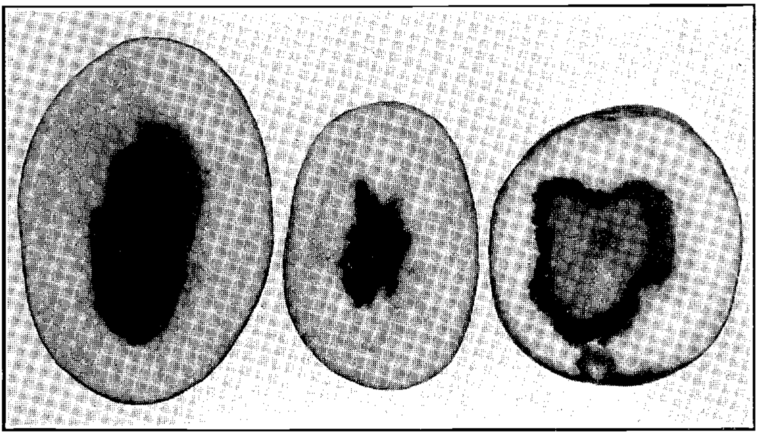


Fig. 56. Black Heart. An irregular area of black, moist, flabby tissue in the center of the tuber. Occasionally the discoloration may occur as a black ring near the center inclosing a gray or darkened area.

in appearance to net necrosis (see pages 78-79). If potatoes are actually frozen solid or on one side they become soft and mushy when thawed and are easily detected and discarded. Tubers showing discoloration from slight frosting should be avoided for seed owing to the chance of confusing them with potatoes affected with the hereditary net necrosis and also with wilt, which they slightly resemble, and because such tubers may give poor stands and weak plants.

Potato tubers are not injured by short exposures at 30° to 32° F. A simple way to determine when this danger point has arrived is to place a pan or tub of water in the storeroom. If the water begins to freeze—which will occur at about 32° F.—it is time to take steps to prevent further fall of the temperature in the storeroom.

HOLLOW HEART. This is a name applied to potato tubers that have a conspicuous cavity in their center. The cavity is usually present without any discoloration of the surrounding tissues though occasionally the adjacent cells assume a brownish, corky appearance. This abnormal condition is confined commonly to the large tubers and occurs mainly in seasons or under conditions favorable for rapid growth. On soils where the trouble is apt to appear it can be very largely if not entirely avoided by closer spacing of the plants, which will prevent such rapid and uneven growth of the tubers and the tendency of the tubers to split.

ENLARGED LENTICELS. Potato tubers left for some time in very wet soil or stored after digging in a very moist atmosphere will frequently develop a large number of small scab-like openings in the skin filled with light or cream-colored growths of cells appearing as though pushed out from below and which frequently assume a corky appearance in older stages or when exposed to air for a few hours after digging (Fig. 57).

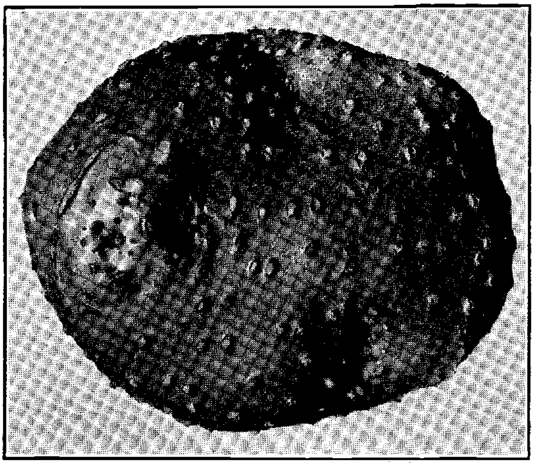


Fig. 57. Enlarged Lenticels. Small scab-like openings in the skin filled with light or cream-colored growths of cells appearing as though pushed out from below.

These are merely abnormally developed lenticels which when natural appear as small inconspicuous slits scattered over the surface of the tuber. Excess moisture is the commonest cause of the unnatural growth of these lenticels. Occasionally this condition is mistaken for scab to which there is only very slight resemblance when both are carefully examined.

POTATOES WITH NO TOPS. Occasionally an odd condition is encountered in which the seed potato gives rise to new tubers without the formation of any leafy sprouts that come to the surface of the soil (Fig. 58). This condition is variously referred to as blind tubers, sprout tubers, and potatoes with no tops. Growers now and then submit specimens for examination and on one occasion an appreciable number of such hills appeared in one of our experimental plots. This condition is not of much importance in Oregon though it has caused much loss at times in other countries. A careful study was made in Holland of the conditions inducing it. The conclusion from this work is that it is not a disease in the sense of being caused by a parasite but is brought on by any condition which causes an abnormal concentration of the cell sap of the tubers. Excessive loss of water from the tuber will cause it. The commonest ways in which this occurs are repeated or excessive sprouting of the tubers before planting, unusually long storage in exposure to light, and storage in light at a fairly warm temperature, 65° to 68° F. It is reported that use is made of this characteristic in England in a limited way to obtain new potatoes out of season. The method used consists in sprouting the seed potatoes a number of times in the dark. Finally these specially prepared tubers are incubated

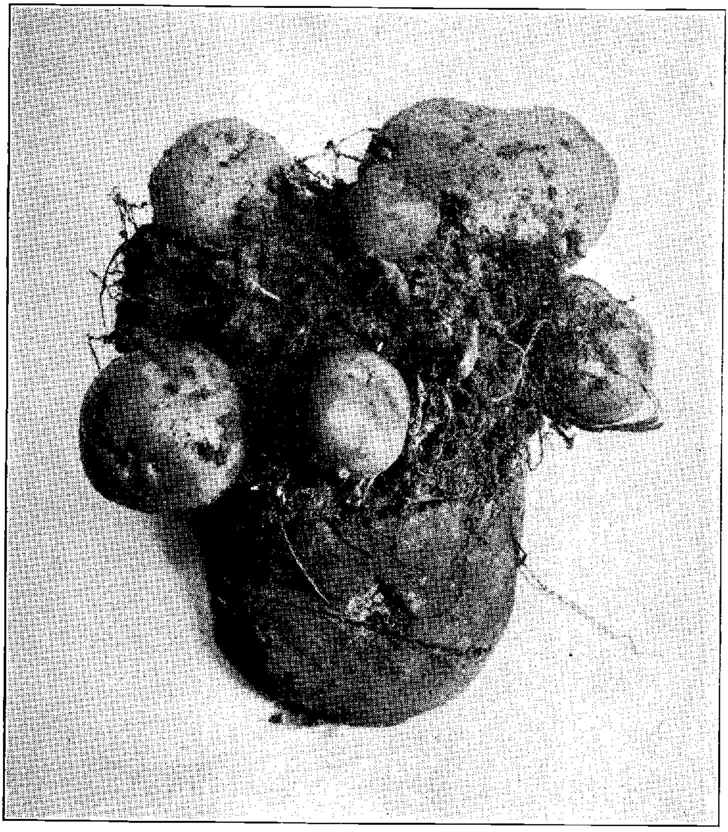


Fig. 58. **Potatoes with no tops.** This trouble is characterized by the production of new tubers in the absence of leafy sprouts. (*Photograph by Arthur Bowman.*)

in moist moss in a warm place shielded from the light where many new small tubers are formed. In normal plantings of potatoes, however, this condition is quite undesirable.

Sprout tuber formation is favored by early digging, small seed tubers, warm storage in darkness, repeated sprouting, and planting in low temperatures in dry soil. Normal development is favored by late digging, large seed tubers, cool storage in full light, absence of sprouting, and planting in higher temperatures in moist soil. The most important factors in avoiding sprout tubers are cool storage, storage in full light, and late planting.