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report on
PLANT
DISEASE

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# CLUBROOT OF CABBAGE AND OTHER CRUCIFERS

Clubroot of cabbage and other crucifers, caused by the soilborne fungus *Plasmodiophora brassicae*, is widely distributed worldwide wherever plants of the mustard family (Crusiferae) are grown. It can cause serious losses in soil that has become infested. Soil commonly remains infested for many years even in the absence of susceptible host plants. Besides cabbage, such related vegetables as broccoli, Brussels sprout, Chinese cabbage, cauliflower, collard, garden cress, horseradish, kale, kohlrabi, mustards, radish, rape, rutabaga, sea kale, turnip, and watercress may become infected. Such popular garden flowers as alyssum, candytuft, dames-violet, honesty (*Hesperis*), peppergrass, rockcress, stock, sweet alyssum, wallflower (*Erysimum*), and western wallflower occasionally become infected. Most cruciferous weeds, including charlock, pennycress, shepherd's purse, wild mustards, wild radish, and yellow-rocket or wintercress are susceptible and serve to perpetuate the causal fungus between crops. The fungus also infects a few plants outside the cabbage or mustard family including corn poppy, mignonette, red clover, and ryegrass.

*Figure 1. Clubroot of cabbage (BASF photo).*

## SYMPTOMS

Plants infected with clubroot become unthrifty, grow slowly, and appear stunted with pale green to yellowish leaves. The leaves may wilt on bright dry days and partly recover at night. The lowest and outer leaves may turn yellow and often drop prematurely. Plants may die before maturing or fail to produce a marketable head. When diseased plants are dug, the root system appears greatly distorted with a mass of small to large, spindlelike, knobby, or club-shaped swellings (Figure 1 and Figure 2, 9-11). The swellings, galls, or clubs may appear on the fine rootlets, secondary roots, the taproot, or the underground part of the stem. Severely distorted roots are unable to absorb and distribute mineral and nutrients and water from the soil, which results in the tops becoming gradually stunted, yellowish, and somewhat wilted. Frequently the clubs are invaded and decay from secondary soft-rot organisms. The swellings are usually smoother and larger than those caused by root-knot nematodes. A microscopic examination may be necessary to distinguish between the nematode damage and clubroot.

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In seedbeds and fields or gardens where the plants are growing well, symptoms may not become evident until the plants are pulled and the tiny clubs are observed on the roots (Figure 2,9).

## DISEASE CYCLE

The clubroot fungus enters a plant through the fine root hairs on the young rootlets or through wounds in the secondary roots and underground stem. Infection occurs between 50° and 95°F (10° to 32°C) with an optimum between 68° and 77°F (20° to 25°C). After the crucifer root enlarges, the fungus reaches the cambium in the plant and is transformed into plasmodia, multinucleate masses of protoplasm (Figure 2, 1-2).

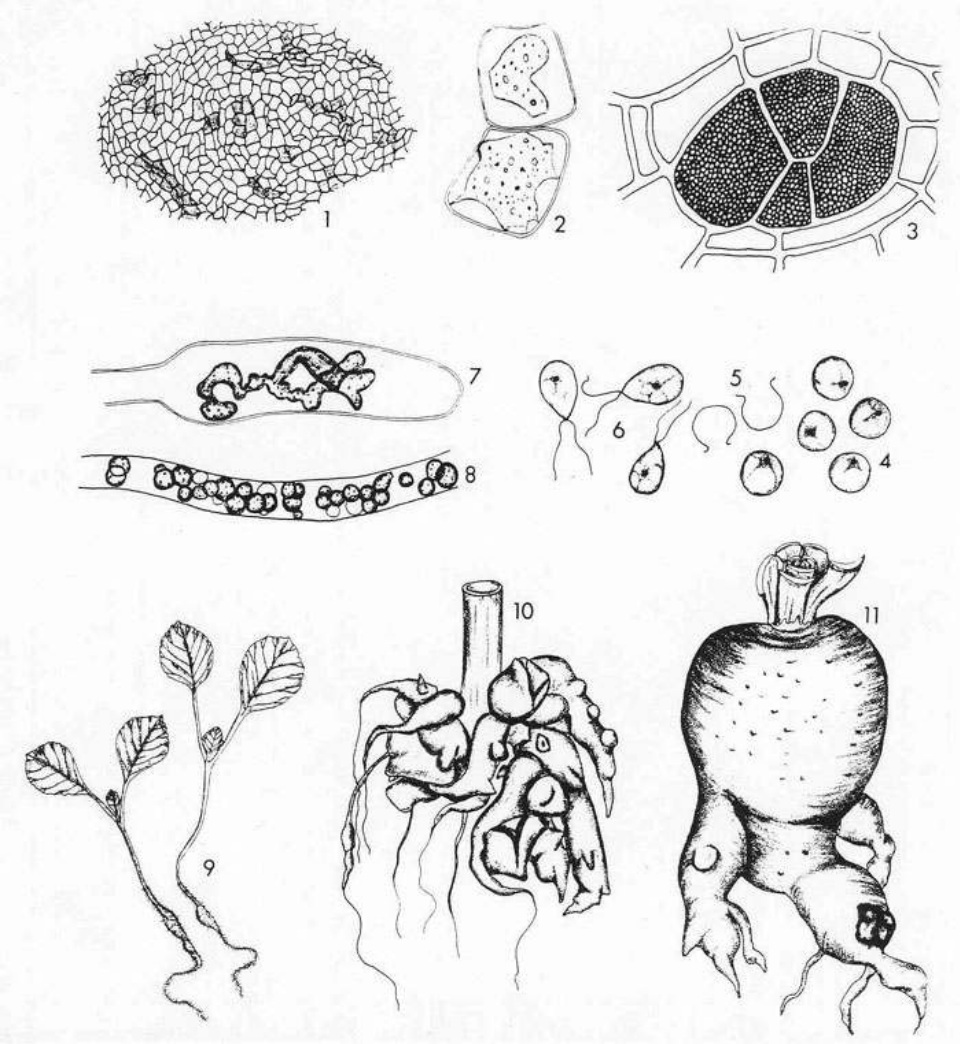


*Figure 2. The clubroot fungus Plasmodiophora brassicae: (1) scattered, plasmodia-filled cells in a cross section of a susceptible cabbage root; (2) young plasmodia within two host cells, which have not yet developed into zoosporangia or resting spores; (3) host cells filled with resting spores; (4) zoosporangia; (5) two empty zoosporangia that have just released biflagellate zoospores or swarm spores; (6) single zoospore; (7) zoosporangial plasmodium in a cabbage root hair; (8) mature and discharged zoosporangia in a root hair; (9) a young infected cabbage seedling; (10) an older, severely distorted cabbage root system; and (11) a clubroot-infected turnip. The fungus overseasons as thick-walled resting spores in crop debris or soil. Drawing by L. Gray.*

As the plasmodia pass through cells, they become established in some of them where they commonly divide into masses of resting spores (Figure 2, 3). The presence of the fungus stimulates cells to enlarge and divide abnormally, and infected cells may be five or more times larger than adjacent noninfected cells (Figure 2, 3). The infected cells are distributed in small groups throughout the diseased tissue (Figure 2, 1).

The stimulus responsible for the abnormal growth of the cells seems to diffuse in advance of the clubroot fungus and acts on the noninfected cells in diseased tissue as well as on the infected ones. Actively growing and dividing cambium cells are more easily invaded by the fungus and are more responsive to the stimulus than are other cells.

When only a small number of cells in a club are infected, the individual plasmodia become large, whereas when many cells are infected, the plasmodia remain relatively small. Thus, there is a fairly constant ratio

between the volume occupied by the plasmodia and that of the total diseased tissue, with the former being about 30 percent of the latter.

The plasmodium-infected clubs not only use much of the nutrients and water required for normal growth of the host plant, but they also interfere with the absorption and translocation of mineral nutrients and water through the root and stem tissues, resulting in gradual stunting and wilting of the aboveground parts of the plant. The rapidly dividing and greatly enlarged cells of the club tissues are unable to form a restraining cork layer at the surface and are easily ruptured and invaded by bacteria and other microorganisms. The later disintegration of the host tissues by the invading bacteria leads to the formation of substances toxic to the plant, causing at least part of the wilting of the tops.

When the host tissues decay, large numbers of resting spores (Figure 2, 4) are released into the soil. Under favorable conditions of temperature and moisture, a resting spore germinates (Figure 2, 5) to form a single zoospore (Figure 2, 6) which swims about for a few minutes, comes to rest, and forms a plasmodium which infects a root hair (Figure 2, 7). The plasmodium spreads to other cells and may later be transformed into zoosporangia (Figure 2, 8). Each zoosporangium releases 4 to 8 secondary zoospores which are discharged outside the host through holes dissolved in the host cell wall. The zoospores swim about for a while before many unite in pairs, form plasmodia, and spread into the host tissues in all directions, producing the typical disease symptoms (Figure 2, 8-11). The plasmodia are eventually transformed into overwintering resting spores which are released into the soil upon disintegration of the host cell walls by secondary microorganisms, completing the disease cycle. The resting spores may persist for 10 years or more in the soil depending on the soil type. The fungus spreads from one locality to another, principally on infected transplants. It may also spread locally in surface-drainage water, windborne soil, infested manure or compost, or crop refuse and in the soil clinging to farm equipment and tools, shoes, and the feet of animals. The organism is not carried on or in the seed. Clubroot is most severe on plants growing in acid to neutral soil (pH 5.0 to 7.0) and in poorly drained gardens or sections of fields.

## CONTROL

1. If possible, abandon badly infested soil for growing crucifers. Locate the seedbed where no diseased crucifers have ever been grown and into which infested soil cannot wash.

2. Prevent contamination of clean fields. Remember that the causal fungus is generally brought in on infected transplants; by surface floodwater draining from an infested field; by infested soil carried on farm equipment, man, and animals; and by propagative plant parts, such as seed tubers and bulbs. Manure from stock fed on diseased root crops may also be a source of infection as is compost containing clubroot-infected plants. The importance of never planting contaminated lots of plants cannot be overstated. Once the disease is present in a field or garden, control measures are difficult, expensive, and not totally effective.

3. Plant only disease-free, preferably certified, seedlings–or grow your own–in a seedbed soil disinfested of the causal fungus by heat or chemicals. Eradicate all crucifer weeds in or near seedbeds and fields. For the latest weed control recommendations read Illinois Circular 1373, Midwest Vegetable Production Guide for Commercial Growers (revised annually).

4. Where feasible, apply sufficient hydrated “quick” lime or calcium hydroxide to the soil (a minimum of 1,500 pounds per acre per crop) about 6 weeks before planting to bring it to a pH of 7.2 or higher.

Ground limestone is ineffective. From the results of a soil test report, your nearest Extension adviser can determine the approximate amount of lime (1,500 to 5,000 pounds) necessary for producing the desired alkalinity. Liming is ineffective in dry seasons or in light sandy or loose muck soils. This practice should not be followed where crucifers are grown in rotation with potatoes since common scab of potatoes is serious in slightly alkaline soils.

5. For transplanting cabbage, broccoli, Brussels sprout, and cauliflower add 6 pounds of PCNB to 100 gallons of water (or 1 ounce per gallon); use 3/4 pint of the suspension per plant or about 400 to 600 gallons per acre for cabbage. This treatment should be used in addition to No. 4 (above). The PCNB can be used in conjunction with fertilizer and insecticide materials and applied simultaneously in solution. Agitate the solution constantly to prevent the PCNB powder from settling out.

6. Where possible, either drain or do not plant in wet soils. This is improtant because the infective zoospores of the clubroot fungus require free water in which to germinate and move to the roots.

7. Always decontaminate equipment and tools after working in a field suspected of being infested with the clubroot fungus. Thorough washing to remove the soil followed by steaming or by spraying or washing all surfaces with a disinfectant such as “Lysol” or 4 percent formaldehyde is required.

8. Resistant varieties are available for some crucifers. Some varieties or strains of kohlrabi, rutabagas, turnips, peppergrass, horseradish, radish, marrow-stem kale, garden cress, stock, candytuft, and wallflower are normally quite resistant in most areas. Numerous strains or races of the clubroot fungus are known, however; therefore a variety that is resistant in one county or locality may be susceptible in another. For current information on recommended varieties for Illinois refer to C1354, Illinois Homeowners’ Guide to Pest Management.

For information on obtaining publications mentioned above, contact your nearest Extension adviser or ITCS, University of Illinois, P345, 1917 S. Wright St., Champaign, IL 61820.