



WHITE RUSTS OF VEGETABLES

White rusts, caused by several species of the fungus *Albugo*, occur worldwide on beet (garden and sugar), Brussels sprouts, cabbage, cauliflower, Chinese cabbage, collards, garden cress, horseradish, kale, lettuce, mustards, parsnip, radish, rape, salsify (black and white), spinach, sweet potato, turnip, watercress, and possibly water-spinach. In addition, numerous common weeds and herbaceous ornamentals are attacked (Table 1).

White rust is one of the most destructive foliar diseases of horseradish (Figure 1). In Illinois, severe outbreaks commonly occur in the spring and fall months during prolonged periods of cool dewy nights and slightly warmer days. Plants are rarely attacked in warm, dry weather. Fall infections cause more damage than spring infections since the horseradish crop makes its most vigorous growth in late summer and early fall.



Figure 1. Typical sori or pustules on underside of a horseradish leaf. Note the variable sizes and shapes. The large sori are formed from the coalescence of several individual sori.

White rust may infect horseradish anytime during the growing season, although the causal fungus becomes established in young plant tissues more easily than in older tissues. It affects the leaves, petioles, stems, and roots. Normal root development is retarded, causing the primary root to be woody and form numerous lateral roots. Secondary, rot-producing bacteria and fungi may enter through white rust infections and cause additional losses.



Figure 2. Radish flower parts grossly deformed by white rust (U. of Wisconsin photo).

The swelling and distortion of the branches and flower parts of radish (Figure 2), cabbage, and cauliflower seed crops may cause heavy losses. Fortunately, white rust fungi are of minor importance on most other vegetables considering their widespread occurrence. Affected leaves may wither and drop prematurely weakening the plants.

White rusts are frequently associated with downy mildew fungi, to which they are closely related, resulting in considerable injury from the combined attacks of these fungi. The name white rust is somewhat misleading since these fungi are not true rusts.

For further information contact Mohammad Babadoost, Extension Specialist in Fruit and Vegetable Pathology, Department of Crop Sciences, University of Illinois at Urbana-Champaign. (Phone: 217-333-1523; email: babadoos@uiuc.edu).

SYMPTOMS

White rust, sometimes called white blister, is easily recognized by the chalk-white, cheesy, raised spore masses (sori) which occur mostly on the underleaf surfaces (Figures 1, 5, and 6). The floral parts of radish, cabbage, and cauliflower seed plants are grossly deformed and sterile. Occasionally, swollen galls form in the petioles and stems of some plants and even the roots of radish, horseradish, and a few other plants.



Figure 3. Leaves of systemically infected horseradish plants curl inward.



Figure 4. Horseradish set root affected by white rust. Note swelling, discoloration, and cracking caused by the mycelia.

The disease may appear as scattered sori restricted

to one or a few leaves (local infections) or the fungus may spread throughout much of a plant and affect both above and below ground plant parts (systemic infections). The leaves of systemically infected horseradish plants are usually smaller than normal and may curl inward (Figure 3). Both local and systemic infections may cause swellings of horseradish roots (Figure 4) and leaf veins. Swellings on the petioles are rare and result only from local infections.

The first and often overlooked symptom of white rust is the appearance of small, irregular yellow areas (chlorotic lesions) on the **upper** leaf surface (Figure 5) which range in size from minute dots to one-half inch or more in diameter. Within one to three days of infection, depending on the temperature, the lesions become visible on the lower leaf surface. The white, raised sori, often arranged concentrically (Figures 6 and 7), may be confluent. They rarely occur on the upper leaf surface. The blisterlike sori, which are variable in size and shape, form beneath the host epidermis in the chlorotic lesions. One or more sori may appear in each lesion. Anthocyanin may be produced around the sori resulting in reddish violet blotches that are most prominent on the upper leaf surface.

The domelike surface over the white rust pustules ruptures the host epidermis to expose the dusty masses of spores (sporangia) in small, circular to elongate cavities.

Host leaf tissues beneath the sori die after spore dispersal, becoming reddish brown to brown (necrotic), and may be difficult to distinguish from other diseases. The tissue die rapidly when temperatures are above 82°F (28°C), but may remain alive for several weeks in cool, moist weather. Diseased salsify and sweet potato leaves commonly wither and fall prematurely. If severe, the plants, including the roots, may be dwarfed and lack flavor.



Figure 5. Irregular yellow areas on the upper surface of a spinach leaf; typical white rust sori form opposite these chlorotic lesions on the lower leaf surface (courtesy Dr. A.O. Paulus)

DISEASE CYCLE

Species of *Albugo* (Table 1) are obligate parasites that can develop only in living host tissues. The fungi reproduce by asexual spores (sporangia) and thick-walled sexual spores (oospores). The oospores and perennial mycelium in host tissues enable these fungi to overwinter in a few, systemically infected, living crop and weed hosts. A few infected plants may serve as a source of inoculum for one or more fields. In systemically infected plants, such as horseradish, the white rust fungus resumes growth early in the spring, invades the shoot primordia, develops along with the growing shoots, and produces pustules on all aerial parts.



Figure 6. Concentric white rust pustules on the lower surface of a spinach leaf (courtesy Dr. A.O. Paulus).

The colorless, nearly spherical to rectangular sporangia are borne on short, club-shaped stalks (sporangiohores), each of which produces a chain of spores with distinct thickening between the sporangia (Figure 8A and B). As sporangia are produced they become tightly packed and eventually rupture the host epidermis. After being freed, the powdery sporangia are disseminated by air currents, splashing rain, farm implements, workers, and insects. With cool temperatures (34° to 68°F or 1° to 20°C) and free water on the host tissue, each sporangium can germinate directly by producing a germ tube or, more commonly, by forming 4 to 18 motile zoospores (swarm spores). The swarm spores swim about in a water film for a few minutes with the aid of two whiplike flagella. The zoospores soon come to rest, become spherical, form a cell wall, lose their flagella, and produce a germ tube. The germ tubes grow and penetrate leaf or other host tissue through stomates.



Figure 7. Close-up of older concentric white rust sori on the lower surface of a mustard leaf (courtesy Dr. J.R. Hartman).

Cool dewy nights and slightly warmer days are ideal for disease development. Free water in the form of light drizzly rains, heavy dews, and fogs are necessary for germination by sporangia and zoospores. Heavy rains and irrigation, however, tend to wash the sporangia off the foliage.

The first external symptoms of white rust appear 5 to 20 days after infection depending on the temperature. Within 3 to 14 days a new crop of sporangia are released, starting a secondary cycle. A number of secondary cycles may occur during a growing season. Under ideal conditions (cool and moist), a complete cycle may be completed every 8 to 10 days. Hot, dry weather checks the disease.

The sporangia require some drying before they can germinate. Most spores exposed to sunshine for a few hours are viable, whereas those exposed on a wet leaf or stem, fail to produce swarm spores. If dry and cool, sporangia may remain alive for as long as two weeks. Globose, chocolate-brown oospores are produced within the leaves, petioles, stems, and roots of thoroughly invaded plants as they approach maturity. Oospores are especially numerous in distorted swellings and galls in infected stems and pods. The oospores form among the dying host cells. These thick-walled, overwintering spores (Figure 8C) can

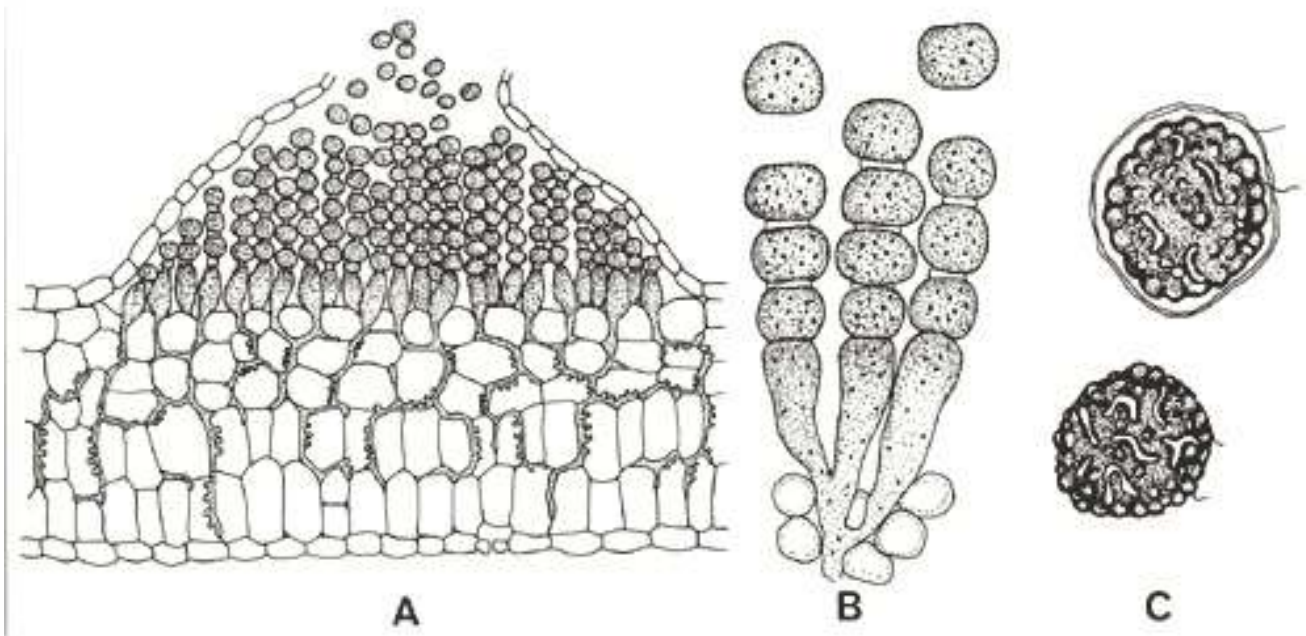


Figure 8. *Albugo candida*, a common white rust fungus, as it would appear under a high-power light microscope. A. Cross section of a typical sorus showing chains of sporangia borne on short stalks (sporangiophores), which have burst through the host epidermis and are being released. The mycelium of the fungus is intercellular except for the small, spherical haustoria in the host cells; B. close-up of three sporangiophores with sporangial chains and two loose sporangia; C. two oospores, the upper one is mature within a persistent, thin oogonial wall (drawing by Lenore Gray).

resist drying as well as temperature extremes. The oospores overseason in the oil or in plant debris and are liberated when the host tissues decay. The oospores germinate in the spring by producing up to 100 or more swarm spores exactly like those formed by the sporangia.

For horseradish, oospores are considered unimportant as a source of inoculum. Illinois researchers found that the white rust fungus that infects horseradish overwinters as mycelium in a small percentage of horseradish crowns and roots. The fungus grows systemically into the crown when a young plant is infected. The organism then spreads down through the primary root and into the secondary or set roots. In the field infection of an entire root is rare due to the destruction of the fungus by secondary, rot-producing organisms. However, **some set roots may be infected** near the crown area.

The sporangia may also spread from infected horseradish tops to the roots during harvest or in a cool, moist storage. Zoospores formed from the sporangia can infect the leaf buds. Set roots quickly become systemically infected and, though few in number, are sufficient to produce white rust over an entire field if the weather remains cool and damp for prolonged periods. Systemically-infected volunteer horseradish and weed plants in fields or cull piles are a major source of spring infections. **Early and complete cultivation of fields** planted to horseradish the previous year will destroy systemically-infected volunteer plants and weeds.

Species of *Albugo* (Table 1) are very sensitive to changes in temperature. The sporangia of *A. candida*, for example, will germinate within a temperature range of 34° to 82°F (1° to 38°C) with an optimum of 57° to 68°F (14° to 20°C). Swarm spores produce germ tubes and penetrate host tissue between 59° and 77°F (14° to 25°C) with an optimum close to 68°F (20°C). Germination and infection are both greatly reduced by temperatures outside the optimum range.

The mycelium of white rust fungi is intercellular in host tissues except for one to several, very small spherical haustoria in each host cell (Figure 8A) which serve to supply the white rust fungus with nourishment. The disjunctive or sterile disks of gelatinous tissue joining two sporangia (Figure 8A and B) are made of callose. Upon maturity it becomes soluble in water aiding in the dissemination of the sporangia.

Several cosmopolitan species of *Albugo* (Table 1) are subdivided into several races which are highly specific in the hosts that they infect. For example, Race 1 of *Albugo candida* infects the leaves and flowering parts of radish. Race 2 infects leaf mustard, collards, Chinese cabbage, turnip, and seed mustard. Race 3 infects only horseradish under natural conditions.

CONTROL

1. Take horseradish sets for planting **only** from the terminal ends of healthy primary roots. Remove sets from the primary root **prior** to storage. Destroy all horseradish sets that are discolored, swollen, or cracked.
2. Where feasible, cleanly plow down or destroy all white rust-infected leaves or other plant parts after harvest. For horseradish, this should be done at least a week **prior** to harvest to reduce the possibility of spread of the white rust fungus to the crown and roots during harvest.
3. Keep down all susceptible weeds (Table 1) and volunteer plants using cultural and chemical controls. Follow suggestions of University of Illinois Extension Vegetable Specialists.
4. Eliminate windbreaks to hasten the drying of the foliage and delay infection.
5. Practice at least a 3-year crop rotation between susceptible crops in the same area or field (see Table 1). If rotation is impossible, plant susceptible crops as far as possible from where they were grown previously.
6. Burn all cull piles.
7. Carefully remove and destroy all systemically infected horseradish and other plants in fields as soon as they are found. Inspect at least every 10 to 14 days during spring and early summer.
8. Soon after the first symptoms appear, apply several fungicide sprays suggested for that crop as given in Illinois Agricultural Pest Management Handbook or Report on Plant Diseases No. 900, "Controlling Diseases in the Home Vegetable Garden." Usually, for horseradish, spray applications should commence shortly after shoot emergence and continue at 7- to 14-day intervals as long as the weather is cool and moist. Omit the sprays in hot weather, but resume again in early fall until close to harvest. Carefully follow the manufacturer's directions and precautions as listed on the container label.

Table 1. Common species of *Albugo* and their principal crop, ornamental and weed hosts.

<u><i>Albugo candida</i></u>	<u><i>Albugo tragopogonis</i></u>	<u><i>Albugo ipomoeae-</i></u> <u><i>panduratae</i></u>
Brussels sprouts	<i>Antennaria</i> spp	bindweed, great or hedge
bittercress (<i>Cardamine</i> spp)	bachelors-button	California-rose
cabbage	basketflower	cypressvine
candytuft	<i>Centaurea</i> spp	ipomoea, star
caper, Jamaica	cocklebur, common	jacquemontia
cauliflower	cornflower	moonflower
charlock	dusty-miller	morning-glory common, bush, ivyleaf, and white
Chinese cabbage	false-chamomile	sedge
collards	feverfew, American	quamoelit
dames-rocket	<i>Franseria</i> spp	sweet potato
false flax	goat's beard	sweet potato-vine, wild
garden cress	groundsel	water-spinach
hedgemustard	<i>Iva</i> spp	
hedgemustard, tall	lettuce	<u><i>Albugo occidentalis</i></u>
horseradish	parsnip	spinach
kale	pineappleweed	strawberry-blight
marshcress	ragweed, common, giant, and western	
mignonette, white	ragwort	<u><i>Albugo bliti</i></u>
mustards (black, leaf, and white)	salsify, black and white	amaranth, common and globe
nasturtium	<i>Senecio</i> spp	beet, garden and sugar
pennycress	sunflower, common	lambsquarters
peppergrass	wormwood, biennial	
pigweed		<u><i>Albugo platensis</i></u>
radish, garden and wild		<i>Boerhaavia</i> spp.
rape		four o'clock, common and trailing
rockcress (<i>Arabis</i> spp)		umbrellawort
salsify		
scurvyweed		<u><i>Albugo portulacaeae</i></u>
shepherd's-purse		purslane, common
stock		
sweet alyssum		
tansymustard		
toothwort		
turnip		
wallflower, common and western		
watercress or yellow rocket		
whitlowgrass		
wormweed mustard		