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MICHIGAN POTATO DISEASES AND THEIR CONTROL

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MICHIGAN POTATO DISEASES AND THEIR CONTROL

J. H. Muncie

The potato is one of the most important and widely grown crops in Michigan. It is only natural that such an established crop and one grown under such a diversity of soil and climatic conditions should be subject to a number of diseases. Some of these have been of only slight economic importance over a period of years; others, like late blight and yellow dwarf, assume grave proportions under certain conditions and at other times cause little loss to the crop. Still others, such as scab and Rhizoctonia, annually cause serious reductions in yield and quality.

It is fortunate that each of the diseases here described is not in itself a limiting factor in potato production in the state, although all of them in the aggregate are responsible for annual losses amounting to several hundred thousand bushels. Such losses are a serious and largely unnecessary waste in the production of the crop.

The purpose of this bulletin is to give to the potato grower and others interested in the industry, information regarding the various diseases—their symptoms, effect upon the plant, means of dissemination, and the methods of control so that these losses may be reduced.

Whether all the disease control methods here enumerated will be put into practice will depend upon the individual grower and the crop prospects. A crop from seed of high-disease content will not yield the same returns as that from high quality seed despite adequate seed treatment and thorough spraying. The grower, therefore, should determine at an early date the incidence of disease in his crop and put into practice those control measures which will yield the greatest returns. If for example, the main field of table stock potatoes shows a high percentage of degeneration or virus diseases, control by roguing would not be economical. In such a case, no seed should be saved from the field but clean seed stock obtained for next year's planting. It has been shown by actual practice over a long period of years that starting with seed of good quality, seed treatment, spraying and roguing of the seed plot, at least, will make possible the production of high quality potatoes.

CONTROL MEASURES

Seed Selection

One of the most essential steps in growing a profitable potato crop is the use of high quality seed. The soil may be of suitable type with sufficient moisture and fertility, but if the seed is of poor quality, maximum yields will not be produced despite seed treatment, spraying and good cultural practices. The principal cause of low or poor quality seed is the presence of various degeneration diseases such as leaf roll, mosaic, yellow dwarf, spindle tuber, and others. Although these diseases are apparent on the vine growth, affected plants often produce tubers that appear normal in every respect. It is only by growing such tubers that the diseases are seen.

Selection of seed potatoes in the bin, therefore, will be only slightly effective in eliminating the degeneration diseases. Many of the virus diseases cause the production of small, misshapen, cracked, elongated or other off-type tubers. These can be sorted out in bin selection. Likewise, scabby tubers and those affected by blackleg and Rhizoctonia or black scurf can be eliminated. To this extent, bin selection is beneficial in obtaining better seed stock than the common run of potatoes.

Hill selection also is of some value. By selecting seed from high-yielding hills, a better grade of stock can be obtained. (After the vines are dead, however, the degeneration diseases are not always apparent, and affected tubers likely will find their way into the seed stock.) This method also eliminates tubers affected with scab, Rhizoctonia, and blackleg but leaves much to be desired in obtaining high yielding seed free from degeneration or running out diseases. A better means of obtaining high quality seed is described under the heading "seed plot," page 9.

Cutting the Seed

Better stands and more vigorous plants result if the seed is cut into blocky pieces averaging 1½ to 2 ounces in weight with at least two eyes. Several diseases are apparent in cut seed, and tubers, showing them should be promptly discarded. A dark brown ring in the flesh at the stem end, internal brown flecks, black heart, and dry rot are some of the manifestations of disease which one should note. Cut seed if properly stored will allow the cut surface to cork over. Such seed often withstands unfavorable soil conditions better than freshly cut seed. Certain diseases such as spindle tuber, unmottled curly dwarf, and probably others of the virus type are spread by means of the cutting knife but usually not to an extent to warrant disinfection of the knife. Bacterial ring rot also is spread in this way and after cutting an infected tuber the knife should be disinfected (page 29).

Green-sprouting

Green-sprouting of seed potatoes is rapidly gaining favor among the growers. This practice affords opportunity to eliminate weak or certain diseased hills before the seed is planted. Diseases such as yellow dwarf and leaf roll cause slow development of sprouts, while tubers affected with spindling sprout send out thin, wiry, weak shoots. Green-sprouting is done by spreading the seed potatoes, after treating, in a thin layer in a cool place where they are exposed to weak light. They are never put out in the bright sunshine, for black heart or scald is likely to develop. The development of short, thick, stocky green shoots is evidence of vigor in the seed and results in more rapid establishment of the young plant. Green-sprouted tubers should be planted before the shoot growth is too long. Cut tubers also may be sprouted. In this case, shoots will develop from the eyes of each piece, while with whole tubers, sprouts develop more readily at the bud end. Green-sprouting is particularly adapted to seed plot growing. It may also be profitable for the entire field, if weather conditions at planting time are unfavorable. Even green-sprouting, however, will not insure a good stand if the seed is planted in soil when the temperature is too high, that is, 80° F. or above. High soil temperature is particularly severe on freshly cut seed, causing the pieces to rot or to produce weak shoots.

Seed Treatment

Seed treatment is designed to destroy surface-borne disease organisms such as those causing scab, Rhizoctonia or black scurf and to reduce to an appreciable extent blackleg, early blight and silver scurf, on the tubers. Because of the disinfecting action of the chemicals upon the surface-borne organisms and prevention of early rotting of the seed piece, treated seed planted in disease-free soil generally results in better stands and higher yields.

Treatment of seed potatoes is usually made a short time before planting, although if properly carried out, treating can be done at any time while the tubers are dormant. If treated in the winter, care must be taken to avoid freezing, and the tubers should be allowed to dry before storing either in bags or bins. Seed treatment with virtually all materials must be made before the tubers are cut.

MATERIALS

The material most commonly used for potato seed treatment in Michigan is corrosive sublimate (mercury bichloride). In some cases, formaldehyde or certain organic mercury compounds are employed. Where Rhizoctonia or black scurf is present mercurial treatments are more effective than formaldehyde. The latter material, however is effective in the control of tuber-borne scab and has the advantage of being less poisonous to animals, does not corrode metal containers nor lose strength with use. It is also cheaper than the other materials, but the fumes are very irritating to eyes, nose, and throat. It has been shown that the hot formaldehyde treatment is more effective than the cold.

Cold Corrosive Sublimate

Corrosive sublimate or mercury bichloride is a white crystalline powder soluble in water. *This material is a deadly poison and in the powder form or in solution must be kept out of the reach of children and animals.* Potatoes treated with any of the mercury compounds cannot be used for human food nor for feeding animals.

The corrosive sublimate solution is made up at the rate of 4 ounces of the chemical dissolved in 30 gallons of water. Best results are obtained when the chemical is dissolved in a gallon of hot water. This concentrated solution is then added to 29 gallons of water in a wooden barrel or trough. Corrosive sublimate corrodes metal containers; therefore, in dissolving the material the hot water should be placed in a wooden, earthenware, or glass container before adding the chemical.

For treating small lots of seed, barrels are used as containers. The barrel is filled almost full of potatoes and enough of the dilute solution added to cover the tubers. Allow the tubers to soak for at least 30 minutes. If the tubers show Rhizoctonia infection and the scurfs are large or thick the time can well be lengthened to 1 hour. Soaking longer than 1 hour may result in slightly decreased yield.

The solution is now drained off through a hole in the bottom of the barrel and another lot treated in like manner. After the second lot is treated, enough water is added to bring the solution up to 30 gallons. The solution also loses strength and after treating the second lot, 1 ounce of corrosive sublimate dissolved in one quart of hot water is added. This procedure is repeated after each two lots of seed. After six lots of seed have been treated discard the solution and make up a fresh one. Do not soak the seed while in bags as this too rapidly weakens the solution. After the potatoes are treated they should be spread out in the shade in a thin layer and dried quickly. Do not store in piles nor leave in the sun, as injury to the eyes and rapid rotting of the seed piece usually will result.

Hot Corrosive Sublimate

By heating the corrosive sublimate solution, the length of treatment is reduced. Heating the solution in a large trough is done with live steam. A temperature of 124°-126° F. is maintained. The tubers are treated 2 minutes. After treating they are quickly dried and are ready for cutting or may be stored. This method has been used only experimentally in Michigan. The advantages of more rapid treatment appear to be offset by the necessity of providing means of maintaining a high solution temperature within narrow limits.

Acidulated Corrosive Sublimate

A modification of the standard corrosive sublimate solution has been developed at the Minnesota Agricultural Experiment Station. The solution is made by dissolving 6 ounces of corrosive sublimate powder in 1 quart of commercial hydrochloric acid (muriatic acid). After the chemical is dissolved the acid solution is added to 25 gallons of water. The addition of hydrochloric acid aids in the penetration of the chemical into the scurfs or sclerotia of Rhizoctonia on the infected tubers. The seed is soaked for 5 to 30 minutes and dried in a thin layer in the shade. This treatment has been used to advantage where Rhizoctonia or black scurf infection was severe. Injury to the eyes of the potatoes sometimes results with the longer period of soaking. Ordinarily with the usual thin type of black scurf infection, a 10-minute treatment is sufficient but gives no better control than the standard corrosive sublimate solution.

Calomel or Mercurous Chloride

The use of calomel or mercurous chloride as a disinfectant for seed potatoes was developed at the New York (Cornell) Agricultural Experiment Station. The treating solution is made by adding 1 pound of calomel and dissolving 4 ounces of corrosive sublimate in 30 gallons of water. The chemicals in required amount should be added to 1 gallon of hot water and this added to 29 gallons of cold water to make the required strength of solution. The potatoes are soaked 5 minutes. Repeated tests by members of the staff of the Potato Office of the Michigan Agricultural Experiment Station failed to show any superiority of this treatment over standard corrosive sublimate.

Organic Mercury Compounds

Certain proprietary compounds containing organic mercury as the active ingredient have been used as potato seed disinfectants for several years. These materials have the advantage of being non-corrosive to metal containers, require shorter time for treating and are less toxic to the eyes of the tuber than corrosive sublimate. They are used in solution at the strengths as recommended on the container label, usually 1 pound of chemical in 7½ gallons of water. Several years' tests with one of these compounds, Improved Semesan Bel, have shown better control of Rhizoctonia where thick scurfs or sclerotia were present than the 30-minute standard corrosive sublimate solution treatment. When the corrosive sublimate treatment was prolonged to 1 or 1½ hours, there was no significant difference in effectiveness. This material may be used on cut seed if the potatoes are dried thoroughly before storing prior to planting.

Cold Formaldehyde

Formaldehyde (formalin) is a gas dissolved to the extent of approximately 40 per cent in water. For disinfecting potato seed, formaldehyde is diluted at the rate of 1 pint in 30 gallons of water, making a 1-240 solution. This material does not corrode metal and retains its strength after repeated use. The whole tubers are completely covered with the cold solution, allowed to soak for 2 hours, then removed and kept covered for 1 to 2 hours before being dried or cut. This material in our tests is not so effective as corrosive sublimate, especially for the control of Rhizoctonia.

Hot Formaldehyde

Hot formaldehyde is simply a modification of the cold method. The solution is twice as strong as for the cold formaldehyde treatment. Two pints of commercial formaldehyde are added to 30 gallons of water and the solution is heated to 122° F. The temperature of the solution must not be allowed to drop below 118° F. Tubers are treated 2 minutes in the solution. After treatment the tubers are kept covered for 1 to 2 hours before drying or cutting. The temperature is maintained by live steam, or a fire beneath the tank. Special apparatus with heating unit attached is manufactured for carrying on the hot formaldehyde treatment. This treatment is used extensively in certain states but has found little acceptance in Michigan. Opinion among growers indicates that the advantage gained by the shorter time of treatment is offset by the difficulty of keeping the temperature of the solution within the prescribed limits.

Rotation

Rotation in which potatoes are planted every third or fourth year is one of the standard practices in growing the crop. It is of special benefit in avoiding soil-borne diseases, such as scab, Rhizoctonia or scurf, and the wilts. The organisms causing these diseases flourish in the soil in the presence of the potato plant. By rotating with other crops, these disease organisms either are reduced by lack of food or by the antagonistic action of other organisms which become more abundant in the presence of another crop.

In special areas, potatoes may be grown for several years in succession provided the soil is free from disease organisms and the tubers are disinfected. In general, however, rotation is a safer practice to follow.

Although rotation is of considerable benefit it is only one of the practices necessary in the production of high quality potatoes. Other practices also contribute largely to the growing of a quality crop and these should be given careful attention.

Roguing

In a seed plot or main field many undesirable plants may be found. Such plants because they are diseased, off-type, unthrifty or of mixed variety are known as "rogues" and should be removed. The removal of these undesirable plants is known as roguing. It is obvious that the practice of roguing will make for greater uniformity in type as well as increase the yield through the elimination of diseased and low-yielding hills. In general, table stock growers do not rogue the main field but only the seed plot if one is used. For the certified seed grower, roguing is an obligatory operation, both in the seed plot and main field. In roguing for certification, plants affected with any of the diseases whose symptoms are expressed in the above ground parts or whose presence on the vines indicates infected tubers are removed. Weak hills, due to soil conditions, shallow planting or other accidents in cultivating, although not diseased are removed if they affect the general uniformity of growth in the field. It should be emphasized that careful roguing of the seed plot will greatly reduce the number of rogues in the next season's main field.

Roguing should be done under favorable weather conditions. It is well-known that the symptoms of certain virus or degeneration diseases are masked or not readily seen in bright sunlight or after periods of high temperature. Conversely symptoms of other virus diseases are expressed after periods of comparatively high temperature. Roguing, therefore, cannot be done thoroughly in a single operation. It should be started when first disease symptoms are seen and repeated at frequent intervals if best results are obtained. This is especially true of the seed plot. Roguing should be done before spraying or dusting because the fungicide or insecticide often obscures the leaf symptoms of certain virus diseases.

In roguing, too much haste will result in missing many of the undesirable plants. Two rows of plants usually are all that can be carefully rogued at one time. In especially clean fields, however, from well-rogued seed stock, four rows at one time may be rogued satisfactorily. In table stock fields, roguing is not so closely done, and faster progress can be made. The rogued plants are pulled along with the seed piece and any tubers and carried from the field, preferably in bags or pails, so that the diseased vines are not rubbed over the healthy ones. If aphids are present, care must be taken to keep them from dropping off the wilting plants while being removed from the field. Aphids may also crawl to healthy plants from wilted rogued plants if piled at the end of the rows. Bury or burn the rogued plants immediately after removing. Early roguing is recommended because of the relative freedom of the plants from leaf-hoppers and aphis at this time. Diseased plants should be removed as soon as possible to prevent the spread of virus diseases by insects.

The Seed Plot

The purpose of a seed plot is to produce high quality potatoes in quantity sufficient to plant the main crop. Such a plot is obligatory for growers of certified seed and is highly desirable and profitable for those growing table stock. There are abundant data to show that the planting of high grade seed, even at prices considerably above those of No. 1 table stock, is justifiable in increased yield and quality obtained. Not every potato grower will wish to grow a seed plot, but for those willing to put in the necessary effort and attention, it will furnish a means of obtaining a constant supply of high-yielding, uniform, relatively disease-free stock.

In planting the seed plot, the use of best quality seed, such as that grown for certification, is likely to prove more satisfactory than the grower's own stock. Certified seed, with its background of many years' effort in eliminating disease and selection for uniformity and high yield will usually be more economical and satisfactory for planting the seed plot.

Planting part or all of the seed plot in tuber units is strongly recommended. By this method the seed tuber is cut into three or four pieces, and these planted in a unit separated from like units by a short space in the row. If one hill of the tuber unit shows disease, the entire number is rogued out and destroyed, thus eliminating the disease in one operation. The use of small whole tubers, relatively free from disease, has the advantage of reducing the amount of disease in the seed plot. Such seed is particularly desirable where bacterial ring rot is present or suspected. Selection of high-yielding units and subsequent planting will lead to a superior strain of seed stock.

The seed should be treated with the standard corrosive sublimate solution or one of equal efficiency as insurance against surface-borne disease organisms. Green-sprouting is desirable in eliminating weak tubers and those carrying certain degeneration diseases. In selecting the soil for planting, care should be taken to see that the field has not previously produced a scabby crop nor one affected by black scurf. For this purpose, soil with somewhat acid reaction will probably be more desirable. If an alfalfa sod is turned under for the seed plot lime should not have been applied within 3 or 4 years. The usual precautions against application of fresh manure just before planting also should be observed. Planting should be made sufficiently early to insure a satisfactory crop of mature tubers.

In general the seed plot should be separated some distance from the main field unless the plants of the latter are relatively free from disease, especially those of the virus type. In such cases the distance between the two may be a number of rows planted to some other crop such as corn, sunflowers, or rutabagas. Spraying should begin when the plants are 4 to 6 inches high and continue at frequent intervals, keeping the plants well-covered. This will largely prevent late blight, early blight and damage from leaf-hoppers and other insects that spread degeneration diseases.

Roguing should be practiced systematically if best results are to be obtained. Beginning when the plants are 4 inches high, the seed plot should be carefully inspected, row by row at short intervals, and all diseased or off-type plants removed. Such plants will comprise those that do not in general conform to the surrounding plants in size, shape, and color of stems and foliage. Roguing should eliminate plants showing blackleg, black scurf on the stems, leaf roll, mosaic, yellow dwarf and other virus diseases as well as weak and giant hills. By close observation and practice the grower will usually be able readily to detect off-type or diseased plants, although he may not know the name of the disease. Those attempting to rogue for the first time will find it of great benefit to obtain the assistance of some one who is familiar with the procedure by actual practice.

Spraying

Applications of fungicides to potato plants are made to protect the vines from infection by the spores of fungous parasites and to repel certain insect pests. Late blight and early blight are prevented, and leaf-hoppers and certain other insects, while not killed, are largely repelled by thorough applications of an efficient fungicide. After many years' tests copper has been found the most effective fungicide for use on potatoes. Copper is applied as copper sulphate in combination with lime as bordeaux mixture. Other copper fungicides have been tried but so far none of them has been found as efficient as bordeaux mixture. Lime-sulphur should not be applied to potatoes because of its burning effect upon the foliage.

BORDEAUX MIXTURE

This material is a precipitate formed by adding a dilute solution of copper sulphate or blue vitriol to a similar solution of lime. Blue vitriol is usually sold in the form of dark blue crystals. Upon exposure to air they become almost white through loss of water and are stronger than the blue form. This should be taken into account when making bordeaux mixture. Blue vitriol is also sold in finely granular form. This form used in making "instant bordeaux" is more readily soluble than the crystals. The lime used in the mixture may be stone lime, burnt limestone or hydrated lime. It should be fresh and contain a high percentage of calcium oxide. Air-slaked lime is not suitable in making bordeaux mixture. Lime especially prepared for spray material can be obtained. More hydrated than stone lime is required in making the mixture. In general, prepared bordeaux mixtures are not as efficient fungicides as the home-made material and are usually more expensive.

Homemade Bordeaux Mixture—For large acreages it is more economical and convenient to prepare stock solutions of the blue vitriol and lime in quantities. The blue vitriol solution is made by dissolving 50 pounds of the chemical in 50 gallons of water. One gallon of this solution will contain 1 pound of blue vitriol. The required amount of blue vitriol is placed in a loosely woven burlap bag and suspended so that it is not completely covered with water. The chemical will dissolve much more rapidly in this manner than if it is completely immersed. Cover the barrel of solution to prevent evaporation.

The stock lime solution is prepared by slaking 50 pounds of stone lime or burnt lime slowly until a paste is formed. Enough water is then added to make 50 gallons of solution. If hydrated lime is used, 75 pounds of the material is dissolved in 50 gallons of water. Hydrated lime contains less calcium oxide than lump lime; therefore, more is required to neutralize the blue vitriol than when lump lime is used. These stock solutions are sufficient to make 625 gallons of standard strength bordeaux mixture.

In making 100 gallons of bordeaux mixture, about 75 gallons of water are run into the sprayer tank and 8 gallons of the blue vitriol solution added and stirred by hand or by the agitator. Next, 8 gallons of lime solution are poured through the strainer into the tank and enough water added to make 100 gallons of spray material. If lump lime solution is used the bordeaux mixture formula will be 8-8-100 and if hydrated lime solution is used, 8-12-100. Hydrated lime is most commonly used because of the ease in making the stock solution. Calcium arsenate may be added at the rate of 4 or 5 pounds to 100 gallons of bordeaux mixture for control of Colorado potato beetles.

Properly made bordeaux mixture is sky blue in color. The lime in solution should neutralize the blue vitriol in the mixture. To test the bordeaux mixture, a few drops are added to a dilute solution of potassium ferrocyanide (yellow prussiate of potash). If the test solution turns brown, more lime should be added to the bordeaux mixture until the material is sky blue in color.

If only a small quantity of bordeaux mixture is wanted it can be made by dissolving 2 ounces of blue vitriol in 1 gallon of water and 3 ounces of hydrated lime in another gallon of water. After stirring vigorously, the two solutions are poured at the same time into a third vessel taking care that the two streams of solution mix while being poured.

Instant Bordeaux—Recent tests at the Michigan State College Potato Experimental Farm show that instant bordeaux mixture gave as good results as the standard mixture described under the heading "Homemade Bordeaux Mixture," page 11. Instant bordeaux mixture is made as follows: Add 75 gallons of water to the sprayer tank, place 12 pounds of finely ground blue vitriol on the strainer and wash through into the sprayer. Add more water until the tank is ¾ full.

Place 18 pounds of hydrated lime on the strainer and wash through into the tank. Add enough water to make 150 gallons of solution. Keep the sprayer agitator in motion throughout the process.

Prepared Bordeaux Mixture—In general, prepared bordeaux mixture is not so efficient as the homemade product in disease control. The efficiency of the material is largely dependent upon the percentage of copper present and this is declared upon the label of the container. Many persons, however, prefer to use the prepared material when only small quantities of spray mixture are needed. The following table taken from Cornell Extension Bulletin 135 gives the amount of prepared bordeaux mixture necessary to add to 50 gallons of water to make a spray material equivalent in copper content to a homemade bordeaux mixture.

Pounds of concentrated mixture necessary to make a spray equivalent in copper content to a homemade bordeaux mixture.

Metallic copper declared on label (per cent)	Equivalent of copper sulphate (per cent)	Pounds of concentrated mixture necessary to add to 50 gallons of water to make a bordeaux mixture of the following formula.		
		3-3-50	4-4-50	5-5-50
1.5	5.89	50.9	67.8	84.8
2.0	7.86	38.1	50.8	63.6
2.5	9.82	30.5	40.7	50.9
3.0	11.79	25.4	33.9	42.4
3.5	13.75	21.8	29.0	36.3
4.0	15.72	19.0	25.4	31.8
4.5	17.68	16.9	22.6	28.2
5.0	19.65	15.2	20.3	25.4
6.0	23.58	12.7	16.9	21.2
7.0	27.51	10.9	14.5	18.1
8.0	31.44	9.5	12.7	15.9
9.0	35.37	8.4	11.3	14.1
10.0	39.30	7.6	10.1	12.7
11.0	43.23	6.9	9.2	11.5
12.0	47.16	6.3	8.4	10.6

Application of Bordeaux Mixture

Applications of bordeaux mixture to be most effective should begin when the potato plants are 4 inches high and be continued at short intervals throughout the season. In general 5 to 7 applications are sufficient but under weather conditions favorable to late blight, a greater number and more frequent applications must be made to give complete control. When the plants are small, approximately 60 to 75 gallons of spray per acre will be sufficient to give thorough coverage. When the plants are small good coverage may be obtained from the top nozzle alone or by using the two side nozzles. This will save material, but it is more important that good coverage be obtained. The amount should be increased to 125 or 150 gallons per acre when the vines are grown. To be most effective, it is necessary that the plants be enveloped in a mist of bordeaux mixture during spraying. Nozzles should be set so that the spray material is directed upward from the two sides and downward from above. In this way both the lower and upper surfaces of the leaves will be covered with fine particles of the spray material. New growth should be kept covered with bordeaux mixture to insure best results in disease and leaf-hopper control.

A pressure of 250 to 400 pounds per square inch should be maintained for best results with machine spraying. With hand sprayers, the operator should maintain as high pressure as possible, consistent with moderate speed in applying the material. A small stream of bordeaux directed at the plant will not give protection; the material must be applied as a mist under fairly high pressure, and the entire plant covered.

Dusting

Although it has been demonstrated many times that spraying with bordeaux mixture is somewhat more effective in potato disease control than the application of dusts, many growers of small acreages prefer to use dusts because of the greater ease of application. For best results in dusting it is necessary to apply the material when the air is still and there is some moisture on the leaves. A canvas trailer attached to the dusting machine prevents blowing of the dust.

Copper-lime Dust—The most commonly used dust contains 20 pounds of the monohydrated copper sulphate and 80 pounds of hydrated lime. This is expressed as a 20-80 dust. If arsenical is added, usually in the proportion of 10 pounds of calcium arsenate in 100 pounds of the mixture, the formula is expressed as 20-10-70, the arsenical replacing its weight in hydrated lime.

Fixed Copper Dust—Other dusts containing a fixed copper with a filler and sticker have been used successfully on potatoes. Dusts containing the following fixed coppers have been tried two years experimentally: Tribasic copper sulphate, Cuprocide, Bordow F48 and Basicop. There are, however, several other forms of fixed copper used in dusts which no doubt could be used successfully on potatoes.

Fixed copper dusts do not contain lime but instead talc, pyrophyllite or other suitable filler is used with or without a sticker such as flour or bentonite. These dusts usually have a metallic copper content of approximately 7 per cent, equivalent to the 20-80 monohydrate copper sulphate-lime dust. Calcium arsenate is added for control of leaf-chewing insects. These dusts are usually available ready mixed.

Application of the Dust—Dust should be applied when the air is still and should be directed so that a cloud of the material will envelop the entire plant. It is essential that both the under as well as the upper surface of the leaves be coated with the fungicide. Moisture present on the leaves will hold the dust, and the particles of the mixture dissolving in the moisture make bordeaux mixture. Tests show that five or more applications using 30 pounds of dust to the acre should be made during the average season to give best results. This amount of dust per application is approximately equivalent to 100 gallons of an 8-12-100 bordeaux mixture. Under late blight conditions the dosage of dust should be increased to 40-50 pounds per acre. More frequent applications also should be made. If the clothing becomes wet during the dusting operations, the operator may be severely blistered by the action of the chemicals on the skin where wet clothing rubs. Rubber boots or waders have been used to advantage by many operators of hand dusters.

Diseases Caused by Fungi or Bacteria

The fungi are very low forms of plant life devoid of green coloring matter or chlorophyll. These organisms draw their food materials from either living or dead green plants. Fungi that obtain their food from living plants upon which they grow are said to be parasitic or are parasites. The green plant upon which the fungus grows is known as the host. Certain of the fungous parasites like that causing late blight are able to live only upon or within the host plant. Others, such as those causing the wilts and black scurf, survive for long periods in the soil in the absence of the host plant.

The bacteria are lower in the plant kingdom than the fungi, and the whole organism is made up of a single cell or a group of such cells massed together. They, like the fungi, are either parasitic, obtaining food from living plants, or saprophytic, in which case the food material is obtained from decaying vegetation. Some of the most serious plant diseases are caused by parasitic bacteria. Fortunately in Michigan there are only two serious diseases (blackleg and ring rot) of potatoes in the field caused by bacteria.

For the control of such diseases, the use of clean seed, seed treatment, elimination of diseased tubers, by sorting, roguing affected plants, and spraying are practiced.

LATE BLIGHT

This is probably the most serious of the potato diseases because of the almost immediate destruction of vines and subsequent rotting of tubers. In 1915 Michigan suffered a widespread epidemic of late blight and in that year the loss amounted to about $4,000,000. Since then restricted outbreaks of the disease have occurred periodically in isolated areas in the state with more or less severe losses. In 1938 and 1939 late blight was again present and in 1940 affected the potato crop throughout the entire state causing serious losses in the field and storage.

Signs of the Disease—First indications of late blight infection appear at the tips of leaflets as dark, greasy, water-soaked spots affecting one-third or more of the area (Fig. 1). These areas rapidly increase in size, involving the entire leaflet. On the under surface the cobwebby mold-like growth of the causal fungus appears. With continued cool moist weather, infection spreads rapidly to the tender petioles and stems, causing them to rot and fall over. Infected plants in this stage of decay give off a characteristic rank odor. Except for the mold-like growth of the parasite, blighted plants have much the appearance of being damaged by frost.

Damage is not confined to rotting of the tops, but usually the tubers also are attacked. Early stages of the disease on the tubers appear as slightly sunken grayish, brown or pinkish areas, (Fig. 2). Such areas may be so numerous as to give the tuber a hob-nailed appearance. More often the sunken spots coalesce or run together, forming larger areas. Beneath the sunken spot, the flesh of the tuber shows a moist brown firm type of decay. Later the affected tissue may dry out and become hard beneath the leathery textured lesion. Such decayed areas vary from ⅛ to ½ inch in depth, (Fig. 3). If infection takes place at the stem end, a broad brown band of decaying tissue often results. Under moist conditions, complete rotting of the tuber may result as the combined effect of the late blight fungus and bacteria that gain entrance through the blighted areas causing a wet rot. Under dry conditions, severely affected tubers become shriveled or mummified by the dry rot.

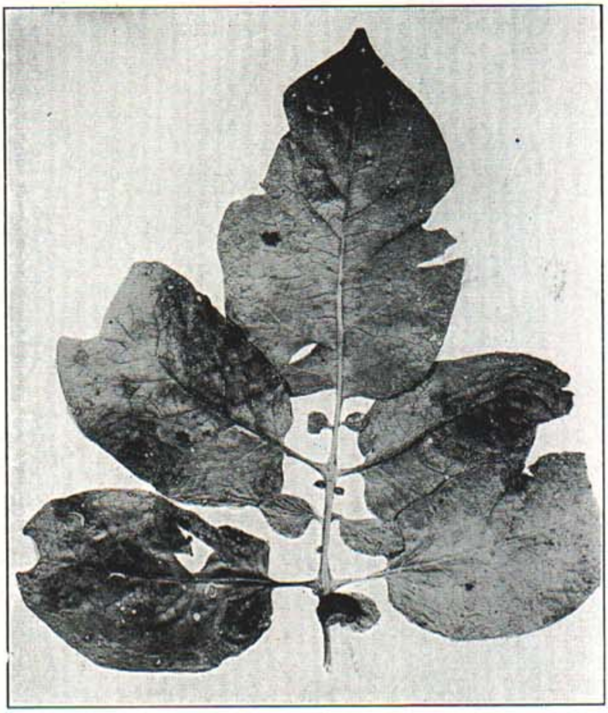

Fig. 1. Under side of blighted potato leaf showing water-soaked spots. From these spots the cobwebby growth of the causal fungus develops.

Cause—Late blight is caused by the downy mildew fungus, *Phytophthora infestans.* Contrary to popular opinion, late blight usually does not appear simultaneously over large areas of potatoes. The fungus may be present in a few tubers in practically all lots of ordinary seed potatoes each year. When such tubers are planted, the fungus grows into and upon the young sprout as it comes above ground or through the soil into the new tubers. If weather conditions are favorable at this time, infection spreads from a few diseased plants to the healthy plants growing along-side. With continued cool, moist weather, spread of the disease is rapid and it flares up in many large areas, seeming to affect the entire field at once. Spread of the fungus takes place by

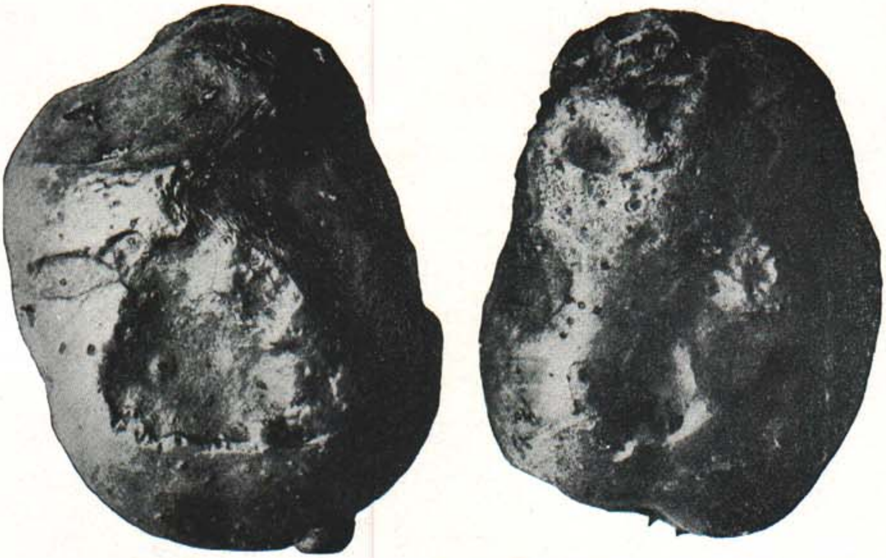

Fig. 2. Sunken areas on tubers indicate early stages of late blight rot.

means of spores produced on the diseased plants, which are splashed and blown to near-by healthy vines. Each spore is capable of infecting a new plant, and thousands of spores are produced in a short time on the diseased vine. Under cool, moist conditions this spore-producing and scattering process is repeated rapidly until whole areas or the entire field may be infected. Late blight may be expected in Michigan when July is wet with cool nights, followed by moderate or heavy rainfall in August.

Control—Although thorough spraying or dusting with a suitable copper compound—such as bordeaux mixture or copper-lime dust—is recommended as a general protective measure, it is particularly effec-

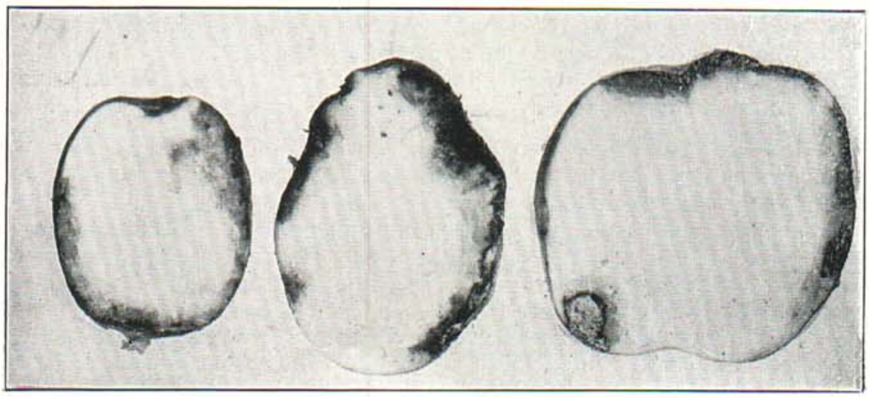

Fig. 3. Penetration of late blight rot into the flesh of the tuber.

tive against late blight. Applications should begin when the plants are 4 inches high and should be continued at intervals of 10 days to 2 weeks, or more often, until danger of late blight is past. Vines free from late blight produce tubers free from blight-rot. In event that wholesale infection has taken place before the disease is discovered, it may be feasible to kill the vines with a suitable chemical. Such treatment is usually made only when the tubers are mature enough for harvest. Digging should be delayed until the vines are dead and there is dry, bright weather.

Usually blighted fields are not dug until the soil is fairly well-dried on the surface. The tubers are allowed to dry in the field and placed in dry, cool storage at a temperature of 40° F. or a little below. Subsequent development of rot will depend much upon the humidity and temperature maintained in storage. Obviously the safest procedure is to prevent blight by giving adequate protection to the vines by means of thorough applications of copper-lime dust or bordeaux spray.

EARLY BLIGHT

Early blight is probably the most common and widespread foliage disease of potatoes. This disease also attacks tomato, eggplant, and other solanaceous plants. In Michigan all commercial varieties of potatoes are affected, although early varieties are more susceptible than the late sorts.

Although the disease is called early blight, it frequently causes greatest damage to the leaves late in the growing season after the vines have passed the period of most vigorous growth. Because the

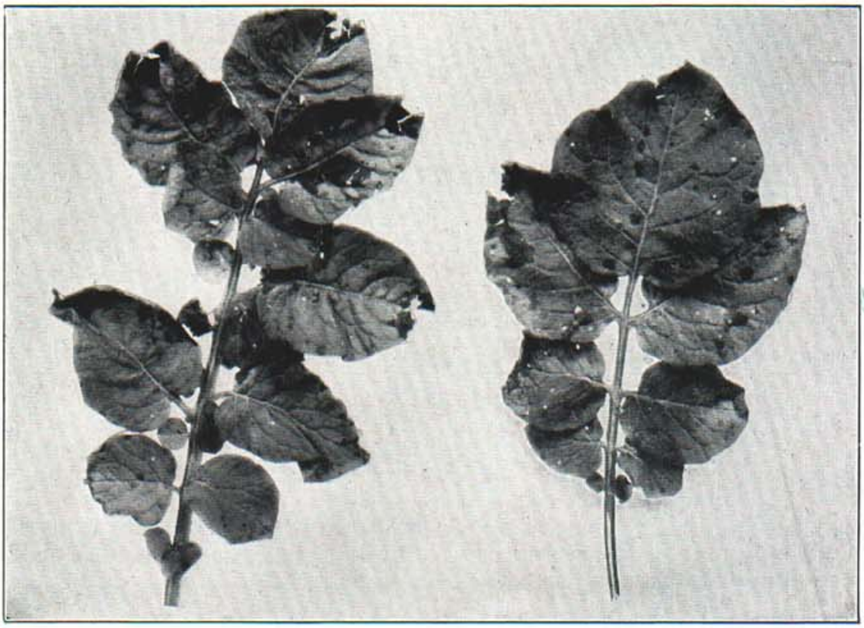

Fig. 4. Early blight spots on leaves.

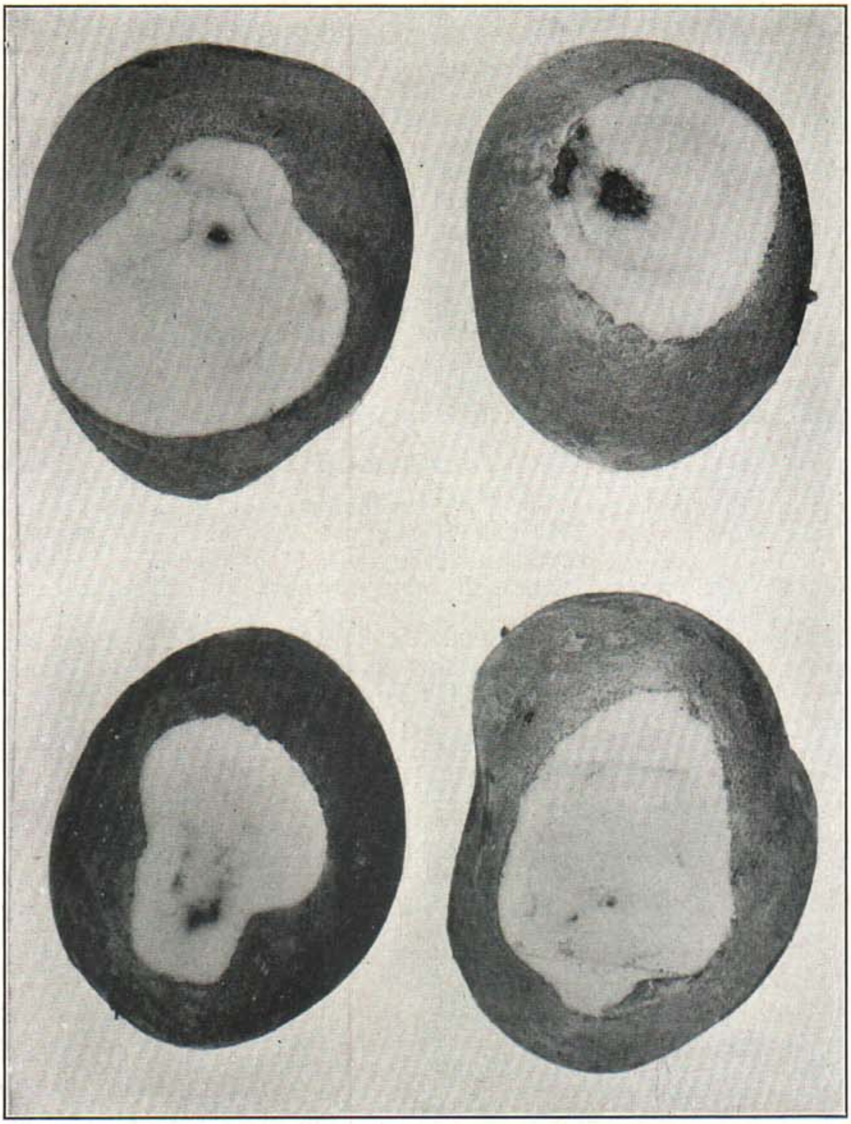

Fig. 5. Tuber infection from early blight (Photo by J. E. Kotila).

blight occurs late in the season, many potato growers do not make serious attempts at control. Under favorable conditions, losses from early blight in Michigan may amount to 25 per cent of the crop. Decrease in green leaf area due to killing of the foliage results in reduction in size and numbers of tubers produced.

Signs of the Disease—Early blight primarily attacks the leaves, although in exceptional cases both stalks and tubers may be affected.

On the leaves the lesions appear at first as small, circular or oval, brown to black spots (Fig. 4). The lesions enlarge, usually on the older mature leaves first, and within the spots circular ridges appear in concentric circles, giving the characteristic target board marking. Similar smaller spots may be found on petioles and stems if weather conditions are favorable. On the tuber shallow, slightly sunken, somewhat circular spots with raised edges are formed. The fungus may also penetrate into the flesh of the tuber (Fig. 5).* Tuber lesions, usually overlooked in sorting, are of little importance except in affording entrance of various molds in storage.

Cause—Early blight is caused by the fungus *Alternaria solani* which lives from year to year on old, affected potato trash in the soil or on solanaceous weeds. The club-shaped spores of the fungus in the soil are splashed or blown to the potato leaves where they germinate, penetrate and produce the typical diseased spots. Spores are produced by the fungus in the lesion and scattered to other plants, thus increasing infection. When spores are washed to the tubers, under moist soil conditions, infection may result.

Control—Timely and thorough spraying with bordeaux mixture will control early blight. Spraying, however, must be prolonged into September to protect the vines from severe infection.

RHIZOCTONIA OR BLACK SCURF

This is one of the most common and widespread potato diseases. It is present and severe under certain conditions in all the northern potato-producing states. Not only does it affect this crop but Rhizoc-

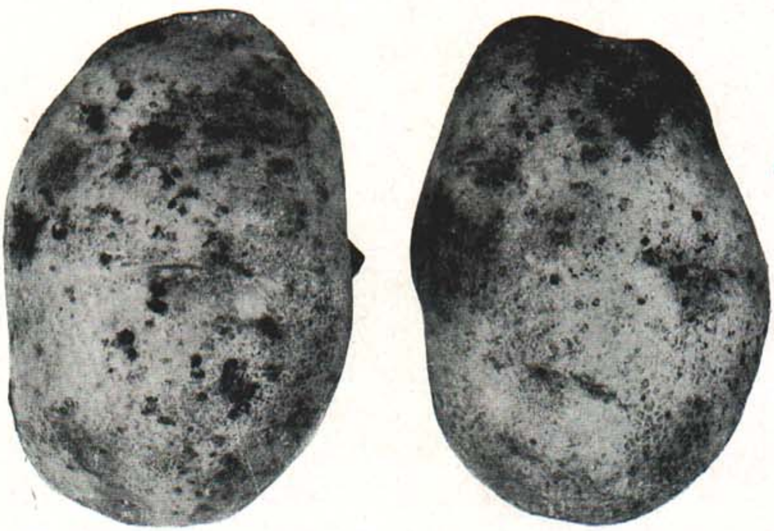

Fig. 6. Rhizoctonia or black scurf on tubers. Note the black lumps or sclerotia of the fungus on the surface of the tuber.

*Figures 5, 21, 23 and 43 were made from photographs taken by Dr. J. E. Kotila and in the files of the Section of Botany and Plant Pathology.

Fig. 7. Rotting of young shoots caused by Rhizoctonia. Note new shoots formed below the decayed portion.

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tonia also affects many vegetables and field crops, ornamental plants, and cuttings, as well as certain weeds. All commercial varieties of potatoes are susceptible, although in local areas some varieties are more severely damaged than others.

On potatoes the disease is usually more severe in the presence of abundant soil moisture whether in heavy soils or in those with sufficient humus to produce a good crop. Damage from Rhizoctonia is difficult to estimate. Actual loss is due to poor stands and yields brought about by the causal fungus causing decay of the stolons, sprouts, and mature stems. Indirect losses result from the production of the black scurfs or sclerotia on the tubers, resulting in rejection for certification in seed stock and lowered quality in table stock. Rhizoctonia appears to be more destructive in acid soils, although the disease is prevalent in those showing neutral or slightly alkaline reaction. It is safe to say that this fungus will thrive under those conditions favorable for the growth of the potato crop. The causal fungus can withstand prolonged drouth, and because of the many different plants which it infects and the fact that it lives for a long time in the soil, rotation is not entirely successful in reducing the disease under favorable conditions.

Signs of the Disease—On the tubers the most common and conspicuous symptom is the presence of numerous small black or brown irregular shaped bodies, the sclerotia or scurfs of the causal fungus (Fig. 6). These sclerotia are the resting bodies which serve to carry the fungus over winter. At digging time, on affected tubers the white cobwebby strands of the vegetative stage of the fungus may be seen. Light surface infection may result in a type of russeting or cracking of the tuber.

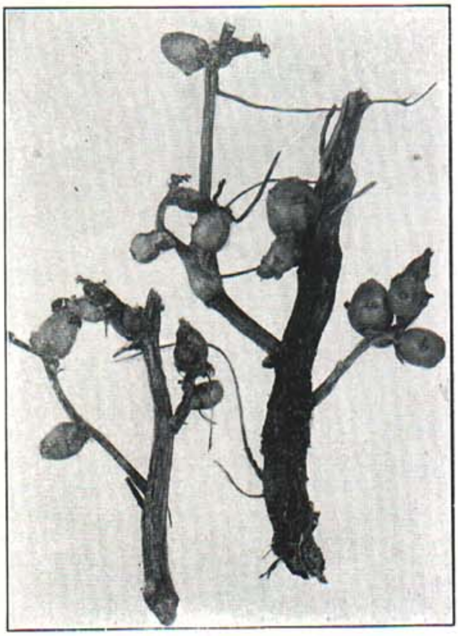


Fig. 8. Aerial tubers formed in axils of leaves as a result of Rhizoctonia stem cankers.

On young sprouts the disease is seen as reddish-brown cankers on one side of the shoot or completely girdling it. When moisture conditions are suitable the fungus threads from the sclerotia may advance upward along the stem of the plant, covering it with a white moldlike growth. This condition is not often seen but represents the fruiting or spore-bearing stage of the fungus, known as *Corticium vagum*.

Frequently the infected shoot decays, and another is produced from a bud on the healthy stump until it gives rise to two or more secondary shoots and the young plant breaks through the soil (Fig. 7). In other cases decay is so rapid that no shoots come to the surface, and missing hills result. Cankers on the shoots often cause the development of spindly plants. Affected stolons give rise to small tubers. Infection may penetrate from the stolon into the stem end of the tuber, forming a black dry decay. When the base of a large stem is infected, the movement of food material is interrupted and green, leafy, swollen buds called "aerial tubers" are formed in the axils of the leaves (Fig. 8). Other types of wounding may also result in aerial tubers so this is not always a characteristic sign of the disease. Yellowing, bunching, and pinching of the top leaves give rise to the rosetting effect seen on large plants with cankers at the base of the stem.

Cause—Rhizoctonia or black scurf is caused by the fungus, *Rhizoctonia solani,* the spore-bearing stage of which is known as *Corticium vagum.* The Rhizoctonia stage of the fungus consisting of sterile mycelium is most frequently noticed. When infected tubers are planted, mold-like strands develop from the sclerotia or scurfs and find their way to shoots, stolens, and soil surrounding the tubers. As the potato matures, the fungus threads reach the tubers and by intertwining, form white masses on the surface. Later these masses turn brown or black and become more compact, forming the sclerotia or scurfs. The sclerotia vary greatly in height, diameter, and compactness, depending upon length of favorable growth conditions for the fungus. Sclerotia, which at maturity of the crop are small and superficial, may be much enlarged in size and increased in number if the tubers are allowed to remain in the soil. It appears that the fungus when growing in the soil produces infection of plants and tubers less rapidly than when it develops from sclerotia on the infected seed piece.

Control—Because this fungus lives for prolonged periods in the soil and over-winters as sclerotia or scurfs on the seed tuber, both facts must be kept in mind in practicing control measures. Many times adequate seed treatment measures have failed to control the disease because planting was made in an infected field.

Seed treatment, however, will reduce the amount of infection by Rhizoctonia as well as that caused by the scab and blackleg parasites, and is therefore advisable even when planting is made in an infested soil. Some difference of opinion exists among growers and investigators in the various states as to the most efficient treating material for the control of this disease. This is largely due to the size and compactness of the sclerotia or scurfs, which depend upon moisture and temperature conditions. Most workers agree that cold formaldehyde is not effective and that the mercurials will give control of the disease. Under the usual Michigan condition, soaking 30 minutes in standard corrosive sublimate solution will give satisfactory commercial control. Where it is necessary to use for seed purposes tubers with thick compact sclerotia, extending the time to 1 or 1½ hours in the above solution or using the acidulated corrosive sublimate solution is more effective than the 30-minute soak in the standard solution. Under ordinary conditions the use of organic mercury dips also has proved effective.

Green-sprouting to insure rapid growth and hardening of the shoots also contributes to the prevention of infection. In heavy soils planting in furrows at the usual depth followed by successive shallow coverings allows the shoots to harden and thus escape infection. This latter method is seldom used in Michigan because of the lighter soils on which the crop is grown. In general, any method that will insure rapid development and hardening of the young plants and the killing of the fungus on the tuber will aid materially in control of the disease.

If the crop is grown on infested soil it is good practice to dig as soon as the tubers are mature. Allowing the tubers to remain in the ground for a prolonged period after maturity often results in increase of tuber infection with Rhizoctonia. This is particularly true of the Irish Cobbler and Chippewa varieties.

COMMON SCAB

Common scab is widely distributed over the state and occurs on all commercial varieties of potatoes. Although all varieties are susceptible to scab attack, under ordinary conditions the white-skinned sorts show more severe infection than the russet varieties. Early-planted crops usually show more severe scab infection than the same variety planted later, due to the influence of high temperature, low soil moisture, and other factors affecting scab development during the production of tubers.

Fig. 9. Potato scab.

The extent of losses due to potato scab is not fully realized by many growers. The disease may cause a direct reduction in yield due to production of smaller tubers or to rotting of scabby tubers through invasion of secondary soil organisms. This frequently occurs when there is a period of heavy precipitation after the tubers are mature. Indirectly, losses result because badly scabbed potatoes are unmarketable for human food. Although the presence of scab spots does not render a potato unfit for food, the scabby appearance of the tuber makes it a cull under the

Fig. 10. Deep scab following mite, wire worm, or insect larvae injury.

grading law. Such tubers are often fed to livestock on the farm. Moderately and slightly scabbed tubers bring a lower price than clean stock.

Signs of the Disease—Common scab affects only the growing tubers. Scab infection is first noted as one or more small reddish-brown, slightly raised spots on the surface of the tuber. These enlarge under favorable growth conditions and often run together until in severe cases the whole tuber surface may represent a solid scab spot (Fig. 9). Usually the spots are smaller in size and scattered over the surface of the tuber. When infection takes place on young tubers, slight cracking or russeting may result. Infection is known to follow the feeding tracks of the flea beetle.

Usually the scab spot extends inwardly only a few cells in depth. The scab lesion, however, may be invaded by certain mites, wire worms and insect larvae causing the formation of deeper pits. These tissues also are infected by the parasite causing the development of deep scab (Fig. 10).

Cause—Scab is caused principally by the organism *Actinomyces scabies,* although some investigators report other species of this genus as being able to cause the disease.

Some species of this genus cause animal diseases, while others live as saprophytes in the soil or are parasitic upon plants other than the potato. The common scab organism is known to live for long periods in the soil in the absence of the potato crop. It is able to withstand extremes of temperature and moisture but appears to develop most abundantly at fairly high soil temperatures and low soil moisture. The organism is seen on freshly dug scabby tubers as a grayish-white mold-like growth. This disappears on exposure to drying. Feeding raw, scabby tubers to farm animals does not kill the organism; it passes through the alimentary tracts of the animals and may be carried to uninfested soil in the manure. Acid soil conditions generally are unfavorable for the growth of the organism, while alkaline conditions cause it to develop in abundance.

Control—That the scab parasite is able to live for long periods in many soils and that it is also present in the scab spots or carried unseen on the surface of the tuber must be taken into account in de-

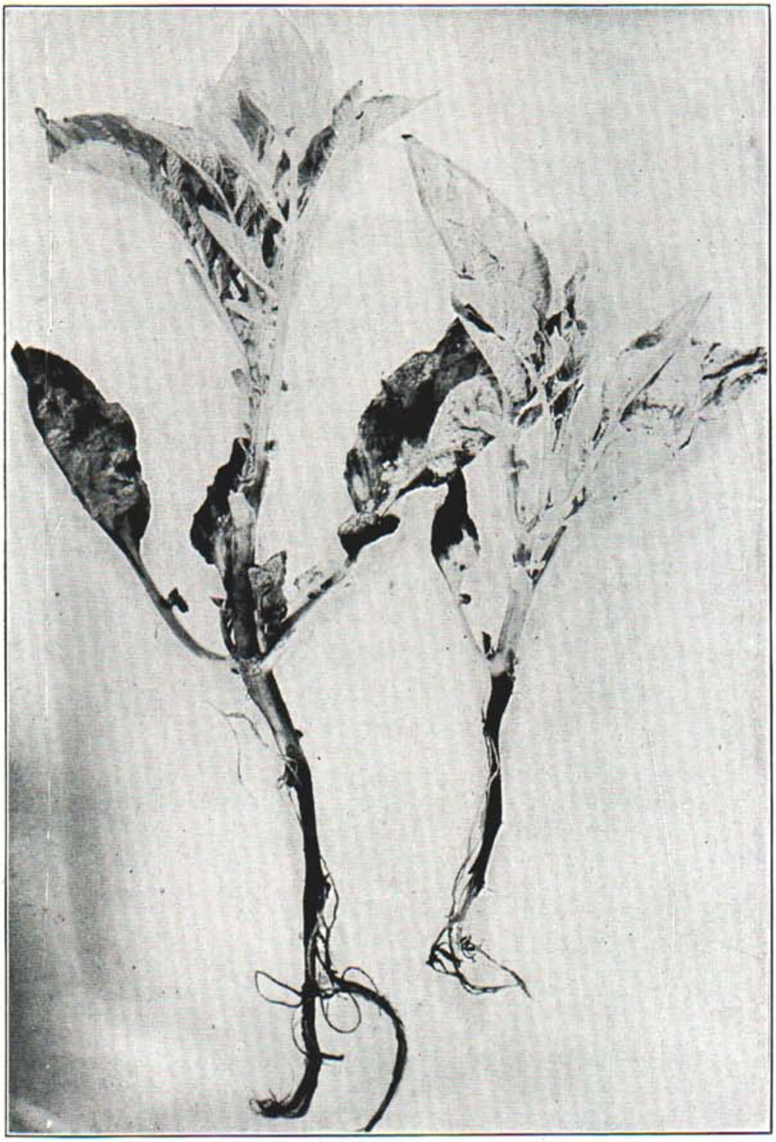


Fig. 11. Blackleg cankers on young plants causing rotting of the stems.

veloping control measures. Since growth of the organism in culture is usually inhibited at soil acidities of pH 5-5.2 selection of fields showing an acid reaction usually will be beneficial in reducing the disease. Tuber treatment to kill the organism in the scab spots and on the surface will reduce the source of infection. Applications of fresh manure should not be made just before plowing for potatoes because such a procedure seems to stimulate scab development. Likewise, liming the soil or applications of wood ashes and nitrate of soda tend to bring about an alkaline soil condition favoring scab growth. These applications should not be made unless other chemicals are added as a counteractive. In some states applications of sulphur are advised to increase soil acidity, thereby, creating a soil condition unfavorable for scab development. Tests with sulphur in this state over a period of five years have failed to reduce scab consistently under conditions of heavy soil infection. Such a soil treatment is also relatively expensive. On moderately infected soils, sulphur at 400 to 600 pounds per acre has reduced scab on small areas. The use of mercury compounds applied to the soil, mixed with the fertilizer or alone has also been advocated in certain potato growing areas. In six years' tests mercurial soil treatments not only did not reduce scab infection but increased the percentage of scabby tubers and in some cases caused a reduction in total yield. Efforts are being made to find a seedling or other variety of potatoes resistant to this disease. Some headway has been made, but scab-resistant varieties are not available commercially. Control measures may be summarized as follows:

(a) Treat the seed to kill the organism in the scab spots and on the surface of the tubers.

(b) Where possible, plant in soil showing acid reaction.

(c) On moderately infected soils applications of sulphur at the rate of 400 to 600 pounds per acre may reduce scab infection.

(d) Do not apply lime, wood ashes, or fresh manure just before planting.

(e) Rotate the potato crop to prevent establishment of the scab parasite in the soil.

BLACKLEG

This disease is found throughout the state each year. In certain regions or in individual fields losses may be severe, involving up to 25 per cent of the crop in isolated cases. Blackleg is not confined to table stock but also occurs in fields grown for certification. Elimination often is difficult when this disease has become entrenched in a seed stock. All commercial varieties are susceptible, although the Irish Cobbler appears to be more severely affected than either Green Mountain or Russet Rural. Severe attacks, however, have been observed on the two latter varieties. This disease not only attacks the vines but also causes serious rotting of the tubers especially in storage.

Signs of the Disease—On young plants the disease is first evident as a gradual yellowing of the normally green foliage, finally affecting all the leaves. Leaves of infected plants roll upward, and the branches growing upward at a sharp angle produce a bunching of the top. At the base of the stem the black lesions of the disease may be found

(Fig. 11). This blackening and decay may extend upward on the stem for some distance and downward through the stolons into the developing tubers. Black depressed decayed areas result from stem end tuber infection (Fig. 12). In some instances the outward blackened area may be small, while the whole interior of the tuber is turned into a slimy mass by the infecting bacteria.

Fig. 12. Typical blackening of flesh caused by blackleg tuber rot.

Older plants under moist conditions often fall over because of the black basal stem rot. The stem may appear water-soaked some distance above the blackening. Under dry conditions no outward blackening of the stem may be seen, but the pith may show blackening into the top of the plant. In such cases in the Russet Rural variety the stems become a deeper reddish purple in color, branches arise at a sharp angle, and the whole plant has a sprawling appearance similar to one showing evidence of the moron disease. Infected plants usually show rotting and blackening of the stem just below ground and are easily pulled.

Cause—Blackleg is caused by the bacterial organism *Bacillus atrosepticus*. The effects of the disease are due to separate causes. The infecting bacteria produce an enzyme, which causes destruction of the tissues of the tuber, and the blackening is due to a toxic substance. Blackleg bacteria usually do not over-winter in the soil but depend upon infected tubers for their perpetuation from year to year. Under certain conditions infected tubers may remain in the field over winter under a heavy snow cover and give rise to blackleg plants the following season. Under Minnesota conditions the seed corn maggot fly has been found to feed upon blackleg infected tubers and to lay contaminated eggs in the potato field. The maggots hatching from these eggs carry the blackleg bacteria to the seed pieces and thus spread infection.

Control—Elimination of all infected tubers in the seed stock and diseased plants in the seed plot will control the disease. Plant seed obtained from blackleg free fields. Careful sorting of tubers and seed treatment with either formaldehyde or corrosive sublimate will also greatly reduce infection in the field. Thorough roguing throughout the season in addition should eliminate practically all the remaining diseased plants. These measures practiced over a period of a few years will aid materially in producing blackleg free seed stock.

Blackleg is often more severe in seed stocks that have been chilled or otherwise injured by poor storage conditions. Care in handling the stored seed stock reduces this source of the disease.

BACTERIAL RING ROT

This disease, new to Michigan, was first suspected in 1939 and definitely proved to be in the state in 1940. All commercial varieties appear to be highly susceptible. At present the disease is confined to only a few fields but in one instance a heavy loss due to killing of the plants and decay of the tubers was reported.

Signs of the Disease—The disease is not readily noticed on the vines until about the time of blossoming or somewhat later. Affected plants show wilting of the foliage, at first without any yellowing. Later, the leaves may roll upward at the outer edges, turn yellow, wilt permanently and usually remain attached to the stem (Fig. 13). Wilting and yellowing begin on the lower leaves and proceed upward. Finally the entire stalk or plant is affected.

Infection of the tubers takes place at the stem and progresses apically through the vascular tissue. At first there is a slight yellowing of the tissue in the vascular ring (Fig. 14). Affected tissue often becomes brownish in appearance and breaks away, leaving an outer firm shell of tissue (Fig. 15). The skin of the tuber may turn reddish brown and crack. When soft rot bacteria invade the infected tubers, decay progresses rapidly.

Cause—Bacterial ring rot is caused by the organism *Aplanobacter sepedonicum.* Extensive tests in Maine have demonstrated that the

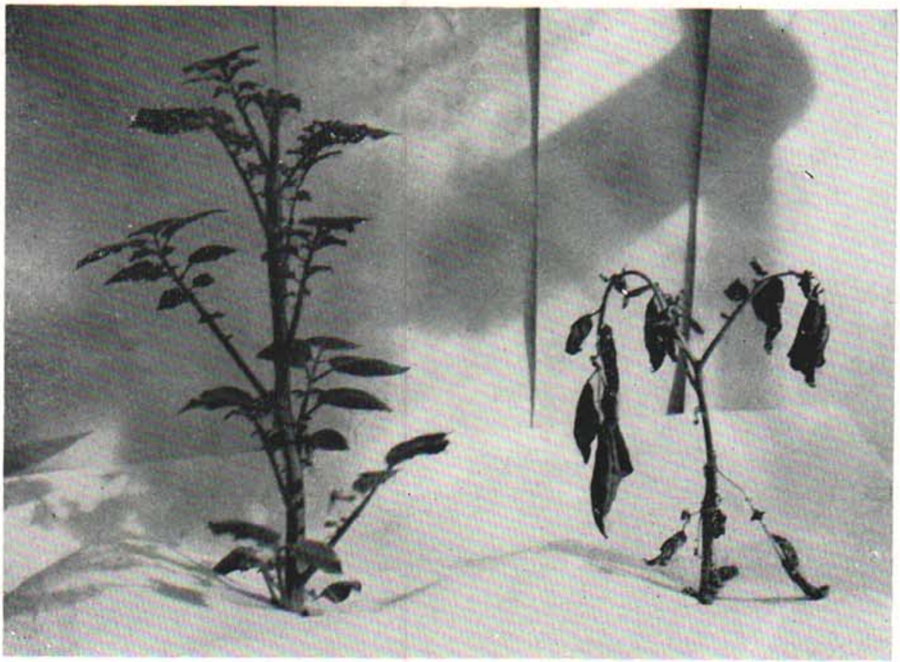


Fig. 13. Chippewa potato plant showing wilting symptoms. This type of wilting may appear on all or part of the plant. Note healthy plant on left.

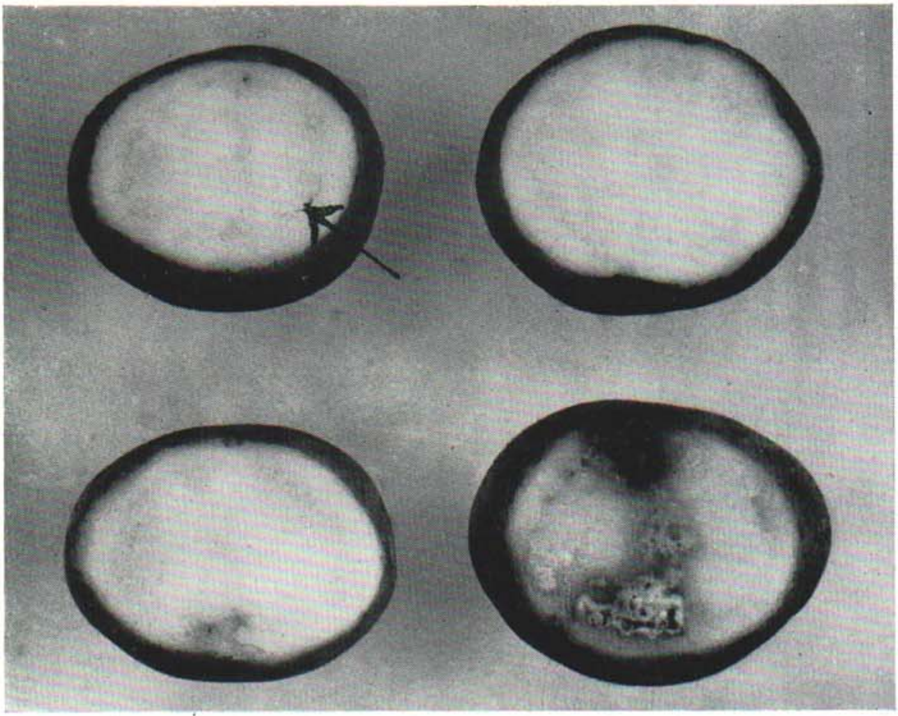


Fig. 14. Cut tubers showing very light infection shown by slight discoloration near vascular ring. The ring rot bacteria are spread on the cutting knife from such lightly infected tubers. Arrow indicates vascular ring.

causal bacteria do not live over in the soil. It is possible that the disease may over-winter in infected tubers under a heavy snow blanket and appear in volunteer plants the following season.

Control—Use of seed free from ring rot is the only means of controlling this disease. Because of delayed symptoms on infected plants in the field and their possible confusion with drouth damage and certain other diseases late in the season, it is impossible to detect all the plants affected with ring rot. It has been impossible to eradicate bacterial ring rot by roguing out diseased plants. It is known that the causal bacteria are spread on the cutting knife, by tines of the picker planter, on the grader and potato digger, on crates, bags and on the hands when cutting infected tubers. Cutting knives may be disinfected in a 1-10 solution of formalin or 1-500 solution of corrosive sublimate. Several knives should be used and the knife should be placed in the disinfecting solution after a few cuts. Use of small whole tubers is even safer for then the disease will be confined to a single plant.

The potato grader, digger, and planter should be sprayed or washed with a solution of formalin, 1 pint in 5 gallons of water, if infected potatoes have been run over them. Crates and bags contaminated with ring rot bacteria should be dipped in this solution before being used

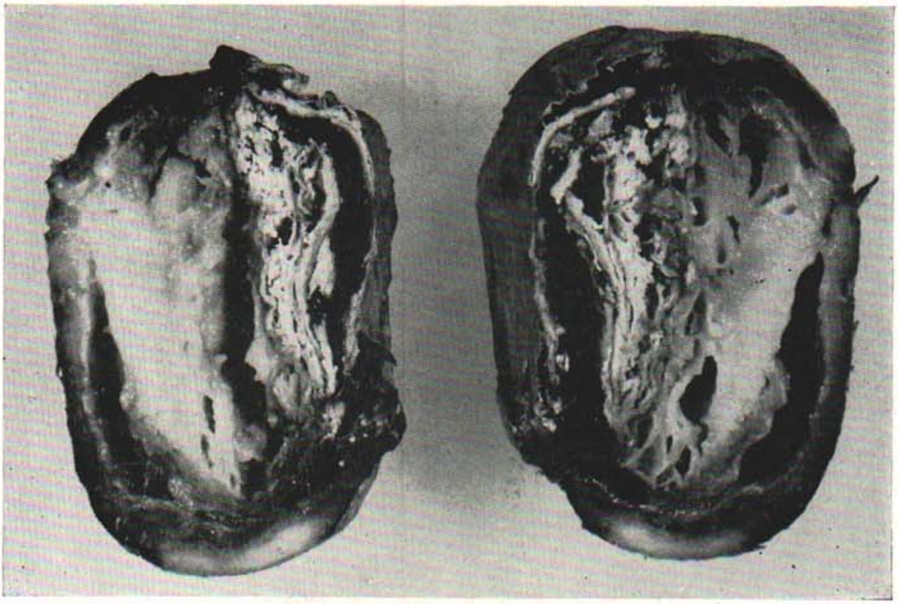


Fig. 15. Internal tuber decay following severe ring rot infection.

for clean potatoes. The storage should be swept clean and sprayed with copper sulphate solution 1 pound in 10 gallons of water.

Fields showing bacterial ring rot are not safe as sources of seed and should be sold for tablestock after careful sorting.

FUSARIUM WILT

This disease occurs in all the principal potato producing areas of the United States. In Michigan it is more prevalent in the Lower Peninsula, but it is also found but in less amounts in the potato fields of the Upper Peninsula. Hot dry seasons favor the development of the causal organism. All commercial varieties are susceptible.

Signs of the Disease—Affected plants usually are more spindling than normal ones and the foliage turns yellow. This is followed by wilting of the leaves and drooping of the branches. Later the vine turns brown and dies, the stems usually remaining erect (Fig. 16). Lower leaves first show the effects of the wilt, which progresses upward involving the foliage of the entire plant. Yellowing of the basal leaves often results during extremely hot weather due to heat reflected from the soil surface and should not be confused with wilt. If the stem of a wilt-infected plant is split lengthwise, the characteristic brown discoloration of the water-conducting tissue is readily seen.

Tubers from wilted plants also show the brown ring of tissue at the stem end, showing the effects of the causal fungus on the vascular tissue (Fig. 17). In case of light attack of the disease or when infection takes place late in the season, infected tubers may fail to show

Fig. 16. Plant killed by Fusarium Wilt. Note the dead plant remains erect.

the typical brown ring at the stem end. For this reason all infected tubers cannot be sorted out of a seed stock after clipping the stem end. When the plant is attacked severely many of the tubers will show a pointed or knob-like growth at the stem end, typical of Fusarium wilt.

Cause—This disease is caused by the fungus *Fusarium oxysporum*. When infected tubers are planted, the fungus progresses through the

Fig. 17. Wilt-infected tubers showing browning of the vascular tissue at the stem end.

seed piece, invading the base of the young shoot. The parasite then grows with the developing plant, invading the stems and branches. From the plant stem the fungus passes down the stolons into the stem end of the tuber.

Certain soils naturally harbor the wilt fungus, while in other instances they become infested with the parasite after growing a crop of potatoes badly affected by the disease. The wilt can live for long periods in the soil in the absence of potato plants. In some instances the wilt fungus in infested soil is known to attack the cut seed piece, thus producing the disease in the resulting crop. More often, however, the fungus is carried to the field in infected tubers used for seed.

Control—Control of Fusarium wilt must take into account the use of clean tubers planted on clean soil. Bin selection of seed and clipping of the stem end will not eliminate all wilt-infected tubers. Hill selection, if done before the plants begin to yellow because of age, is of some benefit. The use of clean seed such as that from certified growers or from a seed plot where thorough, careful roguing of wilt-diseased plants has been practiced throughout the season and planting on clean soil will hold the Fusarium wilt to a minimum.

VERTICILLIUM WILT

This disease has been seen a few times in Michigan. Although it is of considerable importance in certain other states, the disease is of little economic importance here.

Signs of the disease are practically indistinguishable from those due to the Fusarium wilt. The causal fungus is *Verticillium albo-atrum*, which has practically the same developmental cycle as the Fusarium wilt parasite. Control measures for the two diseases are identical.

ARMILLARIA TUBER ROT

This disease occurs frequently enough to be of considerable interest to the grower but is of little economic importance in the state. Losses in individual fields may be very heavy, but the disease is confined to plantings on newly cleared land. The causal fungus, *Armillaria mellea* or honey mushroom, is known to affect the roots of many forest trees and also fruit trees following clearing.

The threads of the fungus grow through the soil and attack potato tubers in their path. Dry-rotting of the tuber results. The disease is readily recognized by the brownish fungous threads that grow over the surface and into the flesh from which the parasite draws its food (Fig. 18). From the brownish strands or rhizomorphs, the honey-colored mushroom clusters arise in the fall.

SILVER SCURF

This is one of the minor diseases of potatoes widespread in occurrence but of little economic importance. It has been observed on all the commercial varieties grown in the state.

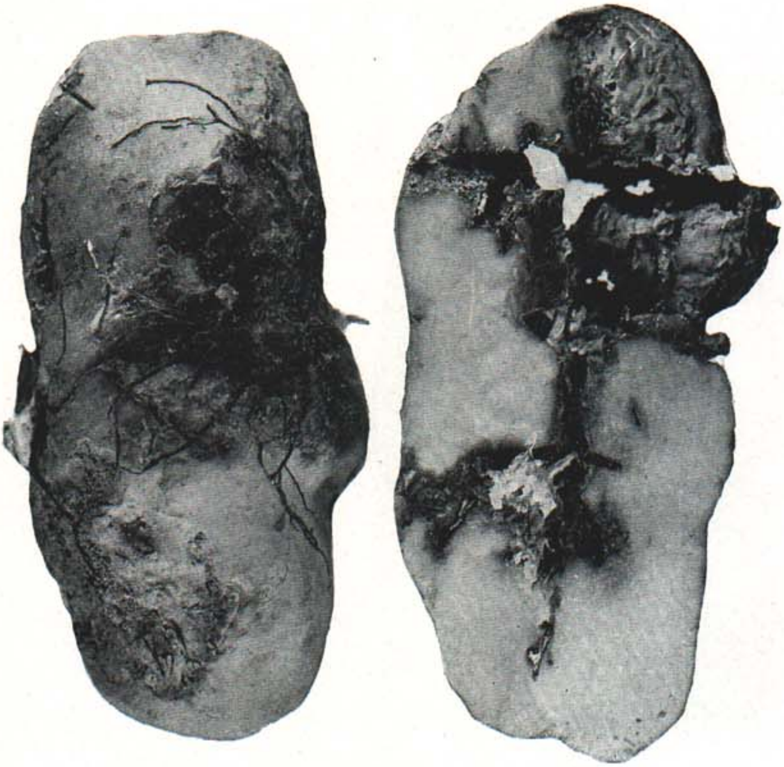


Fig. 18. Rotting of tuber caused by Armillaria mellea. Note brown fungus threads on tuber surface.

Signs of the Disease—Silver scurf as the name suggests is evidenced as lead-colored to silvery patches on the skin of the tuber. These areas are more evident when the tuber is wet and usually have a slightly glossy appearance as contrasted with the duller surface of the normal skin. In severe attacks, affected tissues are more leathery and the infected area is slightly sunken. After prolonged storage under warm moist conditions, the affected areas become black and the small black sclerotia appear in the diseased spots.

Cause—Silver scurf is caused by the fungus *Spondylocladium atrovirens.* Spores of the fungus are borne on short stalks arising from the infected patches on the tuber. In storage these may be carried to healthy potatoes, and under favorable conditions the affected areas become black and the small black sclerotia appear in the diseased spots.

Control—Little is known concerning control, but the disease is rarely found to any extent in high quality seed stock. Sorting out of noticeably infected tubers, seed treatment with corrosive sublimate, and crop rotation should hold the disease in check.

STORAGE DRY ROTS

Rotting of potatoes often takes place in storage in years when late blight has not occurred in the state and when the crop in local areas was not seriously affected by blackleg. Severe losses may result from dry rot in storage or transit.

Fig. 19. Typical Fusarium dry-rot of tuber.

Signs of the Disease—These rots are evident upon the surface of or within the infected tubers as a firm cheesy type of decay. Rotting begins at the stem end, causing sunken, wrinkled, darkened areas on the tuber. In some cases there is only slight external evidence of almost complete inner decay. The rot-producing fungus growing from within the tissue comes to the surface as white, pink, or darker-colored tufts of mold-like growth depending upon the species of Fusarium primarily concerned (Fig. 19).

The interior affected tissue also varies in color from light to dark brown or black (Fig. 20). Cavities lined with the fungous growth may appear within the infected tubers. The consistency of the affected flesh of the tuber may be dry and almost powdery, cheesy, or wet and jelly-like, depending upon the percentage of moisture present and the type of associated rot-producing organism which invades the infected tissue.

Cause—The most commonly found dry rot in Michigan is caused by the fungus *Fusarium trichothecioides,* although *F. radicicola, F. eumartii,* and *F. oxysporum* also may be present alone or in combination as the causative agent. The fungus *F. trichothecioides* is typically a dry rot producer and does not affect the potato plant in the field as do the other species mentioned. Entrance to the tuber takes place through wounds, principally mechanical injuries in harvesting, sorting, and storing. Decay in storage is more rapid at relatively high temperature and with abundant moisture.

Control—Since the dry rot fungus is a wound parasite any practice which reduces injury to the tubers will be of considerable benefit. Digging the crop when tubers are mature and less likely to skin or bruise will reduce injuries. Sorting out bruised, skinned or crushed tubers in sorting or loading in cars is also recommended. Proper storage conditions will reduce infection, but dry rot cannot be prevented by good storage conditions alone; care in handling also is necessary.

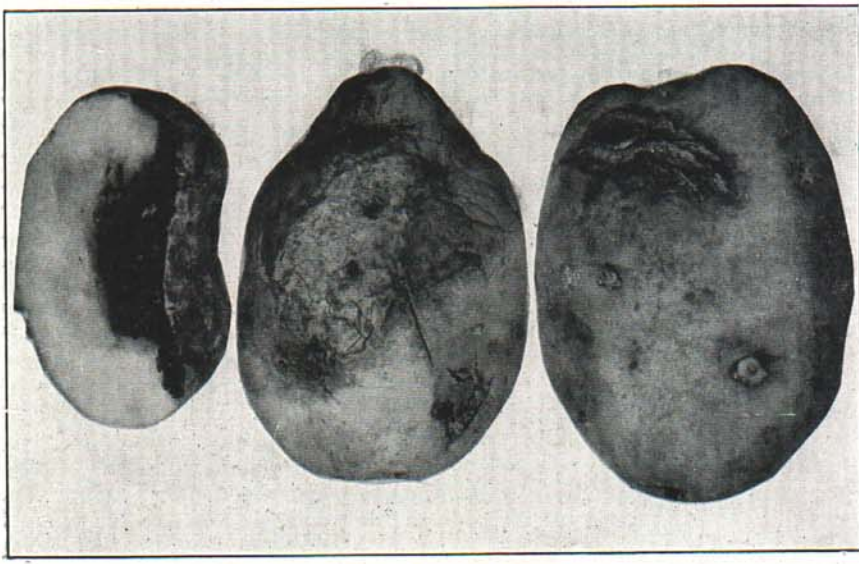
Virus or Degeneration Diseases

Running-out or deterioration of potato seed stock is due largely to degeneration or virus diseases. These diseases are infectious and may be transmitted by means of sap from diseased to healthy plants. The diseases are carried over from year to year within the affected tubers. Certain common potato insects such as potato aphids and leaf hoppers are mainly responsible for the spread of virus diseases in the field.

As the name indicates, these diseases as a class affect the plant in such a way that it becomes less productive as the progeny of affected plants are used for seed. Dwarfing of the whole plant, stunting, wrinkling, rolling, and mottling of the foliage; elongation, cracking, internal discoloration, and reduction in size or number of the tubers, often are characteristic effects of the virus diseases alone or in combination.

In this group of diseases are found the various types of mosaic, leaf roll, spindle tuber, spindling sprout, yellow dwarf, streak, calico, curly dwarf, and unmottled curly dwarf. Further investigations may add giant hill, moron, witches' broom, and other troubles at present only little understood.

The potato plant may be affected by only one or a combination of these diseases, in which case the symptoms of the disease are altered. Age of plant, variety, and conditions under which the potato is grown exert a marked effect upon the symptoms of the virus diseases. Mosaic, readily seen under cool, cloudy conditions becomes masked at high temperatures. Yellow dwarf is far less conspicuous on the plant when infection takes place late in the season or when infected plants are grown under cool, cloudy conditions. Thus it is seen that detection



$6.50

Fig. 20. Fusarium rot following wounds.

of symptoms of the virus diseases is not always an easy matter. By continued practice, however, proficiency can be attained to such a degree that these diseases can be reduced to a minimum.

Because of the differences in character of growth, leaf color, size, and shape due to varieties and to conditions of fertility, moisture and temperature under which the plants are grown, a complete description of symptoms of the virus diseases under all these conditions is impossible. Typical symptoms of the diseases, however, as they occur alone under average conditions will be given as an aid to their determination. Virus diseases are best studied on the living plant in the field where with a quantity of affected plants, variations in symptoms of each disease may be observed and thus a composite picture of symptoms can be obtained.

MOSAIC

The term mosaic as applied to potato degeneration troubles, is not descriptive of a single disease but embraces symptoms of several disorders (Fig. 21). In general, mosaic may be separated into four specific diseases, namely, crinkle mosaic, rugose mosaic, leaf-rolling mosaic, and mild mosaic. These may occur in combination under field conditions but when alone present distinct symptoms on the affected plants. Symptoms vary somewhat, however, with the variety affected, and close observation is necessary to recognize clearly the different types of mosaic on several varieties.

Mild Mosaic—As the name indicates, this type is evidenced by faint mottling either as yellowish spots or diffuse irregular blotches. Slight ruffling or wrinkling of the surface of the leaf may be present, usually not pronounced, in Russet Rural, especially under moderate temperature. Dwarfing may or may not be present and usually is not pronounced. At high temperature, symptoms are masked. Mild mosaic is often prevalent in the Upper Peninsula, especially on the Green Mountain variety.

Leaf-rolling Mosaic—This type of mosaic combines mottling with upward rolling of the margins of the upper or younger leaves. Lack of brittleness in the rolled leaves aids in distinguishing leaf-rolling mosaic from leaf roll. Usually the mottling is mild in character, and the leaves are somewhat dwarfed in size. The entire plant may show stunting. Masking of symptoms to some extent takes place at high temperatures. Necrosis, or death of tissues with accompanying browning in streaks or spots, is not present.

Rugose Mosaic—In this type of mosaic there is a distinct wrinkling and dwarfing of the foliage with or without necrosis. In the absence of necrosis or dying of the stem tissues, the leaves appear mottled and wrinkled with usually a distinct downward rolling of the leaf margins and the entire leaflet. Brown streaks often appear on the stems, petioles, and veins of the leaves which become brittle and drop. Tuber production is greatly reduced and in severe cases may be absent. This type of mosaic is apparent at high temperatures.

Crinkle Mosaic—Symptoms of this type of mosaic consist of distinct mottling of the foliage which later shows wrinkling or ruffling.

The leaflets are dwarfed, and the entire plant appears stunted. Rolling of the leaves to some extent may be present. Affected plants do not show necrosis. Crinkle mosaic symptoms are not apparent at high temperatures.

Cause—The causative agent of potato mosaic has not been found. It is present, however, in the sap of diseased tubers and in the plants

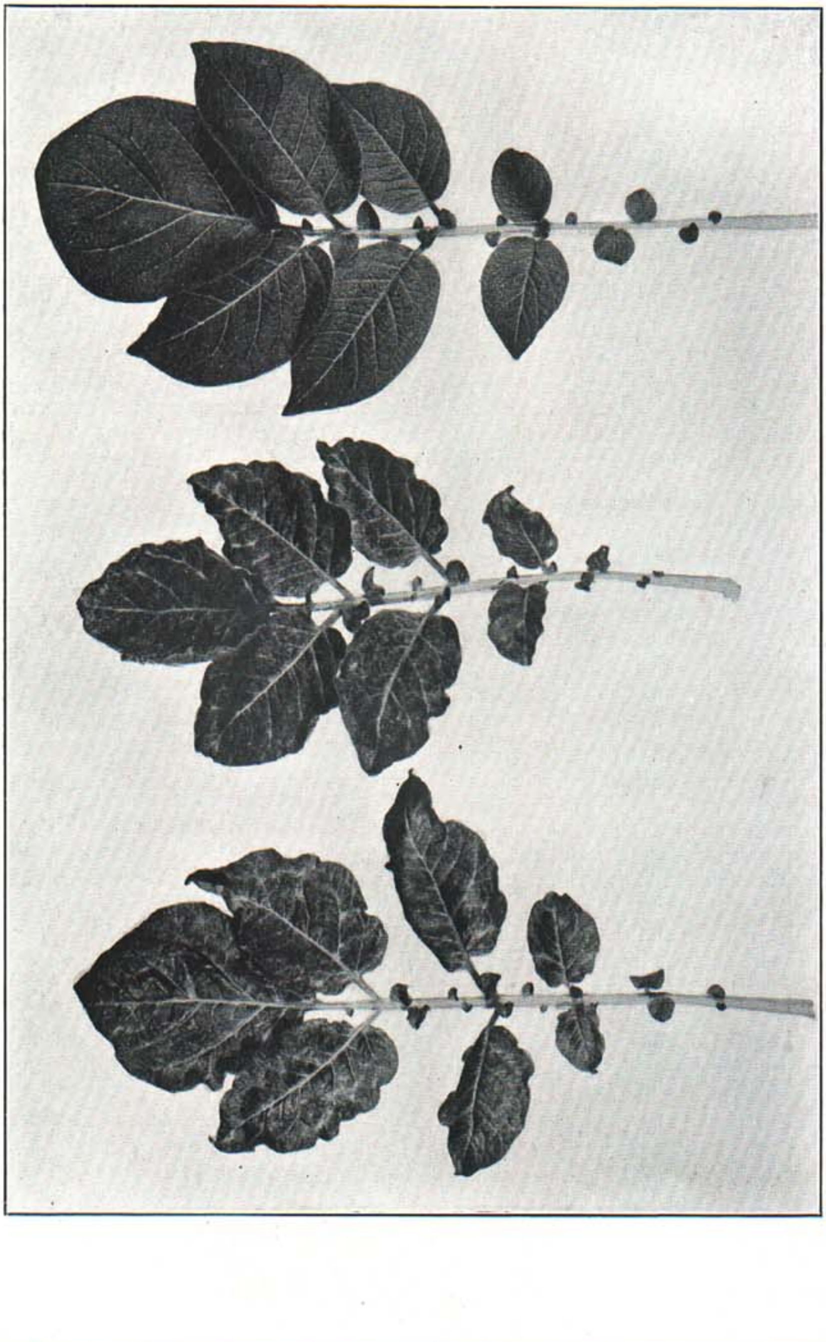


Fig. 21. At left, leaf with mild mosaic; center, rugose mosaic and healthy leaf at right. (Photo by J. E. Kotila.)

arising from such seed pieces. Mosaic is transmitted from diseased to healthy plants by stem grafts, tuber grafts, juice inoculations by leaf mutilation and especially by means of aphids. The rugose type of mosaic is more easily transmitted than either mild, leaf-rolling, or crinkle mosaic.

Control—Control of these diseases lies in planting clean stock and keeping the seed plot free from mosaics by means of careful roguing and spraying to prevent insect transmission. Roguing should begin when the plants first show disease symptoms and be continued throughout the season. Better results are obtained if roguing is done just before spray applications, rather than afterwards. Application of bordeaux mixture before roguing often hides the symptoms of the disease on the leaves.

LEAF ROLL

This disease is one of the most important, if not the most serious of the degeneration diseases of potato. Losses vary considerably, depending upon the quality of planting stock used, but in certain fields it is not uncommon to find 25 per cent of the plants affected. Yields are reduced because of fewer and smaller tubers produced on affected hills. In Michigan the disease has been noted as affecting all our commercial varieties. The Green Mountain appears to be less affected than certain other varieties, while the Russet Rural is susceptible.

Signs of the Disease—Although rolling of the leaves is not peculiar to plants affected with the leaf roll disease, this character is usually in evidence. In this disease the leaves roll upward at the margin and parallel to the midvein, producing a spoon-shaped effect. Usually rolling is first conspicuous on the lower leaves which become thickened, leathery in texture, and brittle so that they crack when folded crosswise (Fig. 22). Rolling may also be seen only in the upper leaves when infection takes place late in the growth of the plant. Dwarfing of affected plants usually accompanies the rolling of the leaves and the leaf stalks take on an upright habit of growth. Affected leaves may be light green to yellowish in color or take on a reddish-purple tinge, especially on the under surface in certain varieties. The leaf rolling in this disease is not to be confused with that found in blackleg, Rhizoctonia or Fusarium wilt. In blackleg the yellowing and rolling usually is apparent over the entire plant, and in addition the internal or external lesions are distinctive. Leaf roll affecting only the upper leaves is similar in the early stage to rosetting caused by Rhizoctonia infection. Here again the presence of the fungous lesions on lower portions of the stem readily separates the two. Brittleness in the leaves in the latter diseases is not definite as in leaf roll. Necrosis or death of the phloem cells of the affected stems may result. This effect is known as phloem-necrosis but is not readily seen except by microscopic examination.

Leaf roll plants typically produce under-sized tubers borne on short stolons appressed to the stem. Affected tubers have a tendency to be hard and brittle and to show delayed sprouting. In some cases a fine network of black dead cells permeates the tuber, although this is not

Fig. 22. Upper plant, early stage of leaf roll showing pronounced rolling of lower leaves; lower plant showing tip leaves erect and lower leaves rolled in later stage of infection.

always a reliable symptom since it is also noted in tubers affected by chilling.

Cause—As with the other virus diseases, no causal organism has been demonstrated for leaf roll. There is abundant evidence that the causal factor is carried over winter in the sap of affected tubers and from here is transferred to the above ground plant parts. The disease is transmitted from leaf roll to healthy plants by aphids and the potato leaf-hopper which extract infected sap from the former and, in the process of feeding, inject it into the latter.

Control—Leaf roll may be virtually eliminated by using for seed, tubers known to be free from the disease the previous year and preventing transmission of the disease by the control of aphids and leaf-hopper. Leaf roll spreads relatively slowly from row to row, and with the use of high quality seed and thorough, timely spraying, and removal of diseased plants, little loss will result.

SPINDLE TUBER

Spindle tuber is one of the very common virus troubles in Michigan. Because the symptoms on the foliage may be inconspicuous, especially in late season infection, many growers fail to recognize the disease. The characteristic elongation of the tuber due to infection is often laid to weather or soil condition by those who do not recognize the disease. Losses from spindle tuber are due to decrease in yield and lowered quality because of poor tuber shape. Spindle tuber increases rapidly in the field and in a short time may render the seed stock unfit for planting. Roguing is effective in eradicating the disease, but such measures may not be practical because of the resulting loss in yield. Individual table stock fields showing 10 per cent or more infected plants are not uncommon.

Fig. 23. Spindle tuber on Irish Cobbler potato. Note upright growth with leaflets rising at a sharp angle from the stem. (Photo by J. E. Kotila.)

Signs of the Disease—Spindle tuber affects both tubers and above ground parts of the plant where infected stock is planted (Fig. 23). If infection takes place during the growing season, however, evidence of the disease may be apparent only after the tubers are dug. With late infection, signs of the disease on the tubers may be entirely absent. Such tubers, however, will produce diseased plants if used for seed stock. The disease is more apparent on varieties which normally produce round or short oblong tubers, while in those producing long tubers it may escape notice until extreme elongation. Affected tubers become more cylindrical with tapering ends, not to be confused with the effects of Fusarium wilt. No browning of the vascular elements of the stem end results as in the latter disease.

The eyes of affected tubers are more numerous and shallower than normal and may even protrude slightly in severe cases. The skin of light colored varieties may become yellowish, while in red-skinned varieties the color fades or becomes blotched with lighter shades. Sprouting of infected tubers is considerably delayed, and sprouts tend to become "spindly". The vine growth is more upright than normal, with the darker green leaflets arising at a sharp angle from the stem. The leaves with wavy margins tend to brittleness and roll upward from the midrib, similar to leaf roll. The leaflets also become more narrow and smaller, with those at the apex of the stem twisted so that the edge of the leaf is upward.

Cause—Spindle tuber has been proved to be a virus disease, and like others of this group, the causal agent is unknown. The virus is transmitted by means of insects, principally aphids, by leaf mutilation, tuber and stem grafts, and the cutting knife. Spread of the disease in the field is known to take place by means of aphids, flea beetles, leaf beetles, tarnished plant bug, grasshoppers, and larvae of the Colorado potato beetle.

Control—Control measures call for planting high quality seed stock, roguing diseased plants in the seed plot, and discarding elongated off-type tubers where the seed is selected for cutting. A thorough spraying program for insect control is essential, at least for the seed plot.

YELLOW DWARF

Outbreaks of yellow dwarf in Michigan first came to the attention of investigators and growers of potatoes in 1927. Former inspectors in the potato certification, however, recall having seen similarly affected plants as early as 1922 scattered in fields in northern Michigan. The disease increased in severity, reaching its height in 1932 when many acres of potatoes were rendered unfit for seed purposes because of its presence. The greatest losses have been suffered during seasons of high temperature by crops grown on light sandy soil. The disease, however, is not confined to the crop grown on any particular type of soil. High temperature during the growing season favors the expression of yellow dwarf symptoms on the potato plant. All the commercial varieties in the state are susceptible. Losses of 10 to 75 per cent of the crop in certain areas have been observed. Yellow dwarf is the most serious virus disease that growers have had to deal with in recent years.

Signs of the Disease—Typical symptoms of the disease are seen on plants grown from infected seed. These manifestations are regarded as secondary symptoms. Primary symptoms result from infection of healthy plants in the field and are much less conspicuous and more difficult to recognize.

Fig. 24. Yellow dwarf-infected plant showing apical leaves and axillary buds dying.

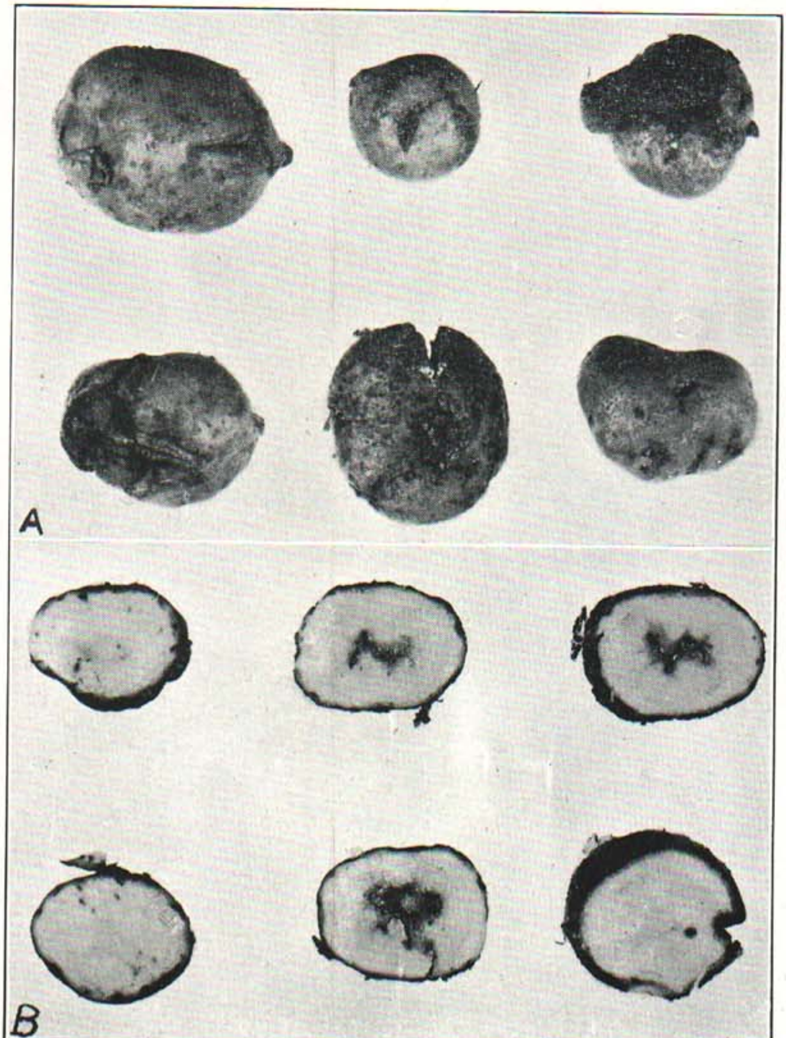


Fig. 25. A. Cracked mis-shapen, yellow dwarf infected tubers.
B. Typical flecks and internal breakdown of tubers in A.

When infected tubers are planted under conditions of high temperature the resulting plants are dwarfed and with small darker green, leathery, curled leaves. Many such plants reach a height of not more than 4 to 8 inches. Gradually the green color of the foliage fades to gray-green, then yellow and finally turns brown, and the plant dies. This is the most severe form of the disease. In cases of less severe infection, plants may reach almost normal height, but the foliage becomes leathery, turns yellow and brittle, and the apical leaves and axillary buds near the top begin to die (Fig. 24).

The stem is thickened, stunted, and of a pale green or yellow color.

On splitting the stem lengthwise, brown flecks are found in the pith and cortex, especially pronounced at the nodes in the upper portion of the plant. On badly infected dwarfed plants the tubers are small, gnarled and often cracked longitudinally. In some cases brown, dead areas surround the eyes, particularly those of the bud end. Reddish-brown circular flecks are found within the flesh of the tuber (Fig. 25). These appear as strands of dead tissue and can often be traced from just beneath the eyes to the center of the tuber. Such tubers are hard and brittle and show much delayed sprouting. On badly affected plants the tubers usually are borne on short stolons or are closely appressed to the stem. Brown flecking may also appear in the stolons.

Evidence of current season or primary infection is less striking and more difficult to find. In fully grown plants in August, the disease is manifested by a pinching together of the edges of the apical leaflets. These leaflets usually show bronzing or a copper color along the edges. The plant usually shows branching at an acute angle. The remainder of the foliage may appear normal. Only one of several stalks or one lateral of the plant may show these signs of infection. Tubers from such plants may appear normal in size, shape, and attachment to the plant. Usually the reddish-brown flecks are evident in the affected tops or in one or more of the tubers. Flecking in this case is less pronounced. Current season infection symptoms have often been confused with yellowing of the foliage due to drouth conditions. Tubers from such plants reproduce typical yellow dwarf when planted the following year.

Cause—No causal agent of the disease has been found. Yellow dwarf is carried over winter in the sap of infected tubers. It is transmitted readily by means of plug or core grafts, stem grafts, and clover leaf-hoppers. It is probable that the virus is carried over winter in the body of the clover leaf-hopper.

Control—Because of the uncertainty in recognizing symptoms due to current season infection and masking under normal cool growing conditions, control of yellow dwarf by roguing is rendered difficult. Spraying is not entirely effective in preventing spread of the disease by insects in the main fields. However, careful roguing of the seed plot, beginning when the plants are 4 to 6 inches high and continuing at weekly intervals throughout the season and thorough spraying at weekly intervals will reduce the disease to a minimum. Where 1 per cent or more of the plants show severe infection, obtaining new seed stock from fields where the disease is absent, has been more effective in controlling yellow dwarf.

SPINDLING SPROUT

The development of wiry, weak, spindling shoots is observed frequently in potato fields in this state. Usually, however, only a small percentage of the hills is so affected. This condition has given rise to the name spindling sprout.

Signs of the Disease—Shoots are slow to appear above ground and then are slender, wiry, and usually more than normal in number (Fig.

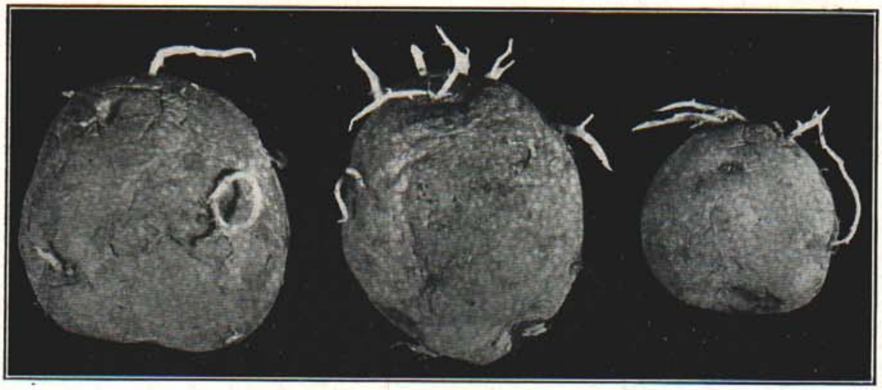


Fig. 26. Wiry shoots produced by tubers infected with spindling sprout. (Photo by J. E. Kotila.)

26). The leaves, although of normal green color, are reduced in size and the whole plant has an upright habit of growth. In some cases both a normal stalk and the spindling sprouts may arise from the same tuber. There is considerable variation in the number, diameter and growth characters of stalks from such tubers. When known spindling sprout tubers are planted they may reproduce the condition or fail to produce shoots.

Cause—The cause of spindling sprout is not clearly understood. It is regarded as a virus disease by certain observers who suggest that it is one effect of leaf roll infection. Spindling sprout is reported to be produced by tubers affected with rugose mosaic, yellow dwarf, spindle tuber and wilt. Earlier bulletins state that it is a physiological abnormality brought on by the effects of high temperature on the soil, too low temperatures in storage after the tuber has passed its dormancy, or repeated removal of sprouts.

Control—Whatever the cause, spindling sprout has been greatly reduced by careful roguing in the field followed by proper storage conditions during the winter. On light, sandy soil during seasons of high temperature and low precipitation, this abnormality has seemed to increase where roguing and green sprouting of the seed were not practiced.

WITCHES' BROOM

This disease is observed infrequently in the potato fields of the state, and occasions relatively little loss. It has been found in Irish Cobbler, Green Mountain, Russet Rural and other varieties. Because of its effect upon tuber production the disease is largely self-eliminating.

Signs of the Disease—When tubers from witches' broom plants are planted, development of sprouts from all the eyes, including those usually dormant, results in production of a large number of shoots. Side shoots are produced from practically all the buds on these stems, resulting in a mass of spindly shoots, giving rise to the name witches' broom (Fig. 27). In many cases the shoots are almost devoid of green color, and the leaves, greatly reduced in size and rounded, are frequently not larger than a clover leaf. Vine growth and flowers have an erect growth habit. The tubers are reduced in size, varying from that of a pea to that of a walnut, and increased in numbers, as many as 200 being produced upon a single plant. The small tubers may send out a stolon from the bud end, and these in turn produce other tubers. These are regarded as secondary symptoms. Primary symptoms are seen late in the growing season on plants presumably infected late in the summer. These consist of a slight rolling of the tip leaves, which appear lighter green with reddish margins and upright growth habit of the plant. Secondary branching also takes place in the axils of the upper leaves. Tubers from such plants are mostly abnormal showing excessive sprouting.

Fig. 27. Witches' broom.

Cause—The cause of this disease is carried in the sap of tubers from affected plants. It has been shown also that the disease spreads from badly infected to adjacent healthy hills in the field. Circumstantial evidence points to witches' broom as a virus disease. It is thought, by some investigators, to be connected with, or related to, the spindling sprout disease, although experimental proof of this is lacking.

Control—Close roguing coupled with the severe effect of the disease upon tuber formation have resulted in holding this disease to a minimum.

STREAK

Streak is found to some extent in the table stock potato fields of the state but is much less serious at present than formerly. The Green Mountain and Russet Rural varieties are susceptible.

Signs of the Disease—The late season characteristic manifestation of the disease is a brown streaking of leaf veins, petioles and the stems.

The streaked stems and petioles are brittle and easily break off (Fig. 28). Broken petioles remain hanging to the stem by a thread of skin tissue. First evidence of the disease consists of dark brown to black angular or elongated spots on the upper leaf surface. Usually the effects of the disease are so severe that it is self-eliminating in the field. Affected plants first show signs of the disease on the leaves about half way up the stem followed by the upper and lower leaves becoming affected.

Fig. 28. Lower leaves die, break and cling to the stem of streak-infected plants.

First-year infection results in decrease in number of tubers. When such infected tubers are planted the plants are severely dwarfed and streaked with small black spots appearing on the leaves. Tubers from such plants are few in number and small in size. Badly infected plants are short-lived, which accounts partially for the rapidity of elimination of the disease in seed stock.

Cause—This is a virus disease transmitted artificially by leaf mutilation and spread in the field by insects. Field spread of the disease usually is slow.

Control—Roguing has been found to eliminate streak from seed stocks.

CALICO

Frequently plants are found in which patches of yellow of varying size occur in the leaves, giving rise to the name calico. Such blotches may involve an entire leaflet or only the margin, or may be distributed irregularly over the leaf. Formerly this disease was thought not to be infectious but more recently its virous nature and infectivity have been proved. The virus is transmitted by leaf mutilation and is carried in the tuber from season to season. The disease has not caused any appreciable loss in Michigan and can be eradicated by roguing.

GIANT HILL

Giant hill occurs throughout Michigan and is particularly evident in the Russet Rural variety. Affected plants are larger in size with coarser vines (Fig. 29). The top leaves are often small with slight upward rolling of the edges. Such plants are more resistant to frost and remain green longer than normal ones. Giant hill plants often produce single stalks and large tubers of irregular shape but few in number. Tubers from such abnormal plants reproduce the disease in a high percentage of cases, although apparently normal plants are sometimes produced from giant hill tubers.

The cause of this abnormality has not definitely been proved. It may be due to physiological causes, mutation, or a virus. Transmission from affected to healthy plants under field conditions is doubtful. Careful roguing of seed plots has greatly reduced this abnormality in many cases.

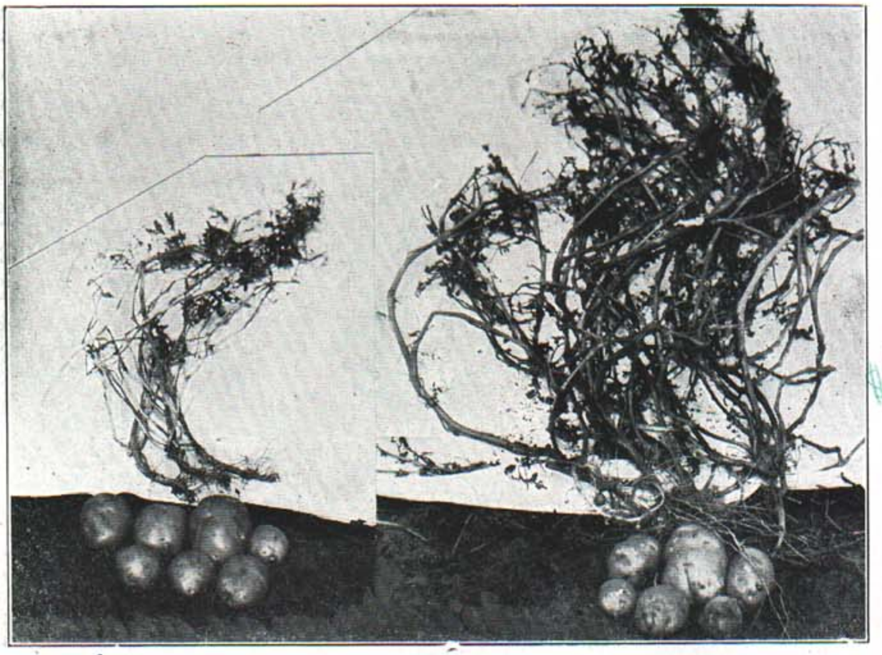


Fig. 29. Giant hill (right) and healthy plant (left). Note coarse vine and abnormal tubers. Giant hill plants are resistant to frost.

Non-parasitic Diseases

Although most of the serious diseases of potatoes are caused by fungi, bacteria, or viruses, there remains a group of disorders of the vines and tubers caused by insects, soil or climatic conditions, or injuries induced in transportation, storage or in the field by chemicals. These collectively are known as non-parasitic diseases and embrace such injuries to the above and below ground parts of the plant as those caused by the potato leaf-hopper, lightning, excess or deficiency of moisture, extreme heat, freezing, spray injury and others. The control or remedy in some cases is not generally practiced by many potato growers because the cause of the condition is not well understood. In other cases both the cause and control are obvious because of the nature of the injuries. These non-parasitic diseases, however, under certain conditions may be responsible, in the aggregate, for severe losses to the individual grower and to the industry as a whole.

HOPPERBURN AND TIPBURN

These two diseases were formerly considered due to the same cause. However, more recent investigations have shown them to be distinct. The effect upon the potato plant of one disease is indistinguishable from the other under field conditions. Because of the similarity of effect upon the plant both diseases may be considered as one which will be referred to as hopperburn. Economically hopperburn is one of the most important diseases of potatoes in Michigan. In 1919 the estimated loss in this state was almost 10 million bushels. During seasons of severe drouth, losses in unsprayed fields have reached 25 per cent of the crop. The average state loss during this period is conservatively placed as about 5 per cent of the crop. Early and tender foliage varieties are more seriously affected than the late varieties such as Russet Rural.

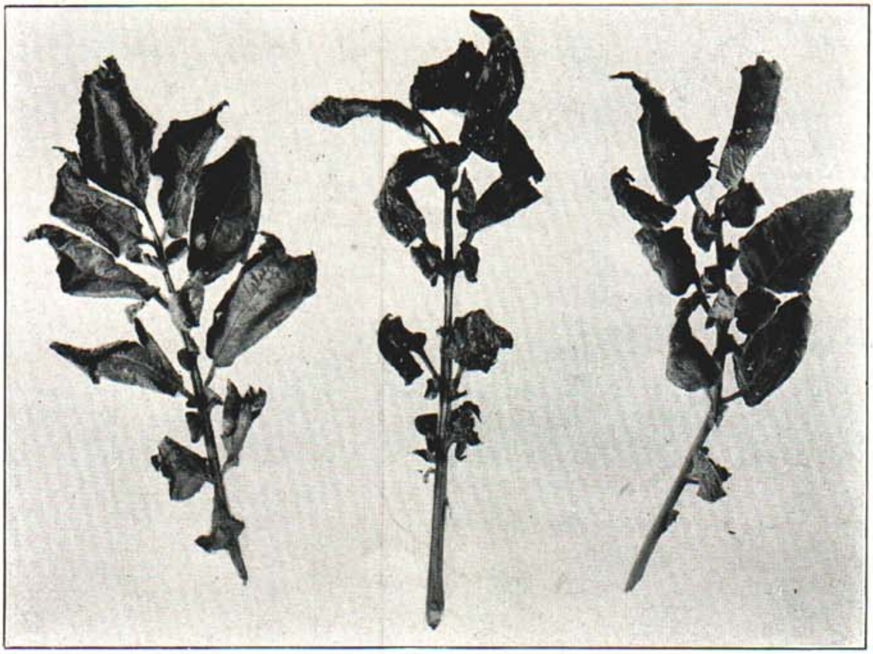


Fig. 30. Dying and blackening of leaflet margins caused by hopperburn.

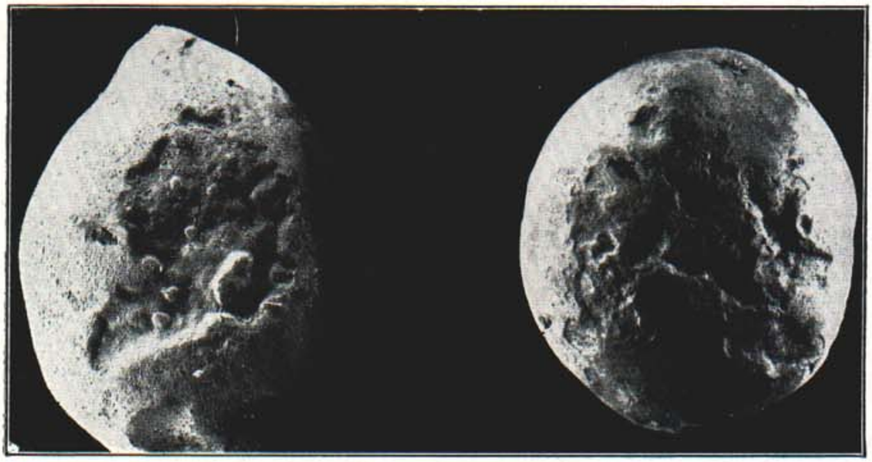


Fig. 31. Surface breakdown.

Signs of the Disease—First indications of the disease show as yellow areas at the tips of the leaflets followed by browning or blackening and drying out of the affected tissue. The dying of the leaflet continues downward and inward to the midrib until the whole area is involved (Fig. 30). As the disease progresses along the margin of the leaflet, the edges roll upward, dry out and become quite brittle. Although only the foliage is directly affected, the results of the disease are expressed in smaller size of tubers due to decrease in green leaf area.

Cause—Hopperburn as the name indicates is caused by feeding of the potato leaf-hopper, *Empoasca fabae,* upon the foliage. The insect punctures the veins and midrib of the leaflet and sucks out the plant juice. During the process of feeding, some investigators believe that a toxic substance is injected by the insect into the leaf. Whether injury results from the injection of this material into the leaf or from extraction of sap from the punctured cells and their subsequent collapse has not definitely been proved. It has been shown that an extract made from the nymphs of the leaf-hopper when injected into the potato leaf will produce typical hopperburn. Hopperburn results from the feeding of the leaf-hopper even under shaded conditions. Damage is most severe in late July and August during seasons with temperature above normal and precipitation below normal.

Tipburn is a physiological disease caused by loss of water from the leaflet more rapidly than it is absorbed by the roots. Under these conditions water is lost rapidly through the hydathodes at the tip and margin of the leaflet, and the tissue wilts, collapses and turns brown in bright sunlight. Progress of tipburn is checked by the advent of cool cloudy weather and normal precipitation. In Michigan, hopperburn appears to be by far the more prevalent and serious of the two diseases.

Control—True hopperburn is controlled by thorough spraying with bordeaux mixture. Copper-lime dust, while acting in some degree as a leaf-hopper repellent, has not been as effective as spraying with bordeaux mixture. Use of late varieties such as the Russet Rural, conservation of soil moisture by addition of humus to the soil, avoidance of light soils, and spraying as mentioned above also tend to reduce physiological tipburn.

PURPLE-TOP WILT OR BLUE STEM

This disease was reported from Pennsylvania in 1937 but was first noted in that state in 1931.

Potato plants apparently affected with this disorder have been observed in scattered areas in Michigan but in such small numbers as to be of little economic importance. In some respects purple-top wilt resembles the moron disease (page 61) but proof of relationship has not been obtained.

Signs of the Disease—Affected plants show dwarfing particularly of the upper portion of the stem with upward rolling of the terminal leaflets. Such leaves soon show a purple tinge, especially in the Russet Rural variety. Aerial tubers are commonly produced. Wilting of the plant takes place rapidly, usually within two weeks after the first symptoms appear. Within the stem, a brown discoloration appears in the vascular tissue and pith often progressing into the tuber. In the tuber the discoloration appears in strands similar to net necrosis as in tubers affected with leaf roll. Plants affected late in the season often produce flabby tubers similar to those produced by vines affected with the moron disease.

Cause—Purple-top wilt or blue stem is induced by the feeding of the aster leaf-hopper, *(Macrosteles divisa)* and may be a form of aster yellows. It is supposedly carried over in the tubers produced on affected plants.

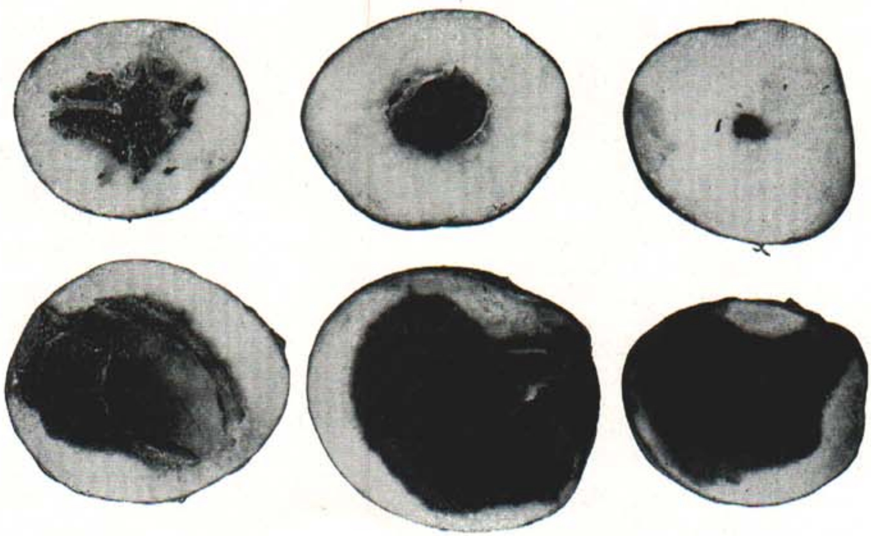


Fig. 32. Cut tuber showing black heart.

Control—Satisfactory control of the insect causing this disease has not yet been developed in areas where the disease is serious. In Michigan thorough spraying probably has some repellent effect upon the insect.

BREAKDOWN

This disease occurs each year to some extent in the stored crop or in potatoes shipped in cars under unfavorable conditions. Further losses may occur in the field from planting affected tubers, many of which produce plants of feeble growth or which fail to sprout. All varieties are susceptible.

Signs of the Disease—Two types of this disease are commonly found, namely, surface breakdown and black heart. Surface breakdown is first apparent as moist areas on the skin of the tuber followed by the development of small circular or irregular-shaped sunken bluish or lead-colored spots (Fig. 31). These areas are superficial, showing only a thin brown area of dead cells beneath the surface of the tuber.

Tubers affected with black heart may appear normal externally but when cut in two, the interior shows various degrees of discoloration. In freshly injured tubers the exposed interior tissue may pass through color changes from normal to pink, gray, purplish and finally black (Fig. 32). Usually discoloration originates at the center of the tuber, spreading outward and may progress to the surface. In some cases brown or black spots are scattered throughout the flesh of the tuber. In cases of severe injury, cavities often develop in the blackened area with gray-bordered canals radiating from them.

Cause—Black heart was the first type of breakdown to be given intensive study. As a result, it was thought that high temperature was the cause. Further investigation, however, has shown that both black heart and surface breakdown are due to insufficient oxygen supply or lack of aeration in storage. Breakdown develops rapidly at high temperatures with insufficient oxygen, while at low temperatures the progress of the disease is greatly retarded.

Tubers in storage piled not over 6 feet deep can be kept safely five or six months if the temperature is held at 40° F. or slightly below. However, if the temperature rises above 50° F. black heart may take place rapidly. At temperatures of 50° to 70° F., potatoes piled more than 3 feet deep may develop black heart in a few weeks. At temperatures above 95° F. the disease will develop despite good ventilation.

Control—Obviously the control of breakdown lies in keeping the storage temperature as near 40° F. as possible and providing for adequate ventilation to insure a sufficient supply of oxygen. For this purpose inlets for fresh air and outlets for foul air should be provided. False floors and walls for the storage and air space between bins should be provided. If the potatoes are piled more than 5 or 6 feet deep, provision must be made to ventilate the center of the pile.

INTERNAL BROWN SPOT

Another type of physiological disturbance in the potato tuber is known as internal brown spot. This trouble appears to be an aggravated form of heat and drouth necrosis. During seasons of drouth and high temperature this condition has been observed in southern Michigan at digging time where potatoes were grown on light gravelly soil with insufficient water supply.

Signs of the Disease—There are no outward manifestations of this disease. Brown or yellow areas of dead tissue of various size are scattered throughout the tuber, usually in the vascular ring and parenchyma tissue (Fig. 33). In severe cases the discolored tissue may extend in an almost unbroken band beneath the skin. When such tubers are also affected with scab, a soft watery type of rotting may result. In case of mild injury, the discolorations have the appearance of the trouble known as heat or drouth necrosis. The presence of disconnected brown areas in the tuber has been mistaken by growers for symptoms of yellow dwarf although closer examination reveals the difference.

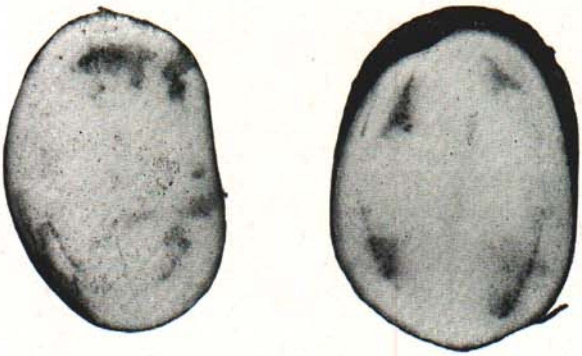


Fig. 33. Cut tuber showing internal brown spot.

Cause—Experimental data are lacking in establishing the exact conditions responsible for internal brown spot. Circumstantial evidence suggests a combination of high temperature around the tubers and lack of moisture during their formation as important contributing factors. This disorder also may be caused by certain viruses as well as by mineral deficiencies. Seed affected with internal brown spot often produces poor stands, weak plants and "no top".

Control—From such evidence control measures would seem to include deep planting, addition of green cover crops and manure to increase water holding capacity of the soil or selection of heavier soils for planting the crop. Irrigation if practicable would be of considerable benefit. Soil tests to determine mineral elements needed and their application may be of value. Care should be taken to discard affected tubers when cutting seed.

HOLLOW HEART

Hollow heart is a disease in which a cavity is formed in the center or heart of the tuber (Fig. 34). The cavity, usually lens-shaped, is surrounded by a thin layer of brown or gray dead cells in contrast to the blackened irregular cavity often found in black heart. There is no surface indication of the trouble. This condition is so commonly found in over-sized tubers that largeness is sometimes considered to be an outward indication of hollow heart. This is not the invariable rule, however, as small tubers often show the trouble when grown under conditions favoring its development.

Hollow heart results when tuber development is too rapid, due to an over supply of moisture, especially after periods of drouth. It may also result with normal rainfall if potatoes are grown in very fertile soil. Wide spacing of hills in the row is conducive to the rapid development in size of tubers and the tendency to hollow heart formation. While certain varieties seem to show more hollow heart than others, time of planting may be the controlling factor and not any varietal tendency toward this abnormality. This condition seems to occur more frequently in varieties that naturally grow rapidly and in which over-sized tubers are found under normal conditions.

Fig. 34. Hollow heart.

Control methods include planting on well-drained soil, close or medium spacing, depending upon soil fertility and timely and judicious applications of water if irrigation is practiced. Water by irrigation should be applied before tuber growth is arrested to avoid too sudden increase in development. Conversely, sudden checking of growth should be avoided if possible.

The varieties Russet Rural, Katahdin, Irish Cobbler and Chippewa are more susceptible to hollow heart than Russet Burbank, Bliss Triumph and Green Mountain.

FREEZING INJURY

Damage due to low temperatures constitutes a yearly source of loss to potato growers and shippers of Michigan. Losses from this cause are difficult to estimate for the state as a whole, but in individual cases they are often serious. Freezing injury occurs in the field (field frost), (Fig. 35), in storage houses, and to the crop in transit. Invasion of the damaged tubers by rot-producing organisms often results in their conversion into a slimy ill-smelling mass (Fig. 36). Even slightly damaged tubers are not fit for seed because of the rapidity of rotting of the seed piece.

When tubers are frozen sufficiently to kill the tissue, upon thawing they become soft and watery and are unfit for food. Entrance of decay-producing organisms soon finishes their destruction.

In cases of lighter injury, that is, where all of the tissues are not killed, symptoms vary with the temperature reached and the time during which the tuber is subjected to freezing temperature. Long exposures to temperatures just below freezing or moderate exposure to lower temperatures usually result in killing of the tissue. After thawing, both external and internal manifestations of injury are apparent. However, moderate exposures to freezing point temperature or short

Fig. 35. Blackened fibrils at stem end of tuber caused by slight freezing.

Fig. 36. Rotting of tuber following freezing injury.

exposures to slightly lower temperature result in killing only the most susceptible tissue, and the ring or blotch type of symptoms appear in the tuber upon thawing. The ring type of discoloration is limited to the vascular tissues which become blackened. In the net type of discoloration there is a blackening of the vascular tissue and the fine fibrils which extend into the flesh of the tuber (Fig. 37). This type of injury is indistinguishable from net necrosis associated with the virus disease leaf roll. Net necrosis, as a result of leaf roll, however, is found in the growing tuber before there is any danger of frost injury. Both

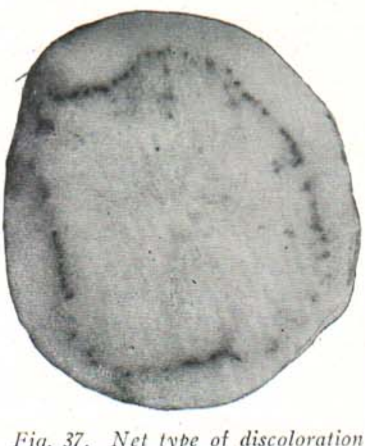


Fig. 37. Net type of discoloration due to freezing injury.

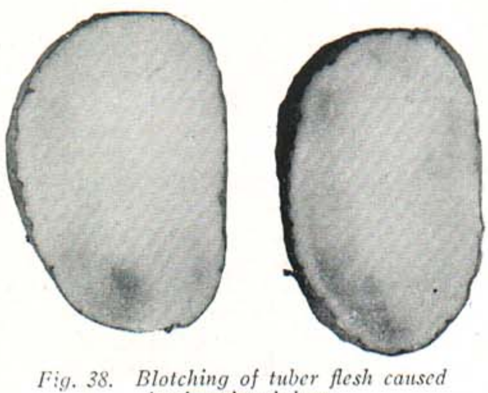


Fig. 38. Blotching of tuber flesh caused by freezing injury.

of these types of injury frequently are confined to the stem end. The blotch type (Fig. 38) consists of gray, bluish or black patches scattered throughout the tuber. These patches of discolored tissue may be located sufficiently close to the surface to be recognized in clear-skinned varieties. The other types show no outward signs of injury.

Control—It is readily seen that control of this trouble lies in protection of the crop from chilling or freezing temperatures. Sufficiently early planting, so that the mature crop can be harvested before field frost occurs, is an important step in prevention. Proper storage facilities where relatively uniform low temperatures can be maintained should be provided. Care must be exercised in loading and shipping the crop during periods of freezing temperatures. Construction of potato storage houses is described in bulletins of the Michigan State College that may be obtained on request.

SCALD

When tubers are dug, especially from moist soil, and exposed too long in the sun, scalding results. This effect may be found also when the tubers are borne near the surface in light soil during seasons of extreme heat.

Under these conditions, the outer tissues of the tuber break down, appearing first as blisters. These areas soon become sunken or may appear bleached with irregular darker colored margins. Within these areas the tissue is soft and watery and later may show grayish brown or black discoloration. Decay-producing organisms readily gain entrance to the tuber through these scalded areas and cause various types of rotting. It is not safe to store or ship scalded potatoes because of their liability to rotting.

GROWTH CRACKS AND KNOBBY TUBERS

Although all the environmental conditions essential for the development of growth cracks and production of knobby outgrowths or second growth in tubers are not known, these abnormalities are often associated in the field with hollow heart.

Growth cracks may extend lengthwise or crosswise of the tuber and vary in depth. In many cases the tissue exposed by the cracking produces a callus layer and the opening heals over. In other cases the cracking may be seen to occur as the tubers are lifted from the soil. If placed in storage before callusing takes place, various bacteria and fungi may gain entrance and cause rotting of the tuber. Growth cracks are not to be confused with those that occur as a manifestation of the yellow dwarf disease and which are usually accompanied by small circular dark brown flecks in the interior of the tuber.

Knobbiness, as the name indicates, is a condition in which second growth takes place indiscriminately over the surface of the tuber. This results in odd-shaped tubers in which the knobs are attached by means of small necks, or the parent tuber seems to be deeply constricted in the middle or near the ends. Fusarium wilt causes the development of tubers with pointed or nipple-shaped stem ends. But in this case the vascular tissue usually shows browning typical of the disease while in knobby tubers the second growth is normal in color and texture. Control measures are not definitely known but from observations good cultural practices such as will afford an even supply of moisture and close to moderate spacing appear to be beneficial.

NO-TOP AND SECONDARY TUBER FORMATION

Under certain conditions, planted tubers give rise to the production of small potatoes from the seed piece without sprout or vine growth (Fig. 39). This condition known as sprout-tuber, blind or Kindel tuber is most frequently designated "no-top" in Michigan. This disease was prevalent in the state in 1931 when losses amounting to 50 per cent in certain fields were reported. In 1932, it was seen in many fields, although losses were much less serious.

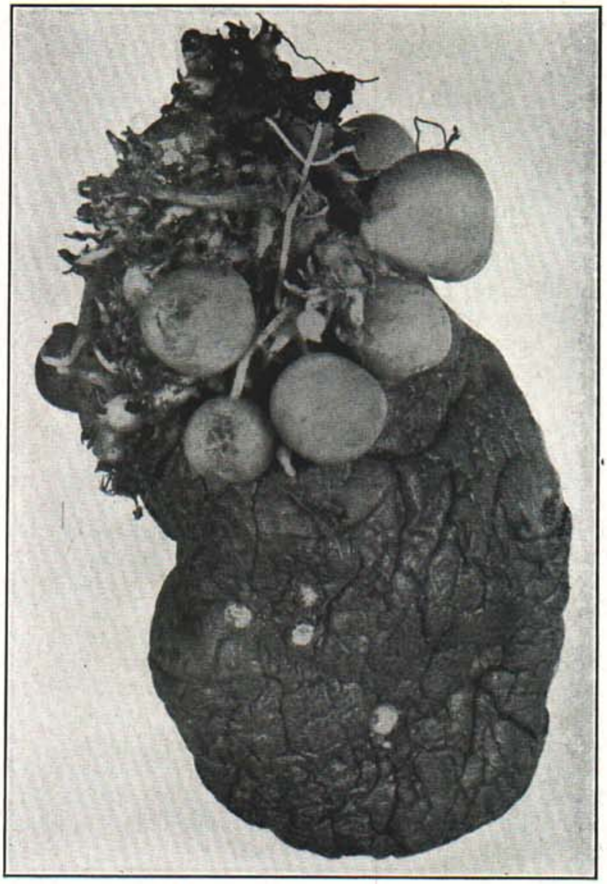


Fig. 39. No-top potato.

No-top has been produced experimentally by storage of tubers at temperature of 60 degrees F. with removal of successive growth of sprouts, and planting in dry soil at 40-45° F. Excessive water loss in the tuber, brought about by repeated removal of sprouts, will cause this condition. Although not definitely proved, it seems probable that dry soil conditions, especially late in the growing season, would also bring about this condition. Seed potatoes from a very light soil lacking in humus showed a high percentage of no-top when grown the following season. Tubers held at relatively high storage temperature when planted the following year produced approximately 50 per cent no-top.

Control of this abnormality lies in preventing soil moisture deficiency by addition of sufficient humus or irrigation and storage of the seed crop at temperatures 36° to 40° F. with adequate ventilation.

ENLARGED LENTICELS

Often when potatoes are grown in wet heavy soil, the tubers show numerous small white raised areas on the surface. By some growers this condition is confused with the white cottony tufts resulting from infection due to dry rot. These white areas are not a manifestation of disease but the enlarged lenticels or breathing pores of the tuber. When the soil contains an over abundance of moisture the air is forced out. In an effort to obtain the normal amount of oxygen, the lenticels or breathing pores are enlarged until they stand out as white raised areas. Upon drying, the lenticels resume their usual inconspicuous size.

LIGHTNING INJURY

Almost every year reports are received of a peculiar dying of vines in certain potato fields. These affected areas are more or less circular in shape and vary considerably in extent. At first usually only a few vines are affected but the condition spreads and completely dried, dead, partly killed and wilted vines may all be found in the slowly enlarged area. The stems of affected plants are usually hollow at the ground line and later these cavities may contain a mold-like growth, although at first no fungus can be found.

Fig. 40. Lightning injury in a potato field.

Fig. 41. Arsenical injury on potato leaflets.

This condition has been found by observation to be caused by lightning striking in the potato field (Fig. 40). The size of the affected spot varies with the strength of the electric discharge and may also be governed by the depth of the surface water. At any rate, death of the plants in the center of the area is more rapid with a slow spreading of the effect of the injury.

ARSENICAL INJURY

Small brown spots often appear on potato leaves after spraying the vines with arsenical compounds for the control of certain insects. These dead areas are caused by the soluble arsenic in the spray material (Fig. 41). Accumulation of arsenic in the axils of the leaves sometimes results in similar burning of the stem tissues. The addition of lime to the arsenical either as a dust or spray will eliminate this type of injury.

CHEMICAL INJURY

Shipments of potatoes in cars previously used in transporting salt, green hides, chemicals, or fertilizer, often results in injury to the bottom layer of tubers. This injury is due to contact of the tubers with various chemicals in the refuse on the floor. Injury takes the form of blackened flesh usually on one side of the tuber, and the affected area may extend ¼ to ½ inch into the potato (Fig. 42). Shipment in clean cars will prevent such injury.

SPINACH LEAF

This abnormality is met with occasionally in plants of Irish Cobbler, Green Mountain, Bliss Triumph, and Russet Rural varieties. Its occurrence is regarded more as a freak than as a source of loss in the crop.

As the name suggests, the leaflets are joined together in such a manner as to suggest a spinach leaf. The affected leaf is often puckered or wrinkled, and the midvein is much wider than normal. Sometimes plants with several such leaves are stunted. Tubers from spinach-leaf plants may produce both diseased and apparently normal plants. Roguing will eliminate this trouble.

MORON

This disease although found to some extent in all our commercial varieties is little understood. In early stages of the disease the foliage is paler than normal, with the terminal leaflets more pointed and slightly rolled. Later in the Russet Rural variety the affected plants show an upright bushy habit of growth (Fig. 41). The stems become reddish-purple in color, and the leaves show pronounced rolling near the apices. Such plants may be mistaken for those affected with internal blackleg stem infection. Aerial tubers often develop in leaf axils. Nodes of affected stems are swollen and distinct flecking of pith and cortical tissues at the base of the stem is often present. Usually one or more of the tubers is flabby. Such tubers may produce either apparently normal or moron plants. Whether this is a physiological trouble due

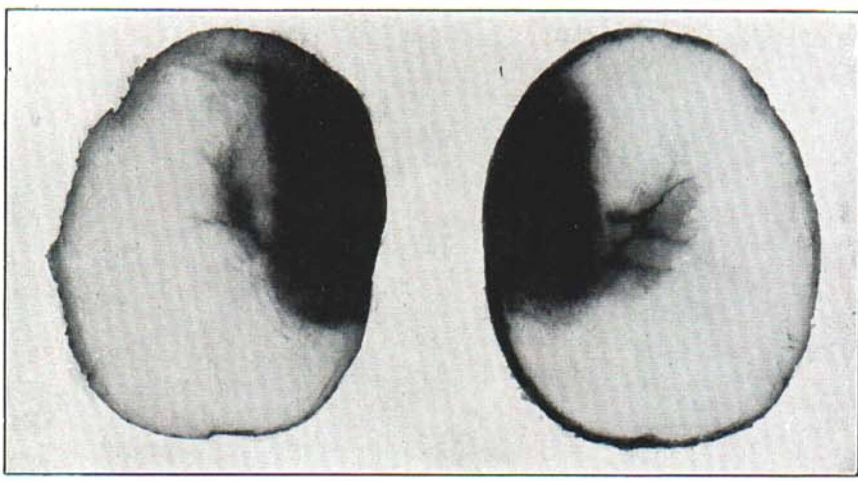


Fig. 42. Blackening of tuber flesh resulting from salt injury.

Fig. 43. Moron. Note bushy upright growth of vine and rolling leaves. (Photo by J. E. Kotila.)

to environmental factors or is inherent in the seed stock is not known. Artificial transmission of the disease has not been successful. Careful roguing holds the disease in check. This disease is very similar to the purple top wilt. However, identity of the two diseases has not been proved and they are therefore listed separately.

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