Special Bulletin No. 144 September, 1931

Blackleg of Potatoes

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Published in furtherance of Agricultural Extension, Act of May 8, 1914. F. W. Peck, Director, Agricultural Extension Division, Department of Agriculture, University of Minnesota, Co-operating with U. S. Department of Agriculture.

Blackleg is one of the major diseases of the potato in Minnesota. It causes an average annual loss of approximately 2 per cent of the crop. In badly affected fields the loss may be 50 per cent or more, and it is not uncommon to find fields in which from 10 to 15 per cent of the plants have been killed by the disease. In the majority of the fields, however, the losses are seldom greater than 5 per cent of the crop. In addition to reduced yields, there may be further losses due to decay of the tubers in storage or in transit. This is especially true where good storage conditions are not possible.

SYMPTOMS OF BLACKLEG

Blackleg is a bacterial soft rot. Any part of the potato plant may be affected, altho in the field it is generally the seed pieces, the stems, and the tubers that are directly infected by the bacteria. The seed pieces are always infected and are usually decayed throughout before the bacteria spread into the stem or out into the stolons to the newly formed tubers. Seed pieces destroyed by blackleg vary in appearance. In the majority of cases the pathogenic bacteria are accompanied or closely followed by many saprophytic bacteria and fungi, which reduce the seed piece to a slimy foul-smelling mass (Fig. 1) in which the

Fig. 1. Potato Seed Pieces Destroyed by Blackleg Bacteria Aided by the Seed-Corn Maggot Notice the slimy nature of the decay and the burrows made by the maggots. Such pieces usually have a foul odor.

larvae of insects, particularly the seed-corn maggot (*Hylemyia cilicrura*), frequently may be found. On the other hand, especially late in the growing season, the seed piece may be affected by a watery translucent decay with no unpleasant odor. In such cases relatively few saprophytes are present.

The stems and leaves frequently show effects of the disease before the bacteria have advanced far into the stem. The growth of the plant is checked and the leaves turn yellow from the margins inward and begin to wilt and droop. (Fig. 2.) Branching is inhibited and the lateral stems often tend to stand more erectt than those of normal plants. The yellow color of the affected plants, with their characteristic habit of growth, makes it relatively easy to detect them in a field among normal plants.

The decay finally advances into the lower part of the stem, changing it to a soft rotten mass. The decayed portions of the stem are usually dark brown or black. (Cover page.) The occasional intense black is not a characteristic symptom of the disease, as is sometimes stated. In many cases the decay is light brown or greenish brown. The latter

Fig. 2. A Potato Plant Affected with Blackleg in an Advanced Stage Beside a Healthy Plant of the Same Age

Note the wilting of the leaves of the diseased plants. The leaves of the diseased plants have a decided yellow color, which does not show in the photograph.

type of decay is observed more frequently in wet weather, because all types of decay on potato stems turn black on drying.

Plants affected with blackleg are easily pulled out of the soil because of the decay of the roots and the lower part of the stems (Cover page). This enables one readily to distinguish blackleg from other diseases that may cause the plant to wilt but do not destroy the roots or soften the stem. Severe cases of stem injury caused by *Rhizoctonia solani* are sometimes mistaken for blackleg. The two can be distinguished by the more moist decay of blackleg, the reddish brown color of the Rhizoctonia lesions, and the presence of Rhizoctonia mycelium, which often can be seen with the naked eye.

Diseased plants usually appear at random over the field, showing no definite centers of infection. In some fields, however, diseased plants are found in groups, which may or may not be the result of chance.

When a plant becomes diseased after tubers have been formed, the decay frequently spreads through the stolons and into the new tubers. In wet and heavy soils these may be completely destroyed before harvest. In light or very dry soils usually a small portion of the stem

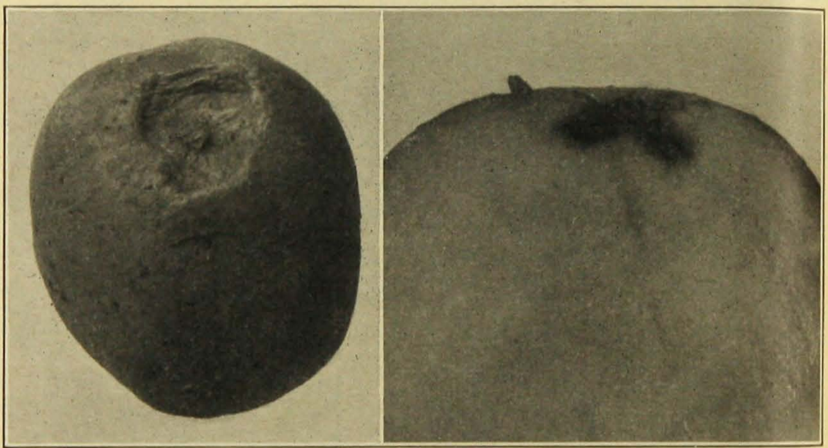

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Fig. 3. Potato Tubers Produced by Plants that Developed Blackleg Late in the Season

The stolons have been rotted away and the bacteria have entered the stem end of the tubers. Such tubers often, but not always, result in blackleg plants. Experiments indicate that disease from this source would rarely amount to more than 1 per cent of the plants in a field. Heavier outbreaks of blackleg usually result from other sources of infection.

end of the tubers will be decayed or perhaps only a browning of the vascular bundle results (Fig. 3).

The symptoms manifested by tubers affected with blackleg also vary extensively. The decayed tissues present a variety of colors through white, gray, brown, and black, depending chiefly upon the amount of oxygen present. The flesh of tubers rotted in the soil as a result of stolon infection may remain nearly as white as normal until cut open and exposed to the air, when it will rapidly turn brown or black. Tubers decayed by a pure culture of the blackleg bacteria have no unpleasant odor, but when other secondary organisms are present a foul odor may result.

CAUSE OF BLACKLEG

Blackleg is caused by bacteria. The blackleg bacteria are rod-shaped organisms about 1/20,000 of an inch in length and each bacterium has many whip-like flagella by means of which it is able to swim about in water or plant sap (Fig. 4). These bacteria get into the plant through wounds and can grow rapidly, spreading through the tissues and causing them to turn soft and mushy. The blackleg bacterium has been named *Bacillus carotovorus* Jones and is known to cause soft rot of many vegetable plants. For many years the bacteria causing blackleg of potatoes were thought to be different from those

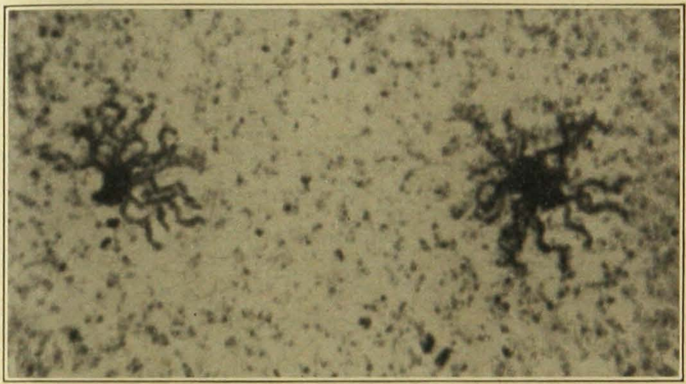

Fig. 4. Two Bacteria of the Kind Causing Blackleg
They are stained to show the whiplike flagella used in swimming about in water and plant sap. Magnified about 4,000 times.

causing soft rot of other vegetables, but recent work has demonstrated them to be the same.

Blackleg May Overwinter in the Soil

Until quite recently there has been a general belief that the bacteria causing blackleg could not survive in the soil over winter. This belief was based partly on the negative results obtained in some experiments made in the eastern states in 1915 and partly on a misunderstanding of the factors influencing infection of potato plants by blackleg. Recent experiments have shown that the conclusion based on the earlier work was not justified and that the bacteria do survive in the soil. In fact, the bacteria are present in most cultivated soils and may infect potato seed pieces when conditions are favorable. When potato seed pieces are planted in a soil in which conditions are favorable for growth, a layer of cork cells are formed over the cut surface and serves as an effective barrier against bacterial infection (Fig. 5). Infection can not occur unless some condition prevents the formation of this cork layer or enables the bacteria successfully to pass through it.

Experiments have shown that if the supply of oxygen is low, cork cells can not be formed. In very wet soils the air spaces are filled with water, thus forcing out the air and limiting the supply of oxygen. Experiments made by the writer have shown that cork formation is greatly inhibited when tubers are planted in very wet soils. But what effect does this have on the growth of the bacteria? These bacteria are facultative anaerobes and are able to grow as well in the absence of oxygen as in the presence of abundant oxygen. Under such conditions, cork can not be formed by the tubers while the bacteria may grow rapidly. This produces conditions favorable for infection of seed pieces by

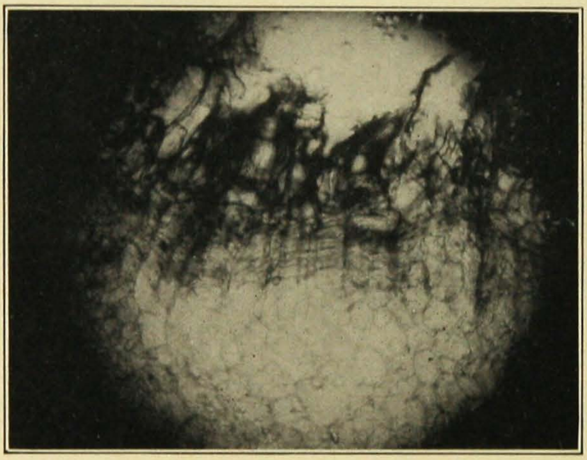

Fig. 5. Highly Magnified Thin Section of a Cut Potato Seed Piece

The photograph, taken several days after planting, shows the brick-shaped cork cells that have been formed and that serve as a barrier against infection by bacteria. These cork cells can form only in the presence of oxygen. In very wet soils water replaces the oxygen and inhibits the formation of cork. The blackleg bacteria are able to grow in the complete absence of oxygen and can rot the seed pieces under such conditions.

bacteria in the soil. This in all probability accounts for the commonly observed fact that blackleg is usually more prevalent in wet seasons than in dry seasons. It may also explain the greater prevalence of blackleg on heavy poorly drained soils as compared with lighter well-drained soils.

Blackleg May Follow an Attack by the Seed-Corn Maggot

During the springs and summers of 1923 and 1924 the writer investigated several outbreaks of blackleg which could not be explained on the basis of infected seed stock. This investigation led to the discovery that the seed piece of nearly every plant affected with blackleg was infested by larvae of the seed-corn maggot (*Hylemyia cilicrura* Rond.). Further studies led to the conclusion that this insect is an important agent of dissemination and inoculation of blackleg.

The seed-corn maggot is a common pest of the potato and many other plants. A survey of the literature revealed reports of injury on corn, peas, turnips, cabbages, radishes, onions, beets, potatoes, hedge mustard, tomatoes, wheat, and several other plants. The insect overwinters in the soil in the puparial stage. The adult flies emerge in early spring. They may be seen flitting about over the surface of the ground in great numbers during the planting season, and appear to be attracted by the freshly turned soil. They are about the size of a house fly, which they resemble in many respects (Figs. 6 and 8). Eggs are deposited on, or in, the soil near seed pieces and young potato plants (Fig. 7). The eggs are slightly less than 1/25 inch in length, but may be seen readily with the naked eye. They are slightly curved, white,

Fig. 6. A Female Adult Seed-Corn Maggot Fly Resting on a Potato Seed Piece
These flies are very abundant in potato fields at planting time. They lay many eggs in the soil near potato seed pieces or young plants.

and distinctly reticulate (Fig. 8). When freshly deposited they are covered with a sticky fluid which causes them to adhere to anything with which they come in contact.

The eggs hatch after two or three days. The maggot, when it emerges, is nearly transparent and only slightly longer than the egg, but it is able to move about rapidly in search of food. The mouth of the maggot is equipped with two black, sharp, claw-like structures with which it is able to penetrate the tissues of the seed piece. Observations have shown that the maggots during the first 24 hours will crawl about over the cut surface of the seed piece scraping with their mouth parts until the tissues begin to decay. During the next few days they penetrate deep into the tissues, thoroly inoculating the seed piece with bacteria. Experiments have shown that the eggs are sometimes contaminated on the surface with the blackleg bacteria when deposited. It has also been shown that the bacteria can survive in the soil. The maggot, therefore, may pick up the bacteria either from the egg shells, from the soil, or perhaps also from the surface of contaminated seed pieces.

The maggot thus acts as a very effective agent of inoculation. By the continued burrowing of the maggot any tendency of the tissues to form wound-cork is thoroly overcome.

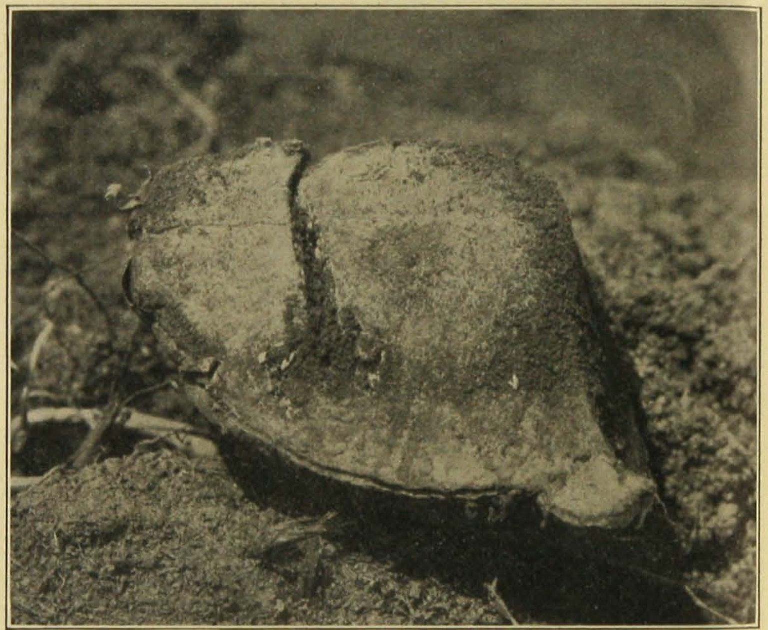

Fig. 7. A Potato Seed Piece Removed from the Soil Three Days After Planting, Showing Eggs of the Seed-Corn Maggot Adhering to the Cut Surface

This seed piece was not completely covered with soil when planted. The maggots hatching from such eggs burrow into the seed piece, carrying the blackleg bacteria with them, causing the seed piece to decay and eventually resulting in a blackleg plant.

It has been demonstrated that bacteria are essential for the development of the larvae on potato tubers. The maggots are not able to grow on normal tissues of the tubers until after the tissues have been acted upon by bacteria. The bacteria in all probability digest the tissues and transform them into materials readily available to the maggots.

After two or three weeks' development in the seed pieces, the maggots reach their maximum size of about 7-8 mm. (Fig. 8 c). They then leave the seed piece and go into the soil and pupate. In the meantime the seed piece is usually completely decayed and the bacteria are invading the stems of the plants, producing typical symptoms of blackleg. Pupation is usually well under way by the time the first above ground symptoms appear.

The puparia are about one-fifth of an inch in length and somewhat oval in shape (Fig. 8 d). They vary from light brown to dark reddish-brown according to age. The duration of the puparial stage varies from 7 to 14 days in summer.

There are usually two broods or more of the insect in Minnesota. The first brood is the more important in its relation to blackleg, as the eggs are deposited near seed pieces or young potato plants. The second brood usually deposits its eggs near or on the stems of plants already affected with blackleg. The maggots of the second brood may frequently

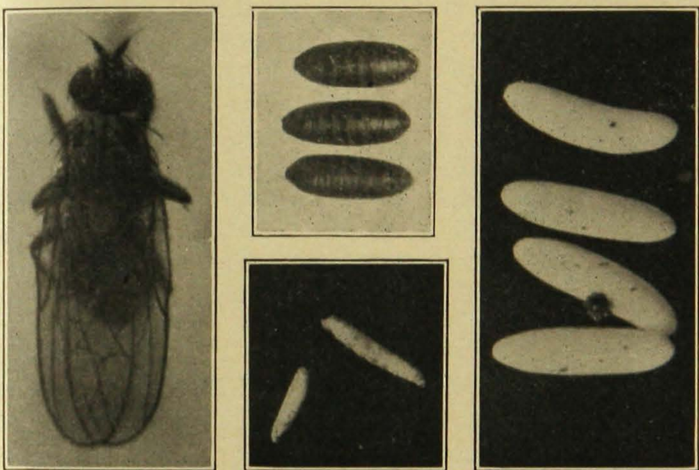

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Fig. 9. The Seed-Corn Maggot
a. An adult female fly magnified approximately 10 times.
b. Eggs, magnified approximately 50 times.
c. Larvae on maggots, magnified approximately 1½ times.
d. Puparia, magnified approximately 3 times.

be found in the stems of blackleg plants while the maggots of the first brood are confined chiefly to the seed pieces.

It has been shown that the blackleg bacteria, along with certain common soil bacteria, may pass through the intestinal tracts of both larva and adult fly in a viable condition. It has also been shown that these bacteria may survive in the puparia and emerge with the adult fly. Thus the insect can serve as agent of both dissemination and inoculation of the blackleg bacteria.

No practical means of controlling this insect is known. It is obvious that if the insect could be controlled the losses from blackleg could be materially reduced.

Blackleg May Also Come From Infected Seed Stock

Thus we have two sources of infection that may result in severe outbreaks of blackleg without regard to the source of the seed stock. Nevertheless, the disease may be transmitted through infected seed pieces and this source of infection should not be disregarded. When a plant becomes affected with blackleg late in the season and is not killed until after tubers have formed, it is frequently found that the decay has extended out through the stolons and has entered the tubers through the stem end. Such tubers usually are not completely decayed but remain sound, with the exception of a slight depression at the stem-end, and a browning of the vascular bundles, for some distance beyond (Fig. 3). Experiments have shown that the bacteria may live over in tubers infected in this way and such tubers frequently give rise to blackleg plants. Tubers infected in this manner appear to be less effective in corking off the bacteria than those inoculated through the cut surface at planting time. Experiments have shown that only a relatively small percentage (10-15) of such stem-end infected tubers are likely to produce blackleg plants. Therefore, when we consider the number of tubers likely to be infected in this way in a given lot of seed tubers, it appears extremely unlikely that this source of infection could result in more than a very small percentage of the infection frequently found in potato fields.

CONTROL MEASURES

It will be realized from the preceding discussion that many factors may influence the development of blackleg and that control of the disease in the field is not a simple matter. However, there are several practices which, if properly carried out, should reduce the losses from blackleg to a minimum. The most important of these are given.

1. Use certified seed stock or seed from fields known to be free of blackleg. When growing tubers for seed, all blackleg plants should be removed and destroyed. When the disease appears late in the season, any tubers that have formed on blackleg plants should be dug and destroyed. If this precaution is carried out, most of the systemically affected tubers should be eliminated.

2. All seed tubers should be disinfected before planting to kill any bacteria on the surface of the tubers which might cause decay of seed-pieces when planted under unfavorable conditions. It recently has been shown that under some conditions small decayed spots may be formed on seed tubers soon after planting. These are attractive to the seed-corn maggot fly and also make the tubers more susceptible to maggot decay. Seed treatment methods, which tend to prevent these lesions and preserve the seed pieces, should help to reduce the amount of blackleg.

3. Under Minnesota conditions, it is advisable to plant the seed pieces as soon as possible after cutting. It has been found that the conditions in a good seedbed are excellent for the formation of wound cork over the cut surface. Seed stored for only a few days after cutting heal poorly and frequently develop some decay which, as stated above, is conducive to maggot attack.

4. On heavy soils, poorly drained soils, or peat soils that are likely to be wet, potatoes should be planted rather shallow. Deep planting in such soils usually results in an inadequate healing of wounds and is conducive to infection from bacteria in the soil.

5. Crop rotation should be practiced because it is known that the organism may survive in the soil, altho little is yet known about the effect of continued cropping on its abundance in the soil. Another reason for rotating crops is that the first brood of seed-corn maggot flies emerging in the spring do not migrate very far during the first few weeks and are therefore to be found in greater abundance in and near old potato fields at planting time. There is also some evidence that flies arising from larvae that have developed in blackleg plants are more likely to be carriers of the bacteria than those developed in other decaying matter.

BLACKLEG DECAY IN STORAGE

The same bacteria which cause blackleg of potato plants in the field often rot potatoes in storage. On account of the numerous fungi that also cause potato rots it is often difficult to determine just how much of the rot is due to blackleg bacteria and how much is due to the fungi. Several organisms may work together in causing tubers to rot. The prevention of such rots is largely a matter of good storage.

Good storage begins at digging time. Care should be taken to avoid bruising the tubers in digging or in handling. Every normal tuber is covered with a corky skin that is waterproof and can resist the attack of the organisms causing decay. When ths skin is broken water escapes and a way is provided for the entrance of rot-producing organisms. If bruised tubers are exposed to the air for a few hours they will usually heal over and become more resistant to decay. Potatoes should be thoroly dried before being put in storage.

It is necessary to control three factors within certain limits to insure good storage, namely, temperature, aeration, and humidity. All of these can be controlled in our northern climate by proper construction of the storage place and a good system of ventilation. The temperature should be kept between 32 and 40 degrees F. This prevents sprouting, retards development of tuber rots, and reduces chemical activities within the tuber, preventing excessive loss through respiration.

The ventilation provided should be sufficient to keep the tubers dry and to allow the healing of any bruises that may occur. Newly stored potatoes give off considerable moisture and heat. This sweating process is decidedly noticeable during the early part of the storage season, especially when potatoes are immature, wet, or covered with moist dirt. Excessive moisture is in itself not injurious to the potato, but it favors the growth of the blackleg bacteria and certain fungi which cause the tuber to rot.

Most bacteria and fungi which rot potato tubers get into the tuber through wounds before they have had an opportunity to heal. An abundant supply of oxygen is necessary for healing. When the tubers are stored they are actively respiring, or breathing, and rapidly use up the oxygen in the air around them. Unless provision is made for replacing this old air with fresh air, the healing can not take place and the tubers begin to decay.

Various devices may be used to insure proper ventilation, depending upon the circumstances. In any case it is essential that there be a slow slow movement of air throughout the potato bin. False bottoms and slatted walls are usually essential when large quantities of tubers are stored. In some cases fans or blowers are used to aid the natural air movement. During the winter months, after sweating has been reduced, less ventilation is required. Excessive ventilation in late winter may stimulate early sprouting.

All potatoes put in storage should first be sorted carefully and all decayed or badly bruised tubers should be removed. Keep the storage cellars clean. Many losses of potatoes in storage are due to rots which develop as a direct result of putting tubers in dirty and unsanitary bins. The cellar should be so constructed as to make it easy to clean out every fragment of refuse before putting in the new tubers. After all refuse has been removed, the floors, walls, and bins should be thoroly disinfected by washing or spraying with a solution of formaldehyde (one pint in 10 gallons of water) or copper sulphate (one pound in 10 gallons of water). Unless this is done the fungi and bacteria which cause tuber rots will multiply and spread to the stored tubers. Potatoes properly stored may be kept in a firm and healthy condition until early spring. Poorly stored tubers are likely to suffer great loss from decay or excessive sprouting or both.