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Clubroot Disease of Cruciferous Crops

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CLUBROOT DISEASE OF CRUCIFEROUS CROPS

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Clubroot has been recognized as a plant abnormality since the thirteenth century in Europe. The first intensive scientific studies of clubroot were made by the Russian scientist Woronin in the 1870s. Clubroot is now found worldwide and can cause severe crop losses in cabbage, cauliflower, broccoli, Chinese cabbage, and Brussels sprouts. Cruciferous weeds can act as reservoirs of the pathogen between susceptible crops.

The susceptibility of various hosts is difficult to measure precisely. For general consideration, the following classification may be used:

- **Most susceptible** — cabbage, Chinese cabbage, Brussels sprouts, some varieties of turnips, wormseed mustard, and some species of candytuft.
- **Medium susceptible** — kohlrabi, kale, cauliflower, collards, broccoli, rutabaga, sea kale, some varieties of turnips and radishes, and some species of candytuft.
- **Mildly susceptible** — rape, black mustard, some turnip and radish varieties, and tumble-mustard.
- **Very resistant or occasionally immune** — winter cress or yellow rocket, horseradish, shepherd's purse, wallflower, dame's violet, peppergrass, garden cress, stock, and some radishes.

Symptoms: The initial indication of a problem is reduced top growth and midday foliar wilt, even under conditions of very adequate soil moisture. The plants recover at night. When plants are dug, the roots will be found to be much enlarged. The enlargement may involve one root to the whole root system (Fig. 1).

Figure 1. Clubroot of cabbage.

The swollen areas may be small sections of root or along its entire length, producing a spindle-shape or "club." As more of the root system becomes involved, the midday wilt intensifies, older leaves yellow and die, and the plants become quite stunted and unproductive. Collapse and death is possible. Because the infected roots (clubs) are made up of enlarged, thin-walled cells, secondary organisms often invade, causing a root rot and general deterioration of the root system.

Pathogen and Disease Cycle: Clubroot is caused by the fungus *Plasmodiophora brassicae*. The body of this fungus is a plasmodium (10 o'clock, Fig. 2), which is defined as a naked, slimy mass of protoplasm containing many nuclei. The plasmodium grows within a cell and matures when each nucleus develops into a separate cell or spore (12 o'clock, Fig. 2). The spores further develop into zoosporangia full of zoospores. These are liberated into the soil when the root deteriorates (2 o'clock, Fig. 2). The zoospores have the ability to swim in the water film on soil particles to make contact with the root of a new host. Infection occurs, and the cycle is repeated. When conditions are unfavorable for infection or no host is present, the spores go into a resting phase, which can persist in soil for at least 10 years.

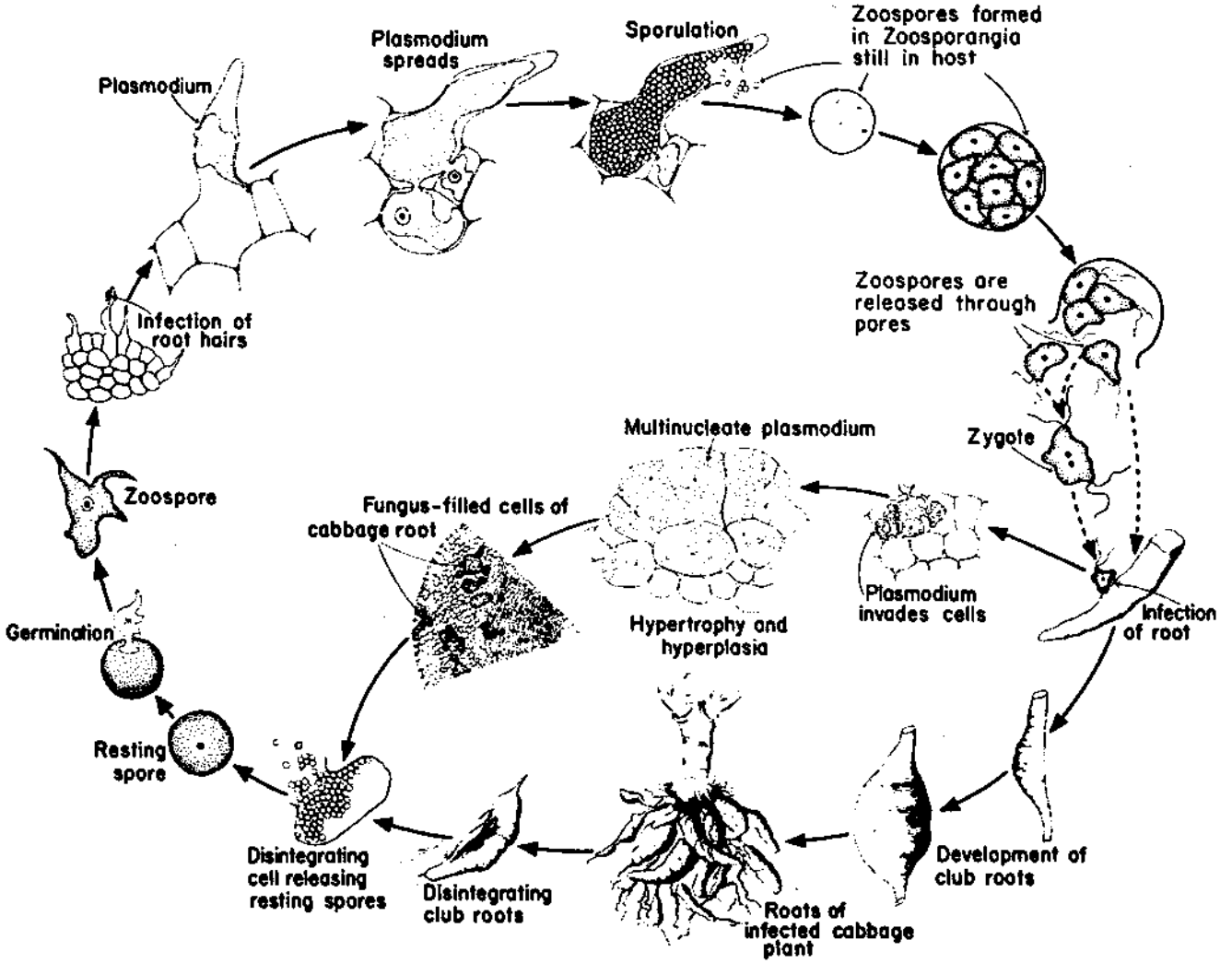

Figure 2. Disease cycle of clubroot of crucifers caused by *Plasmodiophora brassicae*. From AGRIOS, 1997

Environment and Spread: The clubroot fungus must have moist soil (70+% water-holding capacity) to germinate and infect. Acidic soil (pH below 7), and soil temperatures between 55 and 90°F allow the pathogen to operate. For maximum disease activity, soil temperatures of 68 to 77°F are considered optimum.

The pathogen is rapidly disseminated in contaminated soil that may cling to tires, irrigation pipes, transplanters, cultivation equipment, and shoes. Water dispersal is also possible. Any activity that can move soil, can also move *Plasmodiophora brassicae.*

Control: In our current system of vegetable production with the use of custom transplanters, the interchange and movement of sprinkler pipe and custom cultivation, pest control and harvesting, it is extremely difficult, even with stringent attention to the cleaning of equipment, to keep small bits of soil from being moved from one field to another. Therefore, exclusion, although possible, is very difficult.

Plasmodiophora spores are extremely long-lived in soil. Hence, crop rotations out of cruciferous crops and weeds are only marginally effective in clubroot suppression.

Plant breeding to develop clubroot-resistant cultivars is being done. To date, however, commercially acceptable cultivars with good resistance are not available except in radish, rutabaga, and turnip.

The use of fungicides to suppress clubroot has been successful. Pentachloronitrobenzene (PCNB, Terraclor®) may be used as a transplant solution, a band application incorporated before planting, a broadcast application incorporated before planting or a broadcast or row drench applied immediately after planting. The application rate varies slightly depending on the method of treatment selected and the disease pressure in the field. Consult the product label for dosages and amount of water suggested for each application method.

Soil treatment with methyl bromide, chloropicrin or metam sodium will also provide effective control of clubroot. Check product labels for proper use instructions.

Early in the studies of clubroot disease it was discovered that altering soil pH by the addition of calcium compounds ($CaCO_3$, CaO, or $Ca(OH)_2$) helped reduce clubroot incidence. Liming to keep soil pH above 7.1-7.2 is now standard practice for clubroot control. Unfortunately, maintaining an elevated soil pH has failed to suppress the disease in some fields. A review of research indicates that an elevated pH alone will not always suppress clubroot. The amount of exchangeable calcium (XCa) and magnesium (XMg) cations in the soil also affects disease control. It is now recommended that both soil pH and XCa and XMg cations bemonitored. Where *Plasmodiophora brassicae* is present, soil pH should be maintained at 7.3 or above, and the concentration of XCa and XMg together should be the equivalent of 15 milliequivalents (meq) or greater. These are optimum levels on the high side. Where the XCa and XMg are at 15 meq, the pH can be lower but should not drop below 6.7. Where the XCa and XMg are below 15 meq, the pH should be maintained a 7.3. The following table shows approximate quantities of hydrated lime needed to raise the soil pH to 7.2.

Hydrated Lime Rates at Different Soil pH Levels

pH of Soil	Hydrated Lime Required (lb/A)
5.0	5000
5.5	4000
6.0	3000
7.0	1500
7.2	1500
8.0	None

From Sherf + McNab, 1986