Diseases that Seeds Can Spread

K. W. KREITLOW, C. L. LEFEBVRE,
J. T. PRESLEY, AND W. J. ZAUMEYER

SEEDS can spread plant diseases from a neighbor's farm to yours, from one State to another, and from a distant country to the United States.

Some disease pests may survive for years, safely lodged on or in a seed or on bits of stem or leaf mixed with the seeds.

Many seedborne diseases we cannot recognize when we examine the seeds, and we cannot detect them when we incubate them. Only by inspecting the growing crop can we be sure that the seeds are free of viruses, bacteria, and fungi, organisms that cause disease and are called pathogens.

Most seedborne parasites do not affect germination immediately. They do not kill the seeds but multiply on emerging seedlings, which may then succumb to the disease. Some seed lots that show high germination in tests are nearly destroyed when they are planted under conditions that favor development of the organisms they carry.

The control of seedborne diseases begins with the seed. It is easier and cheaper to eliminate a pathogen from a few pounds of seeds than to attempt to spray or dust entire fields of growing plants.

Some pathogens can be eliminated or their range of occurrence can be reduced by treating the seed with suitable chemical compounds, hot water, or fumigants. Seed-cleaning equipment can remove many lighter, disease-infected seeds and fragments of diseased plant parts carried with them.

Some seedborne diseases are not so prevalent in regions of low rainfall and relatively high temperature during the growing season. Seeds produced under such conditions usually are free of many of these destructive, disease-causing bacteria and fungi. The commercial production of seed of certain vegetable, ornamental, and forage crops therefore has been shifted from humid areas of the East and Midwest to irrigated, semiarid western areas.

Careful inspection and weeding out of diseased plants in fields destined for seed production greatly reduce the incidence of seedborne diseases.

Although hundreds of pathogens are known to be seedborne, effective control measures have eliminated some and reduced the incidence of others to the point where they are troublesome only occasionally.

We discuss here the seedborne diseases that occur oftenest or have special significance.

SOME OF THE worst diseases of vegetable crops are seedborne. In most instances, no varieties resistant to seedborne diseases have yet been developed. For some, no chemical seed treatment gives satisfactory control. The vegetable grower therefore should make every effort to plant disease-free seeds.

Most of the seeds of beans and peas used by processors, market gardeners, and home gardeners before 1925 were produced in New England, New York, and Michigan. Frequent rainfall and high humidity there favor development of the three most important seedborne diseases of beans—anthracnose, common bacterial blight, and halo bacterial blight, which are incited by *Colletotrichum lindemuthianum*, *Xanthomonas phaseoli*, and *Pseudomonas phaseolicola*, respectively. The environment is ideal also for the two major seedborne diseases of pea, ascochyta blight, caused by *Ascochyta pisi*, and bacterial blight, caused by *Pseudomonas pisi*.

Before western-grown seeds came to be used, losses from the three bean diseases in some years amounted to 30 or 40 percent of the crop, and severe outbreaks of ascochyta blight and bacterial blight of peas often were reported in the East and the Midwest. These diseases reduced yields and impaired the quality of the canned product.

Although bean seeds grown in the Western States are free of anthracnose, they are not free of the bacterial blight organisms in some years.

The bacterial blight diseases frequently are widespread in Nebraska, Colorado, Wyoming, and Montana and occur infrequently in California and southern Idaho.

Rain, hail, and high humidity following storms, which are responsible for the spread and development of the bacterial blight organisms, occur much less frequently during the growing season in parts of Idaho and California than in the other States. Consequently the production of seed of snap beans now centers in those sections. Seed of most of the bush types is grown in Idaho and that of the pole types in California.

Weather conditions in the Columbia Basin of Washington also are unfavorable for the development and spread of the three bean diseases, but curly top, a virus disease that kills beans of susceptible varieties, is widespread there. Since no garden varieties have yet been developed that resist curly top, no seed of garden beans is produced in the Columbia Basin. Several varieties of dry beans resistant to curly top are grown there.

The most important seedborne virus diseases of beans are common bean mosaic virus and a strain of it referred to as the New York 15 virus. Most of the varieties of snap and dry beans now grown are resistant to these two viruses, and the losses they once caused have been reduced. Certification of seed fields of dry beans also has been effective in reducing seed transmission of viruses in the few susceptible varieties still grown in 1961.

Most of our pea seed originates in southern Idaho, the Palouse section of northern Idaho, and the Columbia Basin. Ascochyta blight and bacterial blight rarely occur there because of low rainfall.

As practically all the bean and pea seeds of the market and processing varieties used in the United States now are grown in a few of the Western States, anthracnose and the bacterial blights of snap beans and ascochyta and bacterial blight of peas have been reduced to minor importance throughout the country. These diseases caused severe and widespread damage to both crops in the 1930's and cost the American farmer millions of dollars each year in crop losses.

Lima beans grown in the South and East sometimes are affected by two seedborne diseases—bacterial spot, caused by *Pseudomonas syringae*, and stem anthracnose, caused by *Colletotrichum truncatum*. These diseases differ from bacterial blight and anthracnose of snap and dry beans.

Most of our seeds of lima beans are grown in California, where the environment does not favor the development of these diseases and they are not known to occur. Even though disease-free seed is used, stem anthracnose sometimes causes severe losses in the South and in some of the Eastern States. The causal fungus may overwinter on lima bean refuse and infect a crop the following year if the environment is ideal for the development of the disease and strict crop rotation is not practiced.

Seed of cabbage, cauliflower, rutabaga, and turnip, like seed of beans and peas, once were produced commercially in the East and Midwest. Because of the destructiveness of two seedborne diseases—black rot, caused by the bacterium *Xanthomonas campestris*, and blackleg, caused by the fungus *Phoma lingam*, both of which spread and develop only in humid, rainy weather—production of seeds was shifted to the Pacific Coast States. Because of low rainfall during the time these vegetables are growing in the seedbed and as transplants in the field, the organisms causing the two diseases do not become established.

Bacterial canker of tomato, a seedborne disease caused by *Corynebacterium michiganense*, is found in field-grown tomatoes from New Jersey to California and in several Southern States. The disease can be controlled by fermenting the seed and pulp for 72 hours before extraction. Soaking freshly extracted seed in acetic acid is also effective. Inspection and certification of seed fields has greatly reduced the importance of the disease.

Another seedborne bacterial disease, angular leafspot of cucumber, caused by *Pseudomonas lachrymans*, occurs mainly in humid regions. Seed grown in arid parts of the interior of California usually is free of the organism.

Late blight, *Septoria apii-graveolentis*, a destructive foliage blight of celery, affects the seeds and is widely distributed by this means. Since the fungus in infected seed usually dies before the seed loses viability, 3-year-old seed is recommended as the most effective control measure.

Lettuce mosaic virus causes considerable damage in the coastal valleys of California and losses in all parts of the United States. Fewer than 1 percent of the seeds are infected with the virus; the disease therefore causes little damage unless the virus is transmitted by aphids from infected seedlings or weeds to lettuce plants.

No resistant varieties are available but losses from the disease are being reduced by roguing diseased plants from seed fields and producing seed in fields free from wild lettuce species and other weeds infected with the virus. Isolation of seed fields from other lettuce fields is also recommended.

Many of the most destructive diseases of oilseed crops are seedborne. They occur primarily in the more humid regions of the United States with the possible exception of bacterial blight of cotton, which is most severe in semiarid areas. Because of climatic requirements and for economic reasons, much of the total oilseeds are produced in humid sections where rainfall is moderate.

The production of soybeans in the South Central and Southeastern States has increased. This shift of production from the North Central States has accentuated the seedborne disease problem in this crop. Such diseases as purple seed stain, target spot, wildfire, and bacterial pustule, caused by *Cercospora kikuchii*, *Corynespora cassiicola*, *Pseudomonas tabaci*, and *Xanthomonas phaseoli*, respectively, are more prevalent and destructive in the South than elsewhere.

Other seedborne diseases of soybean, such as brown spot, frogeye, downy mildew, and bud blight, caused by *Septoria glycines*, *Cercospora sojina*, *Peronospora manshurica*, and the tobacco ringspot virus, respectively, are hazards. Varieties of soybeans resistant to several of the important seedborne diseases are available and are usually recommended for areas where these diseases occur.

The gradual shifting of the center of cotton production toward the Southwest has increased the problem of bacterial blight, caused by *Xanthomonas malvacearum*.

Although the seedborne diseases anthracnose and wet weather blight, caused by *Colletotrichum gossypii* and *Ascochyta gossypii*, are largely controlled by the use of chemical seed protectants, diseased crop residues frequently are the source of new epiphytotics.

Resistant varieties are available that provide practical control for the seedborne diseases fusarium wilt and bacterial blight, which are caused by *Fusarium oxysporum* f. *vasinfectum* and *Xanthomonas malvacearum*. Destruction of diseased crop residues and thorough treatment with chemical seed protectants control most seedborne diseases of cotton.

Ohio and Kentucky led in the production of flax before 1900. Production has shifted since to Indiana, Illinois, Iowa, Minnesota, and North Dakota. This shift was caused partly by the injurious effects of flax wilt in the older cultivated lands. Wilt, rust, and pasmo caused by *Fusarium oxy-*

sporum f. *lini*, *Melampsora lini*, and *Septoria linicola*, respectively, are perhaps the most important diseases of flax in the United States.

Another seedborne disease that is widely distributed and occasionally destructive is anthracnose (*Colletotrichum lini*). Although losses from seedborne diseases may be spectacular, in recent years such losses have been smaller in flax than in many other crops. Resistant varieties give adequate control of wilt, rust, and pasmo, while chemical seed treatment is effective in controlling anthracnose and seedling blight.

Although commercial production of peanuts is concentrated in the Southern and Southeastern States, where conditions are favorable for the development of many disease-producing organisms, there are no seedborne diseases of economic importance. The practice of planting only shelled peanut seed and the use of chemical seed protectants has largely eliminated seedling disease problems.

Production of safflower is confined to the arid and semiarid parts of the United States. Leaf spots and molding of the seed before harvest in the humid areas have been factors limiting production. The only serious seedborne disease of safflower is rust caused by *Puccinia carthami*. Use of volatile mercury compounds as seed protectants has given satisfactory control.

The production of castorbeans also is concentrated in areas of relatively low rainfall because of leaf spot diseases and molding of the capsules, which frequently cause half of the crop to shed before harvest in humid areas. The seedborne disease organisms *Alternaria ricini*, *Sclerotinia ricini*, and *Xanthomonas ricinicola* occasionally cause damage, but they are satisfactorily controlled by chemical treatment of seeds.

Sesame is grown mostly in the northwestern part of Texas, eastern New Mexico, and western Oklahoma. The only seedborne disease of consequence is bacterial leaf spot, which is caused by *Pseudomonas sesami* and is controlled by soaking the seed in bactericidal solutions before planting.

MANY of the bacteria that cause diseases in cereals and grasses are seedborne. Some, such as bacterial wilt of corn (*Bacterium stewartii*), are restricted largely to one host. Others, such as the halo blight of oats, caused by *Pseudomonas coronafaciens* var. *atropurpureum*, and bacterial blight, caused by *Xanthomonas translucens*, occur widely on cereals and grasses.

The bacterial diseases occur most frequently in areas where high humidity or wet weather occurs during the time heads are forming. Bacterial infection in cereal and grass seeds usually is confined to the hull, however; the bacterium that causes wilt of corn can penetrate deeply beneath the seedcoat.

Bacterial diseases are best controlled by growing available resistant varieties. They can also sometimes be controlled by treating the seeds with bactericides.

Numerous fungi are seedborne in cereals and grasses. Some of the commonest, such as species of *Alternaria*, are weakly pathogenic. Among the most destructive are species of *Helminthosporium*, *Fusarium*, and *Diplodia*. The *Helminthosporium* and *Fusarium* fungi are the commonest seedborne root rotting pathogens. Sowing infected seed results in seedling blight, root rot, and lowered yields. Striking differences exist in the prevalence of these fungi in different seasons and in different localities. Seed of wheat, oats, and barley with 10 to 25 percent of *Helminthosporium* and *Fusarium* infection is fairly common some seasons, and seed lots containing more than 50 percent of infected seed are not uncommon.

Species of *Helminthosporium* frequently incite kernel blights of cereals and grasses. *Helminthosporium teres* causes net blotch and kernel blight of barley. *H. sativum* causes a kernel blight of barley, wheat, and grasses. Diseased kernels turn dark brown or almost black, notably near the germ end. The condition is sometimes called black point.

A similar disease incited by *H. avenae* occurs on oats and several related grasses. Most of the commercial varieties of oats are moderately resistant.

Victoria blight of oats, incited by *H. victoriae*, nearly eliminated several high-yielding, rust- and smut-resistant varieties of oats in 1946 and 1947. The disease is primarily a seedling and culm trouble, but infected seeds spread the pathogen. Resistant varieties are available. Treating seeds with organic mercury fungicides frequently reduces seedling losses from helminthosporium diseases.

Fusarium head blight or scab, a seedborne disease of wheat, barley, rye, and some grasses, occasionally is damaging. The disease occurs most frequently in the humid and subhumid eastern and central Corn Belt. Flower infection occurs, and diseased heads turn straw colored or light brown. Frequently a pinkish mold growth develops, and kernels have a rough scabby surface. Diseased grain is weakened in germination and contains compounds poisonous to humans and pigs. No highly resistant varieties of wheat, rye, or barley are available. Treating seed with organic mercury compounds helps to control seedborne infection.

Seed infection is less common in hybrid corn than in open-pollinated varieties, partly because most hybrids contain lines selected for disease resistance and the artificial drying of most hybrid seed corn checks the spread of initial disease infection.

Among the most destructive seedborne diseases of corn are ear and stalk rots, which are incited by *Diplodia zeae* and species of *Gibberella*. Diplodia ear rot is most prevalent in the warmer, more humid regions and in seasons when June and July are dry and August and September are wet. Hybrids that have loose husks, which expose the ear tip, or have upright ears show a high incidence of diplodia ear rot. Hybrids that dry quickly usually are less diseased than those that dry slowly.

The gibberella ear rots are more prevalent in the northern and western Corn Belt. Wet weather at silking time favors infection of the ears. The fungi often gain entrance to the ear through channels made by earworms and corn borers. Some varieties that develop breaks in the seedcoat enable fungi to gain access for infection.

When seeds infected with either *Diplodia* or *Gibberella* fungi are planted in cold soil, they decay or the seedlings die before emergence. In warmer soils, seedlings usually emerge but are stunted because the roots rot.

Ear and stalk rots are best controlled by planting disease-resistant hybrids, treating seeds with recommended fungicides, and rotating crops.

The smut fungi are among the most important seedborne organisms of cereals and grasses. Smuts that attack all or parts of the heads generally destroy the seeds. Leaf and stem smuts only occasionally affect the heads, but often they suppress the formation of seeds in diseased plants.

Head, kernel, and leaf smuts infect cereals and grasses by spores, which lodge in or on seeds of healthy plants. During threshing operations, smut spores from infected plants coat the surface of healthy seeds. Seed and smut spores germinate simultaneously, and young seedlings become diseased.

Treating the seeds with fungicides destroys adhering smut spores. Crop rotation also aids in controlling the smut diseases. Where resistant varieties are available, they should be grown to prevent infection by spores in the soil.

Loose smut of wheat, barley, and some grasses differs from most other smut diseases in that it is flower infecting and incites a deep infection in seeds. The disease occurs widely in humid and subhumid areas and is less common in dry areas. Because of the deep-seated infection, treatment with fungicides is ineffective, and diseased seed must be treated by immersion in hot water or by steeping in warm water and storing for a period under anaerobic conditions.

Ergot of cereals and grasses, not strictly a seedborne disease, is important because flower infection induces sterility. In infected heads, seeds are replaced by fungus sclerotia that are harvested with the seeds or fall to the ground where they germinate and infect plants the next season. Because ergot infection spreads from grasses to cereal crops, neither crop rotation nor the use of ergot-free seeds completely controls the disease. No varieties of cereal grains are resistant to ergot, but some resistance has been found in forage grasses like dallisgrass.

Most grain and grass nematode diseases are associated with soil infestation, but several are seedborne. They include the white tip disease of rice, which occurs in Louisiana, Arkansas, and Texas; the nematode disease of wheat and rye, which occasionally is troublesome in the Southeastern States; and the grass seed nematode, which exists mainly in the Pacific Northwest.

In each disease, nematode larvae infest the growing point and are carried upward as the plant grows, ultimately infesting the grass or grain head.

White tip disease of rice differs from the others in that the nematode larvae are seedborne on the surface of the kernels or under the hull, and they do not induce formation of a gall that replaces the grain.

In the nematode diseases of grain and grass seed, kernels are replaced by one or several galls in each head. The galls are filled with nematode larvae that are very resistant to drying, low temperatures, and chemicals.

The nematodes can remain alive in dry galls for 10 years or more. Because of their longevity and resistance to ordinary treatment, nematodes can be spread in the screenings, on threshing equipment, in floodwater, and with the seeds.

White tip disease of rice is controlled by seeding grain in water. Infested seed can also be treated with nematocides and fumigated with methyl bromide.

The grain and grass seed nematode diseases are controlled by sowing seed from noninfested fields, by removing galls with specific gravity separators, by treating infested seed in hot water, and by growing nonsusceptible crops in infested fields.

The grass seed nematode in chewings fescue has been controlled in some fields by burning straw and stubble following seed harvest.

Barley stripe mosaic or false stripe is one of the few virus diseases of cereals and grasses known to be seedborne. Infection has resulted in reductions in yield of 75 percent in wheat and 64 percent in barley. The disease is controlled by growing resistant varieties and by treating seeds with hot water.

Many diseases are seedborne in forage legumes, but it is difficult to evaluate their importance because many of the legumes are perennials and diseases attacking them occur in epidemic proportion in nearby fields and on uncultivated plants growing in fence rows or along roadways.

In most fields, airborne contamination largely nullifies the benefits derived from planting disease-free seeds. The only practical solution to the problem is to sow adapted, disease-resistant varieties where available.

Blackstem diseases of alfalfa, clovers, and vetches induced by *Ascochyta* spp. are among the most prevalent and destructive seedborne troubles of these crops. Heavily infected alfalfa fields have yielded 30 to 50 percent of diseased seed. Inspection of random alfalfa seed samples has revealed that 1 to 40 percent of the seeds are infected by the blackstem fungus. Blackstem severely restricts seed production if infection occurs during the flowering and seedset period. Seed infection can be reduced by treatment with fungicides.

Some diseases occur infrequently or are locally important. They usually reduce seed production and may be spread to uncontaminated fields with the seed. An example is blackpatch, a fungus disease of red clover and several other legumes. During wet seasons, heavy infection by this fungus reduced seed yield up to 50 percent in fields of red clover in West Virginia. Treating seed with fungicides was only partly successful in controlling the disease.

The bacterial wilt disease of lespedeza is seedborne and is widely distributed. Reductions of 30 to 50 percent in forage yield have been recorded in Missouri. The disease occurs chiefly in annual lespedeza. Some experimental strains of plants are more tolerant than others, but no resistant varieties are available. Only seeds from disease-free fields should be planted.

Several diseases are seedborne in lupines. During wet seasons, the fungi that cause anthracnose (*Glomerella cingulata*) and brown spot (*Pleiochaeta setosa*) attack plants and often infect the seeds.

In northern Florida and southern Georgia, the incidence and destructiveness of seedborne virus diseases is one of the major factors limiting seed production of sweet yellow lupine. Blue and white lupines are damaged less severely. Incidence of the diseases can be reduced by planting seed from disease-free fields. No resistant varieties were available in 1961.

Stem nematodes perhaps are introduced into new areas on seed or in plant debris carried with the seed. The stem nematode disease of alfalfa and red clover is most serious in the Western States, but infested fields have been reported in New York, Virginia, and North Carolina. Only seed from noninfested fields should be planted. One should avoid moving soil or irrigation water from infested to noninfested fields. Volunteer plants should be destroyed when a field is plowed. Nonsusceptible crops should be grown for at least 3 years. Lahontan and Nemastan, which are resistant varieties of alfalfa, should be grown in the West.

MANY DISEASES of ornamentals are seedborne and cause serious losses, but much of the seed is grown in Western States, where the dry weather during seed formation and harvest favors the production of disease-free seed. Some bacteria, fungi, and viruses attack ornamental plants grown for seed. They exact a toll in loss of seed yield and poor stands.

The heterosporium disease of nasturtium, incited by *Heterosporium tropaeoli*, is internally and externally seedborne in up to 93 percent of the seed. Infection occurs in maturing fruits when humidity is high. The fungus survives in seeds for at least 3 years. Stem lesions develop in seedlings from infected seeds, and the fungus multiplies and spreads to adjacent plants. The disease is controlled by treating seeds in hot water.

The alternaria disease of zinnias, caused by *Alternaria zinniae*, may be seedborne. The disease occurs oftenest in the humid Eastern States, where it causes spotting of blossoms, leaves, and stems. Treating seeds with a fungicide to reduce the hazard from seedborne inoculum is suggested. Field and garden sanitation should be practiced, because the fungus may overwinter in the soil.

Fusarium wilt, caused by *Fusarium oxysporum* f. *callistephi*, is the most serious disease of China aster. It causes damping-off of seedlings, a wilt of mature plants, and decay of flowers in storage. Seeds presumably become contaminated with spores during threshing. Spores can also be carried on debris mixed with the seed.

The seedborne fungus is even more destructive in steamed soil and is thus more severe in greenhouses and seedbeds. Soil once infested with the fungus is ruined for growing susceptible varieties of asters. Seeds therefore must be treated with mercury-containing fungicides before planting them in noninfested soil, but seed treatment does not protect seedlings growing in infested soil. Varieties possessing some resistance to fusarium wilt are available and should be grown in infested soil.

Erwinia phytophthora, the organism that causes bacterial crown, stem, and bud rot of delphinium, is carried in seeds. Development of the disease is favored by excessive soil moisture. The crop should be irrigated with the least amount of water required and water should be applied in furrows somewhat distant from the rows. Treating seeds in hot water is helpful.

A bacterial blight of garden stock, *Mathiola incana*, caused by *Phytomonas incanae*, has occurred since 1933 in plantings for seed production in the coastal areas of California. The principal damage has been a serious reduction in seed production in some years. In home gardens and commercial cut-flower enterprises, many plants may be killed or severely stunted. Since the organism is seedborne, seedlings are often infected and killed. Under humid conditions the disease may spread rapidly from the infected seedlings to neighboring plants. The disease can be controlled by treating seeds in hot water.

K. W. KREITLOW *is research leader for forage crop disease investigations in the Forage and Range Research Branch, Agricultural Research Service, Beltsville, Md. He received degrees from the University of Minnesota and Louisiana State University. He has investigated forage disease problems since 1941.*

C. L. LEFEBVRE *is Assistant Director for Plant Science Programs in the State Experiment Stations Division, Agricultural Research Service, Washington, D.C. He is a graduate of the University of Minnesota and Harvard University. He joined the Department in 1937.*

J. T. PRESLEY *is research leader for cotton pathology investigations in the Cotton and Cordage Fibers Research Branch, Agricultural Research Service, Beltsville, Md. He received degrees from the University of Maryland and the University of Minnesota. Since 1935 he has devoted the major part of his time to cotton diseases.*

W. J. ZAUMEYER *is Leader, Bean and Pea Investigations, Vegetables and Ornamentals Research Branch, Agricultural Research Service, Beltsville, Md. He is a graduate of the University of Wisconsin.*

Seed Treatments for Control of Disease

EARLE W. HANSON, EARL D. HANSING, AND W. T. SCHROEDER

SEED treatments are used to prevent or reduce losses from diseases caused by organisms associated with seed or present in the soil.

Such organisms are associated with seeds in several ways. They may be mixed with seed in the form of sclerotia, smut balls, nematode galls, and infested plant parts. Pathogens may be present in or on seeds.

Treating infested seeds with chemicals or with heat greatly reduces the incidence of many seedborne pathogens. Seed treatment is used also to protect healthy seed against soilborne organisms, notably *Pythium*, *Fusarium*, and *Rhizoctonia*, which cause seed rots, preemergence damping-off, and seedling blights of many crops.

Some treatments kill organisms mixed with the seed or on its surface. Some destroy pathogens within the seeds. Others kill or retard the activity of soil organisms near the planted seeds.

Mechanical, physical, and chemical methods are used.

The mechanical method is designed to remove infectious materials mixed with seeds. Seeds should be thoroughly cleaned before seeding. Mechanical treatment does not kill pathogens within a seed. It does not remove all organisms from the surfaces of seeds or protect them against soilborne organisms. Mechanically treated seed therefore often requires further treatment.

Physical methods are used primarily to kill pathogens deep in the seeds. Some pathogens, such as those that