



White Rust of Cruciferous Vegetables in Hawai'i

Erik Patnude and Scot Nelson
Department of Plant and Environmental Protection Sciences

Introduction

Cruciferous vegetables in the Brassicaceae (Cruciferae) family are valuable exports and important staples of the human diet in many countries, providing essential vitamins, minerals, and fiber. Crucifers are dominant food crops in Hawai'i and globally. In addition to agricultural sales and exports, many species of crucifers are grown in community and private gardens. The plant name derives from the Latin *crucifer* ("cross-bearing"), a reference to the symmetrical arrangement of four petals in the flowers of several species in this family.

Brassicaceous plants contain important organic compounds, glucosinolates, comprised of glucose and amino acids containing sulfur and nitrogen. Glucosinolates convert to isothiocyanates via the plant enzyme myrosinase during digestion (Talalay and Fahey 2001). Research suggests that isothiocyanates can potentially prevent carcinogenesis in some animal organs, such as the liver, lungs, prostate, colon, breast, and pancreas (Herr and Büchler 2010) and the alimentary tract (Johnson 2002). Although no clinical trials have directly linked cruciferous vegetables to cancer prevention, the results show a positive correlation between the amount of glucosinolates in *Brassica* species and the inhibition of mitosis and tumor growth (Herr and Büchler 2010). The abundance of these putatively chemo-preventive phytochemicals in the Brassicaceae is much greater than in most other families of edible plants. Therefore, this is another instance of the importance of this family of plants, and pest control is thus important for growers who propagate crucifers for food production, biofuels, and human medical treat-



White rust of lettuce.

ments, as well as the suppression of some soilborne plant pathogens.

In 2010, an estimated 10.2 million pounds of head cabbage was harvested in Hawai'i. That year it was the second-highest produced vegetable in the state, with a farm value around \$3.1 million. Half of this production was from two varieties of Chinese cabbage (bok choy and Napa cabbage), having a farm value of over \$1.6 million. Another \$1.3 million derived from the sale of watercress, rendering cruciferous vegetables as one of the most valuable production crops in Hawai'i (NASS 2011).

White rust is an economically important disease of crucifers worldwide. It is common in Hawai'i and can severely affect the production of cabbage and watercress on large farms and in residential gardens.

Pathogen

Races of the white rust pathogen, *Albugo candida*, infect crucifers wherever these vegetables grow. The disease was reported in Hawai'i as early as 1918 (Department of Agriculture, State of California, *Monthly Bulletin*, Vol. 9). White rust was given its name due to the white pustules that form on the underside of infected leaves (Reddy 1996). *Albugo candida* is an obligate biotroph in the family Albuginaceae. It is classified in the order Peronosporales, which also includes the downy mildews (Reddy 1996).

Pathogen Life Cycle and Disease Cycle

The pathogen begins the asexual stage of its life cycle as sporangia dispersed by wind or splashing rain. When these propagules land on a susceptible host plant, they germinate and penetrate the epidermal layer of leaves and begin to form a mycelial wall between plant cells. The invading hyphae develop special organs called haustoria within the epidermal cells and absorb nutrients from the host cells. Intercellular hyphae eventually produce sporangiophores, which erupt through the plant tissue, appear as white blisters or pustules, and release sporangia. Under optimum conditions, between 16 and 25° C (60–77° F) and high relative humidity (Damicone and Roberts n.d.), the sporangia germinate to produce

biflagellate, motile, infective zoospores (Reddy 1996). If there is no free moisture available on the host surface, the sporangia may simply re-infect the host plant without producing zoospores. If free water exists on leaf surfaces, the zoospores drop their flagella, encyst, and form germ tubes, which enter leaves through the stomata to cause systemic infections. Once the systemic infections infiltrate the vascular system of a host, the pathogen can move to plant inflorescences, where it may stunt and malform the reproductive organs and may infect and contaminate seeds. After sexual reproduction, the pathogen produces oospores, which may also infect hosts and may survive for extended periods of time in soils or infested plant debris.

Hosts

Albugo candida has a wide host range that includes over 29 genera of crucifers (Jacobson 1998, Farr et al. 1989). The pathogen affects both wild and domesticated species of crucifers. Commonly affected species in the genus *Brassica* include horseradish, field mustard, Indian mustard, brown mustard, rutabaga, cauliflower, broccoli, the cabbages (including bok choy), and radish (Ferreria and Boley 1991). Currently, only two known hosts are considered highly resistant to *A. candida*, rutabaga and brown mustard (Ferreria and Boley 1991).



White rust of radish leaves, with blisters on the upper leaf surface and white rust lesions on the lower leaf surface (photographs by Dirceu Macagnan).

Symptoms

One of the most identifiable symptoms of *A. candida* infection is the white blistering on the undersides of infected leaves (Armstrong 2007). Other disease symptoms include chlorosis, necrosis, defoliation, swelling and distortion of stems and flowers, stunted growth, and leaf curling (Babadoost 1990). If the disease becomes systemic, an infected plant may form swollen, twisted floral parts called “stagheads.” If a plant is infected through the soil or seed, stagheads will most likely appear later in the plant’s life (Armstrong 2007).

Albugo candida may develop an endophytic relationship with some species of cruciferous vegetables. This means that it may live within the host without causing any symptoms (Jacobson 1998, Carroll 1988, Sinclair and Cerkauskas 1996). Some research has suggested that when the disease becomes systemic, the pathogen moves into the seeds of the host plant (Jacobson et al. 1998).

Management

Managing white rust poses challenges, as pathogen spores are dispersed readily by wind and splashing water and may survive for years in soils. The pathogen may be seed borne and thereby introduced into a field unwittingly.

- Use pathogen-free seed stock.
- Practice sanitation. Remove infected plant tissue or debris from growing sites and destroy it (Damicone and Roberts n.d.).
- Grow resistant plant varieties. For example, UH-CTAHR sells two varieties of kai choy (mustard cabbage): ‘Hirayama’ (white rust resistant) and ‘Waianae Strain’ (slightly tolerant to white rust). To purchase seeds, please visit <http://www.ctahr.hawaii.edu/seed/seeds.asp#kaichoy>.
- Modify the environment. Knowledge of the epidemiology of diseases caused by *Albugo* species can help with their management. As spores of *A. candida* require free water to germinate, and not just high humidity, minimizing the occurrence and duration of leaf wetness, as by using a drip-irrigation system, can reduce infections.
- Time of planting. Since the disease is more prevalent in areas of high humidity or in moderately wet climates, planting crops in drier seasons can reduce infections and the dispersal of the pathogen.
- Polycrop or intercrop crucifers with non-susceptible hosts.



White rust of mustard leaves, with blisters on the upper leaf surface and white rust lesions on the lower leaf surface (photographs by Dirceu Macagnan).

- Plant windbreaks around or within fields to reduce the ability of the fungus to spread aerially among hosts.
- Rotate crucifers with non-hosts of the pathogen.
- Remove symptomatic weed hosts from around the crop, as the pathogen infects more than 240 different plant species (Jacobson et al. 1998).
- Apply pesticides. Several products have been approved for use against *A. candida* in Hawai'i. Table 1 lists those registered by the U. S. Environmental Protection Agency and the Hawai'i Department of Agriculture. Depending on the type of infection,

systemic vs. foliar, a specific fungicide and application method should be selected. Read and follow all manufacturer directions for product use and adhere to state and federal regulations for the application and storage of each product. It is also best to use a spreader or adjuvant to help products adhere to the leaves and to minimize runoff.

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Table 1. Some of the products registered for use against white rust in Hawai'i, as listed in the National Pesticide Information Retrieval System (see References).

| Product Name | Active Ingredient | Formulation | EPA Registration Number | Suggested Crop Use |
|---|---|--------------------------|-------------------------|---|
| Ridomil Gold® SL | Metalaxyl-M | Emulsifiable concentrate | 100-1202 | Broccoli, cabbage, cauliflower, Chinese broccoli, Chinese cabbage, radish |
| Serenade® MAX | <i>Bacillus subtilis</i> strain QST 713 | Wettable powder | 69592-11 | Broccoli, cabbage, cauliflower, watercress |
| Abound® Flowable Fungicide | Azoxystrobin | Flowable concentrate | 100-1098 | Daikon, watercress |
| Champion® WG Agricultural Fungicide | Copper hydroxide | Wettable powder | 55146-1 | Broccoli, cabbage, cauliflower, watercress |
| Earth-tone® Garden Fungicide | Octanoic acid, copper salt | Solution - ready to use | 67702-1-83598 | Broccoli, cabbage, cauliflower |
| Regalia® Biofungicide Concentrate (organic) | <i>Reynoutria sachalinensis</i> | Emulsifiable concentrate | 84059-3 | Broccoli, cabbage, cauliflower, bok choy, watercress |

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