Root Rots, Wilts, and Blights of Peas

W. T. Schroeder

The pea (*Pisum sativum*) is subject to various types of diseases—blights, root rots, and wilts. The formulation of control measures for them requires knowledge of their symptoms, causes, relations of host and parasite, and possible inherent resistance.

Blight refers to the discoloration, gradual drying, and eventual death of the affected plant parts. Bacteria and fungi cause blights, which usually are seed-borne and develop best during wet weather.

Only one major bacterial blight (*Pseudomonas pisi*) affects peas. A number of fungal blights, however, do occur on peas, among which are septoria blotch (*Septoria pisi*), downy mildew (*Peronospora pisi*), powdery mildew (*Erysiphe polygoni*), anthracnose (*Colletotrichum pisi*), ascochyta blight, and several minor ones.

Ascochyta blight is among the oldest and worst. Its nature and control are much like those of other fungal blights (except powdery mildew). Details about it therefore apply generally to the others.

ASCOCHYTA BLIGHT is a composite of three diseases resulting from infection, singly or collectively, by *Ascochyta pisi*, *A. pinodella*, or *Mycosphaerella pinodes*.

The nature of the disease was first determined in Europe in 1830. It was a constant threat in the United States until about 1915, when it declined with the shifting of the seed industry to areas in the West where the low rainfall before and during the harvest reduced the amount of infected seed. But in some years unseasonal rainfall during harvesttime in western seed-growing districts means contaminated seed, so that the disease remains something of a problem.

The symptoms the three parasites cause are almost alike. Most evident are the lesions that begin as small purplish specks on leaves and pods. When infection is caused by *M. pinodes* or *A. pinodella*, the specks may enlarge on the leaves into round, targetlike spots. If numerous, they join to make irregular brownish-purple blotches on both leaves and pods. *A. pisi* produces relatively few, rather definite, sunken, tan or brown spots, which have dark-brown margins and are circular on leaves and pods. The pod lesions usually become sunken.

Stem lesions are elongated and purplish black. They originate as separate infections or as a continuation of petiole infection around the nodal area. They also may coalesce and girdle the entire stem, weakening it so that it is easily broken.

Affected leaves eventually shrivel and dry into a blighted condition, which resembles freshly cured clover hay. *M. pinodes* may also blight the blossoms and young pods and cause withering, distortion, and eventual dropping.

All three organisms can attack that part of the stem and root at the soil line and produce a bluish-black foot rot. It is severest when it is caused by *A. pinodella*. *A. pisi* seldom causes severe foot rot.

The three organisms responsible for the ascochyta blight complex are closely related, but each has marks that classify it as a distinct species. In pure culture on artificial media, the light-colored mycelium and the abundant carrot-red spores of *A. pisi* readily distinguish it from the darker-colored mycelium and relatively scarce light-buff spore exudate of *M. pinodes* and *A. pinodella*. All produce water-borne spores, the pycniospores, but those of *A. pinodella* are only half as large as the spores of the other two species. The incubation period of the disease caused by *M. pinodes* and *A. pinodella* is 2 to 4 days, compared with 6 to 8 days for *A. pisi*. *M. pinodes* is the only species that produces ascospores. Such spores can be carried for considerable distances by air currents and largely account for the more aggressive nature of that pathogen.

The three disease organisms can infect the seed. Such infection serves to overwinter the pathogens and is a means of transporting the disease from one region to another. The pathogens also overwinter in infected pea straw. In regions of extremely mild winters, they may remain active on infected volunteer plants. The ascochyta blight organisms do not live indefinitely in the soil as in the case of the root rot and wilt fungi, but remain there only as long as the infected pea straw is not completely decomposed.

When infected seed is planted, the disease first appears as a foot rot on the young seedlings at the point of seed attachment and often kills or weakens the young plants. Spores are produced during wet weather on such plants and spread the disease to nearby plants.

Infected pea straw in the soil from the crop of the previous season may give rise to both pycniospores and ascospores. As pycniospores need spattering rain for their dissemination, they spread the disease only a few feet from the source. Ascospores, however, are shot out from the spore-bearing structures in the old plant tissue and are carried quite far by air currents. They usually are more abundant than pycniospores and spread the disease uniformly over the field rather than in small patches. If conditions are favorable, both types of spores may be formed continually on the dead parts of the infected plant. Because the ascospores are more widely and uniformly distributed, however, infection by *M. pinodes* (the only species producing ascospores) is more damaging.

Because moisture is required for spore discharge and infection, rainfall, dews, and high humidity are the most important environmental factors in the development of ascochyta blight. The number of periods of wet weather during the pea season largely determines how bad the disease will be.

Because there is no practical resistance in the pea to the ascochyta blight complex and because nothing can be done at present to change the weather, the disease is best controlled by avoiding, eliminating, or reducing the causal organisms—by the use of disease-free seed, crop rotation, and sanitation.

It is unwise to plant seed grown in humid sections of the East and Middle West. That seed is likely to be infected with the disease organisms. Furthermore, the straw from a seed crop is apt to be more heavily infected with the organisms than a crop cut in the green stage for processing. That increases the inoculum potential on the overwintered straw and affords a better chance for the disease to establish itself earlier and more severely. Seed grown in drier regions of the West is the best insurance against seedling infection. Treatment of seed with fungicides reduces the surface contamination but will not eliminate internal infection.

Rotation to control pea blights implies more than merely avoiding planting pea crops on the same land more than once every 4 or 5 years. Such a rotation undoubtedly would eliminate the organism from the soil. But, in addition, every effort should be made to locate new plantings as far as possible from those of the previous season. Even though most of the vines from the old fields are removed to the viner station, there may be enough infection on the stubble and debris to provide for the dispersal of ascospores the following spring.

Of equal importance is sanitation. Any infected plant parts—whether stubble in the field or vines on the viner stacks—offer a constant source of inoculum for the next crop. After the ensilage has been removed from the stacks, the outside part of the stack, which usually is raked off, should be destroyed before seeding the next spring. If mobile viners are used in pea fields, the vines and pods, instead of just the stubble, are left in the fields. That will create a situation comparable to one in which seed peas and processing peas are grown in the same area, for the fresh vines will dry, and the organisms will continue to develop, thereby increasing the inoculum potential for the next season.

A good practice would be to plow down all pea stubble and vines immediately and plant the field to a crop, such as grain, in which the soil will not be cultivated during the next season. In some places it is customary to plant early varieties alongside late ones or to stagger planting dates. In either event, ascospores may develop on the stubble of the earlier planting and provide for abundant dispersal of spores to the younger plantings nearby. Such practices should be discouraged.

ROOT ROT is caused by a number of fungi, which singly or together attack the cortex, the tissue outside the water- and food-conducting cylinder of the roots and lower stem. Invasion of the cortex may be quite general, or it may be somewhat localized. The rot may be soft and watery, or it may be more like a dry, corrosive decay, depending on the causal organism. The various types of root rot are designated by the names of the fungi that cause them, such as aphanomyces root rot, fusarium root rot, and ascochyta root rot.

The damage done by root rot varies with the season and the causal organism. One year the crop may fail; the next year on the same piece of land the crop may be all right. The disease may act as a seedling blight and kill scattered plants at an early stage, or it may not attack the plant until quite late in its development. Two different pathogens attacking the same plant frequently cause more harm than either alone. Complete crop failures can occur. More often, however, yields are reduced in varying degrees as a result of an impaired or restricted root system. Under those conditions, the affected plants look as though they were suffering from malnutrition.

The disease pattern or symptoms and the conditions favorable for root rot development depend upon the specific pathogen. Practically all the types may occur wherever peas are grown, but certain ones are more prevalent in some areas than in others.

APHANOMYCES ROOT ROT, caused by *Aphanomyces euteiches*, occurs to some extent wherever peas are grown and is often referred to as common root rot. It is especially prevalent in the older pea-growing regions of New York, New Jersey, Wisconsin, and Minnesota. Some 10,000 acres of canning peas were lost in 1942 in Wisconsin as a result of the disease.

The disease is first detected by a soft and watery condition of the stem an inch or two above the soil line. By then the roots have become similarly affected. The diseased tissue becomes discolored because other fungi invade the softened tissue. Ordinarily most of those fungi cannot infect the healthy tissue.

In time the affected tissue on the stem above the soil line collapses and shrivels. The outer tissues of the roots then are so rotted that when the plant is pulled all that remains of the root system is the stringy central core of the taproot. That condition usually distinguishes the aphanomyces from other root rots in the field.

Severe infection of young plants usually kills them before they blossom. Plants infected later seldom die but, because of a restricted root system, they are stunted; their leaves turn yellow and die from the ground up.

The fungus that causes aphanomyces root rot belongs to a group of fungi commonly called water molds. It has two kinds of spores. One, the oospore, or resting spore, is the thick-walled spore generally found in diseased tissue. It may also occur in culture on artificial media. The other, the zoospore, or free-swimming spore, has two long hairs, which enable it to move about in water.

In artificial culture media of relatively concentrated food materials, the oospore germinates directly into hyphae or fungal strands. If the nutrients are diluted or removed by washing, it germinates indirectly and produces the motile zoospores, which germinate into more hyphae. If the food supply is not too concentrated, the hyphae give rise to a multitude of zoospores capable of infecting the host tissue.

Very likely the nutrient concentration in the soil water affects hyphal growth and spore germination similar to that observed on artificial culture media. Aphanomyces root rot can occur on relatively dry soils, but it never becomes severe unless the soil is wet either as a result of a high water-holding capacity, as in clay soils, or frequent heavy rains. Severity of infection is associated generally with a large number of infection points on the root system. In relatively dry soil the nutrients are concentrated in the soil water; then few zoospores are apt to be produced and the infection points may be scarce. In wet soil, however, the soluble nutrients are leached or diluted and abundant spores may form, so that severe disease develops. That supposition is strengthened by the fact that commercial fertilizers, especially those high in nitrogen, sometimes aid in controlling root rot. The nitrogen fraction contributes heavily to the soluble salt content of the soil.

Fusarium root rot is serious in Colorado and the Pacific Northwest. In some places, New York among them, it and aphanomyces often occur together, and then the damage is worse than that caused by either organism alone.

The disease usually starts on the seedling at the junction of the root and stem where the germinated seed remains attached. From there it extends upward as a wedge-shaped, reddish-brown lesion. The decay also may extend downward and involve primary and secondary roots. There is no pronounced water soaking of the invaded tissue, and the discoloration is immediately apparent.

Further progress of the disease causes the tissue to shrink. In time the stem is girdled, and often the plant breaks near the place of seed attachment. A reddish discoloration of the central water-conducting vessels may occur, but usually only in the zone of seed attachment and seldom more than an inch beyond. If the main root is severed from the plant in the seedling stage, the plant attempts to maintain itself by sending out new roots through the underground part of the stem, but eventually it dies or is severely stunted.

Many species of *Fusarium* have been described as causing a root rot of pea, but the generally accepted causal organism is *F. solani* f. *pisi*.

Fusarium root rot occurs in fairly dry soils as well as wet soils. It flourishes when the soil temperature is around 80° F. It develops most severely when the spring planting time is warm or when the peas are planted late.

Rhizoctonia root rot of pea is primarily a disease of the seedling stage. It usually is of minor importance. The causal fungus is the sterile or *Rhizoctonia* stage of *Pellicularia filamentosa*. It causes injury to a wide variety of farm crops, particularly young seedlings and potato sprouts. The same fungus causes black scurf of potato tubers.

On peas, in the early stages, the

disease appears first as a slightly eroded, yellowish-brown zone on the underground stem and root in the region of the seed attachment. The tissue later turns a darker brown, and the lesions become sunken and heavily eroded. They may girdle the stem. More frequently, however, it attacks the growing tip of the emerging seedling, killing it before complete emergence. When that happens a new shoot is sent up, which also may be killed, so that the affected seedling may have a number of growing shoots with dead terminals. That is quite characteristic of this root rot.

Temperature is the primary factor in the development of this disease on pea. A soil temperature of 60° to 65° F. is most favorable.

VARIOUS SPECIES of *Pythium*, notably *P. ultimum*, can parasitize the tissues of the underground part of the pea plant. In the field, however, most of the damage from the organism results from seedling injury or seed decay.

Affected plants show a water-soaked, somewhat translucent and softened tissue extending above and below the region of seed attachment. As the disease progresses, the tissue becomes more and more discolored. It develops best in wet soil.

It is unlike *Aphanomyces* in being most aggressive during the seedling stage—it rots the germinating seed or kills the emerged seedling. If the plant survives and conditions are not unusual, *Pythium* by itself has little effect on root rot. High temperature, accompanied by high humidity or wet soil for a long time, may incite the organisms to further decay of the root system.

CONTROL OF THE ROOT ROT complex of pea is difficult because of the nature of the different causal fungi, most of which live indefinitely in the soil.

No resistant varieties are available. In infested areas growers have to depend on seed treatment, rotation, and good management of soil and crops.

Seed treatment offers protection against some phases of some of the root rots. It largely controls the seed decay and damping-off stages that result from infection by *Fusarium*, *Pythium*, and *Rhizoctonia*, but it does not preclude infection beyond those stages. Aphanomyces root rot, however, is not affected by seed treatment. The main purpose of seed treatment is to provide for healthier, more vigorous plants which are better able to ward off the effects of later infection.

Crop rotation, properly carried out, keeps the pathogens from accumulating in the soil. Because some of the pathogens—including *Pythium*, *Rhizoctonia*, *Aphanomyces*—attack different crop plants, rotation may seem of little value against them. Actually, though, a nonsusceptible crop immediately preceding the peas is of some value. Surveys of pea fields affected by *Aphanomyces* and *Fusarium* have demonstrated that the severity of root rot declines as the interval between pea crops increases. The main purpose of rotation, however, should be to prevent the build-up of the fungi in relatively healthy soil by 4- to 5-year intervals between crops rather than to attempt to reduce the pathogens after the soil has become heavily infested with them.

Good management of soil and crops deters the establishment of the fungi and enables the crop to produce if disease is present. High soil moisture favors aphanomyces root rot and others to some extent. Soils with good external and internal drainage should be selected therefore for peas. One should not return diseased pea straw to the soil immediately. Because peas affected by root rot have a restricted root system and behave as plants suffering from malnutrition, one should maintain high fertility in the soil. Applications of fertilizers sometimes make a crop possible despite aphanomyces root rot. In New York applications of commercial fertilizers at the rate of 50 to 100 pounds of nitrogen to the acre have given good results. At times, especially in bad disease years, the increase in yields does not justify the added cost of fertilizers. Gypsum at rates of one-half ton to 1 ton an acre have reduced aphanomyces root rot but not fusarium.

PEA WILT is one of a group of diseases that are incited by certain vascular Fusaria. It used to be confused with the root rot complex generally attributed to "pea-sick" soils. It differs from the root rots in that the cortical tissue is seldom affected under field conditions. Rather, the fungus establishes itself in the central core of water-conducting vessels and produces a toxin that causes a progressive yellowing and wilting of the foliage. Death of the plant may ensue.

The two distinct fusarial wilts of pea are wilt and near-wilt.

Fusarium wilt of pea was first discovered in Wisconsin in 1924. Since then it has been found in the major pea areas of the United States.

Its first noticeable symptom is a downward curving of the stipules and leaflets and a slight yellowing of the leaves. A superficial grayness like waxy bloom may also occur. The lower internodes thicken and the entire stem becomes somewhat rigid. Thereupon the plants may wilt abruptly at the top, followed by a shriveling of the stem. If soil temperature is low, such wilting may not occur. Instead the affected plant becomes yellow and withers slowly, leaf by leaf, from the ground upward. The central water core turns yellow or orange. Symptoms often occur in advance of the fungus in the vessels. At times wilt symptoms appear with very little vascular discoloration. The cortex, the outer part of the root and stem, is usually quite sound, unless root rot fungi enter it. In a newly infested field only a few scattered plants may show infection the first year. With repeated plantings to susceptible varieties the infestations appear as enlarged round areas, which eventually merge until the entire field becomes infested. The disease can spread rapidly.

Fusarium wilt of pea, caused by *Fusarium oxysporum* f. *pisi* race 1, exhibits features not altogether common among diseases caused by other forms of the species. But like the others the pathogen inhabits the soil and, once established, remains there indefinitely. The best temperature for growth of the fungus on artificial media is about the same as for other vascular Fusaria—about 80° to 85° F. The best temperature for disease development in soil differs from that of the other Fusaria. With most of them, disease development follows closely the optimum temperature for growth of the fungus, but in pea wilt it is distinctly lower, about 70°. If, however, peas are grown in nutrient sand culture and the sand is artificially infested with the pathogen, the optimum temperature for disease development is not different from that for the growth of the fungus. This suggests that a biological antagonism occurs at the higher soil temperature, which interferes with the infectivity of the pea wilt pathogen. That possibility is supported by earlier demonstrations that fusarium wilt would not establish itself in certain types of Wisconsin soils.

Fortunately for the pea industry in districts where the disease appeared, a heritable resistance was found among some varieties in the field. The resistance, a clear-cut character governed by a single dominant gene, was soon incorporated into desirable canning and market varieties. Today virtually every canning pea variety possesses wilt resistance and the disease is completely controlled.

After wilt-resistant varieties had been established, another vascular wilt appeared. It was discovered in Wisconsin in 1931 and was called near-wilt, because it resembled the old wilt in certain respects. Soon the same or similar diseases were reported in other regions.

The symptoms of near-wilt in the early stages resemble those of wilt—the stipules and leaflets curve downward and the foliage yellows. The wilting of the plant, however, resembles that in wilt when the soil temperatures are low; namely, a progressive withering of the leaflets upward from the base. The yellowing and wilting often occur up one side of the stem. There is less stunting of infected plants and the total progress of the disease is slower than in wilt. Usually the symptoms do not appear in a destructive manner until after bloom or pod set. As in wilt, there is a vascular discoloration, but in near-wilt the color is more of a brick red and occurs farther up the stem than in wilt. Sometimes the near-wilt fungus may cause some cortical decay, particularly of seedlings. In the field near-wilt appears on scattered plants, which may become quite numerous with repeated planting, but the spread generally is not so rapid as with wilt. Near-wilt does not occur in circular patches.

The near-wilt pathogen, *F. oxysporum* f. *pisi* race 2, has much in common with the wilt pathogen. It remains indefinitely in the soil. Its best growing temperature is the same as for the wilt fungus. It is unlike the wilt pathogen in that the best temperature for disease development in the soil is higher and follows that for the growth of the fungus.

Near-wilt is worse in warmer seasons, on late varieties, and on late plantings. The fungus that causes near-wilt establishes itself on all soil types. It enters the water-conducting vessels of the pea through either the root tips or at the cotyledonary node. The wilt fungus does not progress far enough up the stem to infect the seed, but the near-wilt fungus frequently travels the entire length of the stem. As a result, seeds (especially those of the dwarf, late varieties) are likely to become infected. The fungus can be disseminated to other fields by infected seed and surface-contaminated seed and by spreading diseased vines on the soil.

Workers at the Wisconsin Agricultural Experiment Station discovered one line of breeding material that appeared to have complete field resistance to near-wilt. The resistance is inherited as a single dominant gene. Delwich Commando was introduced as the first variety completely field-resistant to wilt and near-wilt.

Bacterial blight, although caused by a bacterium, behaves like some of the fungal blights. The disease occurs on all above-ground parts of the plant, but is most pronounced on the leaves, stems, and pods. The symptoms first appear as small, irregular water-soaked spots, which may enlarge to one-eighth inch across on the foliage and to about one-fourth inch on the pods. Streaks usually appear on the stems. The translucent leaf lesions usually turn to a golden-brown color. In time the lesions coalesce. The leaves wither and become papery. The stem lesions elongate and remain water-soaked or turn brown with age. On the pods the spots become slightly sunken but retain the water-soaked character. They may occur on the cheeks of the pods or along either suture.

The causal organism, *Pseudomonas pisi*, is carried over winter chiefly through the seed, either as a contaminant on the seed surface or internally as an infection. The organism can infect cowpea, sweet pea, hyacinth bean, and the perennial or everlasting pea. Possibly the bacterium overwinters in the vines of those hosts, although the seed-borne character is most important.

Spread and damage depend on weather. Spattering rains carry the bacterium from one plant to the next. Seedling infection may kill the plant. Usually, however, such infection provides the inoculum for spread to adjacent healthy plants. The extent of spread depends upon the frequency of rainy periods. If they occur often enough, within the span of a week, the primary infection from a tiny amount of infected seed can spread over a large field. In continued rainy periods the crop might be destroyed. Dry weather may check the disease.

The bacterium enters the plant through the stomata and through wounds. Any practice, therefore, that injures the plants, especially when they are wet, serves to increase infection. Hail injury frequently paves the way for rapid and severe infection.

The most effective control of bacterial blight is the use of disease-free seed. A 4- or 5-year rotation, recommended for the control of other pea diseases, would certainly eliminate diseased vines as a primary source of infection.

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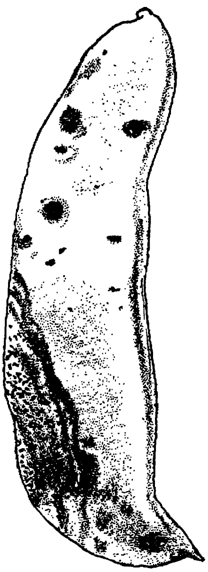

Lima bean scab.

Blights and Other Ills of Celery

A. G. Newhall

Celery is grown extensively as a truck crop on the muck lands and irrigated mineral soils of many States from Florida to Massachusetts, the Great Lakes States, and some of the Mountain and West Coast States. It is grown also as a market garden crop near many large population centers. It has an annual value of more than 50 million dollars.

In some districts celery has been grown intensively for nearly a century. The importation of much of our seed from Europe before 1920 and the free exchange of seeds and plants within the States at all times have meant that there are few if any celery diseases that we have not acquired. Appropriate control measures have been developed for many of them by Federal and State agencies and seed growers.

THE MOST WIDELY DISTRIBUTED and costly diseases of celery are the early and late blights, caused by the fungi *Cercospora apii* and *Septoria apii* var. *graveolentis*, and the rather minor bacterial leaf spot, caused by *Pseudomonas apii*.

Cercospora may be seed-borne, hence early blight occurs almost everywhere that celery can be grown. Because it requires hot weather for its most rapid development, the fungus is most troublesome on the early summer crops in the Northeastern and Great Lakes States. In Florida