LATE BLIGHT BIOLOGY - UNDERSTANDING THE ENEMY

by
Dr. Randall C. Rowe, Dept. of Plant Pathology
Ohio State Univ./OARDC, Wooster, Oh. 44691

Since the early 1990s, severe epidemics of late blight (caused by the fungus *Phytophthora infestans*) have occurred in many potato production areas of the U.S. and Canada -- far worse than anything that had occurred for decades. Many commercial and seed growers have experienced large economic losses. In the northcentral and northeastern U.S., late blight has been severe on potato in some years in the Red River Valley (northern Minnesota/North Dakota), Wisconsin, Michigan, New Jersey, Pennsylvania, New York and Maine. In localized areas, disease epidemics also have developed in commercial fresh-market tomatoes and home-garden crops of both potatoes and tomatoes. Although a few areas of the Pacific Northwest had experienced some problems with late blight in the early 1990s, it was not until the 1995 season that the disease developed in epidemic proportions across many areas of eastern Washington and Oregon and into southwestern Idaho.

During the summer of 1995, potato growers in these areas became all too familiar with the symptoms of late blight. On potato leaves, the first symptoms appear as small, dark spots on the upper surfaces. In a few days, these enlarge into large, irregular, brownish-black lesions with light grayish-green to light brown margins. A pure white mold growth is often visible on the undersides of infected leaves, usually when conditions are moist. This is the best diagnostic sign of the disease. Eventually these lesions enlarge further into purplish-black areas covering large portions of infected leaves, which eventually die and fall from the plant. The late blight fungus, especially the new strains, is also capable of infecting potato stems. Stem lesions can occur in the upper canopy at bases of leaves and on major stems lying on or near the soil surface. These lesions are purplish-black and may be up to 3-4 inches long and nearly encircle the stem. Stem lesions caused by other fungi may be confused with late blight. Lesions of Sclerotinia stem canker may be this size or larger, but appear tan to brown with very sharp margins. Lesions of aerial stem rot, caused by soft rot bacteria, may be nearly the same color. However, these usually appear slimy and the tissues decay rapidly and may have hollowed out pith areas. Late blight lesions generally remain firm. Late blight-infected tubers may have one to several small lesions scattered across the surface or large portions of the tuber surface may be involved. In uncut tubers, infected tissues appear somewhat darker brown than healthy tissues and are usually slightly sunken and shriveled. When cut, infected internal tissues appear copper-colored and granular in texture. The infection may lay just under the skin or may penetrate tuber tissues 1/2 to 3/4 of an inch. Rarely does the infection extend to the center of the tuber. Tuber tissues infected only by the late blight fungus remain firm and become slightly shrunken. Blighted tubers often become infected with secondary bacteria, however, and then usually break down quickly with a wet or slimy decay.

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Fortunately, the late blight fungus is capable of causing disease in only a few plants. Besides potatoes, tomatoes are the other primary host. Symptoms of late blight on tomato leaves and stems appear the same as those on potatoes. Tomato fruit can also be infected, usually when it is still green. Late blight lesions appear as dark brown, leathery, sunken areas on the infected fruit. The white mold growth typical of late blight often appears on the surface of these infected areas.

Potato growers should be aware of nearby tomato production areas (even home gardens) and watch them for late blight because infected tomatoes can be an important source of late blight for potato crops. A few weeds in the nightshade family (solanaceous weeds) are mildly susceptible, especially Hairy nightshade (*Solanum sarachoides*). Black nightshade (*Solanum nigrum*) is not susceptible.

A thorough understanding of the biology of late blight and the fungus that causes the disease is the key to understanding late blight management strategies. Unlike most plant pathogenic fungi, the late blight fungus cannot survive in soil or plant debris. For an epidemic to begin in any one area, the fungus must survive the winter in potato tubers (culls, volunteers), be reintroduced on seed potatoes or tomato transplants, or live spores must blow in with rainstorms. In the spring, only a few leaves or stems supporting active sporulation of the fungus are necessary to begin the disease for a new season. This is called the primary inoculum.

Cull piles have often been shown to be an important source of the first spores of the season. Cull tubers originating as pickouts from harvested tubers being loaded into or out of storage, or as discarded tubers mixed with soil removed when cleaning out emptied storages, must be disposed of in a manner that will result in their destruction. Late blight-infected tubers contained within cull piles are protected from frost and decay and may sprout in the spring, serving as a source of spores that can infect nearby fields. Infected seed tubers are also an important source of spores that can start the epidemic. Rapid distribution of new strains of the late blight fungus around the country has probably occurred in this manner. Late blight-infected tubers that are not harvested and survive the winter to sprout as volunteers the following spring may also be a source of spores of the late blight fungus. Of these three sources, cull piles are probably the most important. It is, thus, very important not to make cull piles and to eliminate existing ones completely.

Although we know that the late blight fungus survives the winter in infected potato tubers, many studies have shown that very few blighted tubers actually do sprout the following spring. Most simply rot. Recent research conducted by Dr. Ken Deahl, USDA/ARS, Beltsville, Maryland, has shed some light upon this mystery. His research has demonstrated that newly sprouted tuber eyes are very susceptible to infection by the late blight fungus, especially if they have not been exposed to light. This can easily happen during handling of seed tubers by either the seller or buyer if they come into contact with spores of the late blight fungus formed on infected tubers in the storage. Although blighted tubers sprout infrequently the following spring, a key finding of this study was that tubers with blight-infected sprouts grew readily when planted. Infected sprouts often contained small late blight lesions that remained dormant as the sprouts emerged and developed into plants. Later, however, these lesions enlarged and formed spores of the late blight fungus that could then easily spread to other plants.

The important of sprout infection of seed tubers in the whole cycle of late blight is as yet undetermined. But this important new finding may improve our knowledge of how the disease spreads among tubers, leading to new disease outbreaks the following year.

Once the disease begins in an area, the formation of spores (the white mold growth seen on leaves and stems) is dependent on environmental conditions in the crop canopy. Spore formation occurs under moist conditions (at least 90% relative humidity) and in the temperature range of 40°-80°F. There is some question as to whether the newer strains may be able to tolerate somewhat higher temperatures. After spores have formed and been transported onto healthy potato tissues, they require free moisture on the foliar surface in order to germinate. Germination occurs in two ways, and this helps to explain the "explosive" nature of this disease (Fig. #1). If temperatures are 70°-80°F, the spores will germinate directly with a germ tube that can penetrate the leaf or stem tissue and result in a single late blight lesion. However, if temperatures are cooler, in the range of 45°-65°F (optimum 55°-60°F), the contents of the spore will divide up into 6-10 smaller swimming spores. These can exit the larger spore case and swim through the water film on the surface of the leaf. Each of these swimming spores is infective and can results in a separate late blight lesion. Thus by the temperature simply dropping about 20 degrees, the number of spores capable of beginning infections increases 6-10 times. Once the spores have germinated and penetrated leaf or stem tissues, the outside environment is less important. Late blight can continue to develop throughout the temperature range of 45°-85°F. Temperatures above 85°F do not kill the fungus, but simply slow down its development. There is some reason to believe that the newer strains of the late blight fungus can perhaps remain active at slightly higher temperatures. Late blight remains, however, a disease of moist and cool conditions and, thus, most sporulation, spore germination, infection, and disease development occurs at night when conditions are more favorable, especially deep within the plant canopy.

It has been widely reported that the new strains of the late blight fungus have a much increased capacity to form stem lesions on infected plants. This is not only of interest as a diagnostic symptom of late blight, but plays a key role in the annual cycle of disease. The older strain of the late blight fungus formed lesions mostly on leaves and, when the weather turned hot and dry, these lesions would turn brown and dry up. Under these conditions, infected leaves often fell off the plant. Since the late blight fungus cannot survive off a living plant, the fungus within these tissues would die, thus eliminating this infection site from any further role in the epidemic. In the case of stem lesions, however, this is not the case. These lesions are formed on the surface of living stems and they remain intact and viable even when the weather turns hot and dry. They stop forming spores under these conditions, but then resume doing so as soon as cooler, moist conditions return. Thus <u>stem lesions, once established, serve as a season-long reservoir of disease</u> capable of forming spores of the late blight fungus whenever conditions are favorable for doing so. This continues to occur until the stems die.

Movement of late blight from field to field during the season results from airborne dispersal of spores formed on infected plants. One of the most commonly asked questions about late blight is "How far can the spores be blown?" Fortunately, spore of the late blight fungus are very susceptible to desiccation and die rapidly if exposed to relative humidity less than 95%.

They can easily be carried 5-10 miles in wind-blown rain or irrigation water, but spread by dry winds is unlikely. Long distance movement of late blight spores has been shown to occur, usually in association with widespread storm patterns with high winds and blowing rain. However, the chances of late blight blowing several hundred miles over mountain ranges is very low. Most instances of late blight showing up in areas previously free of the disease have been traced to a local source that resulted from an introduction of the fungus on seed tubers or garden tomatoes.

Infection of tubers by late blight occurs when spores of the fungus are washed down to the soil from infected leaves and stems. Spores may come into contact with tubers through cracks in the soil or may be washed through the soil profile to the surface of tubers. The latter is most likely to occur in sandy soils and where tubers have been allowed to form close to the soil surface. This is the reason that good hilling practices can help to protect tubers from late blight infection. Tubers may also become infected during harvest by coming into contact with spores from vines and stems that remain alive. This is particularly important with large stem lesions and is the reason that delaying harvest until vines have been dead for 2-3 weeks is an important management practice.

It has long been recognized that the late blight fungus cannot survive for long away from living potato and tomato plants. Most management practices take advantage of this weak link in the fungus' life cycle. The reason this is so is that, until recently, only one of the two mating types of the fungus has been widespread. When both mating types of this fungus come together, an entirely different type of spore is formed, called an oospore. Unlike other spores of the late blight fungus that are very short-lived and susceptible to desiccation, oospores are long-lived and capable of surviving in soil under a wide range of conditions. In the early 1950s, oospores of the late blight fungus were first found in the highlands of southern Mexico. New strains of the fungus, including both mating types, appeared in Europe in the 1980s. Oospores have been found there and appear to be able to survive the winter, at least under some conditions. In N. America, oospores have been found in naturally infected potatoes, but so far only quite rarely. In the future, if this type of spore becomes more common, it has the potential to change the cycle of this disease. If oospores can survive our northern winters in sufficient numbers, and if they can germinate the following spring and result in infection of newly sprouted potatoes, they could serve as a permanent reservoir of disease in areas where late blight is well established. At present, this is an area of active research and no evidence is yet available that would indicate any change is needed in current management practices.

When knowledge of all stages of a disease are known, these can be assembled into what is called a "disease cycle" (Fig. #2). In the illustration, one can follow the causal fungus and its activities throughout its annual cycle. It spends the winter in potato tubers and emerges the following spring on an infected sprout. Most cultural management practices are aimed to block this stage of the disease cycle by preventing overwinter survival and production of spores in the spring. Once the disease has begun, spores are formed and dispersed to susceptible tissues. Spore germination takes place either directly or via swimming spores, depending on prevailing temperatures. Infection occurs under moist, cool conditions. Protectant fungicides, such as mancozeb or chlorothalonil, are used to block spore germination and infection. Following infection, disease development can occur over a wider range of temperatures.

Within 4-5 days, under favorable conditions, a new crop of spores can be formed on infected tissues. Systemic fungicides are most useful at blocking this stage of the disease cycle and preventing spore formation. Eventually spores come into contact with tubers, resulting in infected tubers. The fungus is, thus, ready to survive the next winter. The potential importance of oospores in the disease cycle can be seen in this diagram. If this type of spore becomes widespread and survives the winter, infected tubers could be bypassed as the primary method of overwinter survival for the fungus and many of our cultural control methods aimed at that bottleneck in the disease cycle may be overcome.

Organizing our knowledge of a disease into a diagram such as this can be helpful to ensure complete understanding of the biology of the causal organism. With late blight, once you understand how the disease works, then the steps you need to take for successful disease management become common sense. It all fits together!!

Figure 1. - At temperatures of 70°-80°F, spores of the late blight fungus, *Phytophthora infestans*, germinate directly (left). At lower temperatures, spores germinate by forming smaller swimming spores which are released from the larger spore case (right). From: Rowe, R.C. (ed.). 1993. POTATO HEALTH MANAGEMENT. APS Press, St. Paul, Mn. Pg 143.

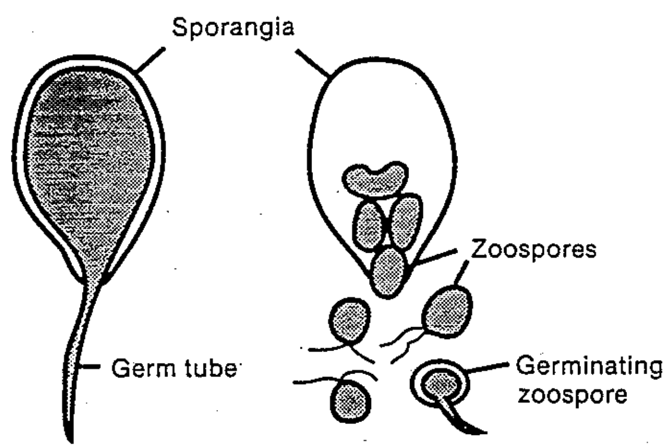

Figure 2. - Disease cycle of potato late blight, caused by the fungus *Phytophthora infestans*. Drawing provided courtesy of K. L. Deahl, USDA/ARS, Beltsville, Md.