



**Fig. 1.** Affected Chinese cabbage crop showing typical symptoms of stunting and wilting (a); Root galls on broccoli (b); Broccoli root with root hairs containing zoosporangia (arrows) (c); Zoospore release from zoosporangium (d); Cells from a root gall containing numerous resting spores (e). Photo credits: Ian Porter and Caroline Donald, DPI Victoria.

**Disease:** Clubroot

**Classification:** K: Protozoa, P: Cercozoa, C: Phytomyxea, O: Plasmodiophorida, F: Plasmodiophoraceae. (Note: the taxonomy of this organism, even the Kingdom to which it belongs, is the subject of ongoing debate and changes constantly).

Clubroot is a widespread and serious disease of vegetable brassicas in Australia. It is potentially a serious threat to oilseed brassica production. To date clubroot has not been reported in Australian canola however, it is an economically important disease of oilseed brassica crops in Canada and much of Europe. It is caused by the soilborne obligate biotroph *Plasmodiophora brassicae* Woronin.

**The Pathogen:** Clubroot disease has a European history dating back to the 13<sup>th</sup> century. *Plasmodiophora brassicae* was formally identified as the cause of clubroot by Woronin in 1878. More than 130 years later much remains unknown about the taxonomy, full lifecycle and interaction of this pathogen with its hosts.

*P. brassicae* has a three stage lifecycle: survival in soil, root hair (primary) infection and cortical (secondary) infection. Resting spores can survive in soil for many years. In the presence of a suitable host resting spores germinate to release a single biflagellate zoospore which penetrates root hairs to form a primary plasmodium. Following nuclear division and cleavage zoosporangia containing 4-16 secondary zoospores are formed. These zoospores penetrate the cortical tissues developing secondary plasmodia causing cell hypertrophy and the formation of root galls containing resting spores. Resting spores are released into soil as root material decays.

**Distribution:** Widespread worldwide.

**Host Range:** Typical symptoms are observed only on species within the family Brassicaceae including crop species *B. oleracea* (broccoli, cabbage, cauliflower, Brussels sprouts), *B. rapa* (Chinese cabbage, turnip, bok-choy), *B. napus* (canola, fodder rape, mustard, swede), *B. juncea* (Indian mustard), and weeds *Raphanus raphanistrum* (wild radish), *Capsella bursa-pastoris* (shepherd's purse) and *Arabidopsis thaliana*.

**Impact:** Clubroot is the most significant disease of Brassica crops causing estimated in-field losses of 11% worldwide.

**Detection and control:** Spread of the pathogen can be limited by restricting the movement of infested soil and water through improved farm hygiene. The host-pathogen system is responsive to a range of control measures, including crop rotation, calcium and boron amendments, manipulation of soil pH (to 7.0-7.5) and chemical application. Molecular tests have been developed to predict clubroot disease and resistant cultivars are available for some crops. Increasingly, a multifaceted or integrated approach is being used to manage clubroot, particularly in vegetable crops.

**Further Reading:** In 2009 the Journal of Plant Growth Regulation produced a special clubroot edition. It contains nine comprehensive reviews including economic impact, lifecycle, metabolism and hormone action, molecular biology, resistance breeding, detection and control. See Journal of Plant Growth Regulation (2009) 28 (3) 193-303.

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