Chrysanthemum White Rust (CWR) is widespread and considered endemic in parts of Europe and South America and other areas of the world, but so far, is not established in the United States. Any introduction of this pathogen from offshore is a significant threat to the United States floriculture industry. White rust spreads rapidly in greenhouse and nursery environments, resulting in severe losses.

As a quarantine action pest, detection of white rust leads to federal and state regulatory action. The prevention and control of white rust depends on effective plant quarantine laws, healthy planting material, management of humidity and irrigation, and the proper selection and use of fungicides.

**CAUSAL ORGANISM**
Puccinia horiana Henn. is a filamentous fungus. It is an obligate parasite - it only grows and reproduces on host plants.

**SYMPTOMS AND SIGNS**
Growers who monitor or scout their crops on a regular schedule will be most likely to find any potential infection early. All stages of plant production should be examined, as the disease is capable of infecting young plants as well as finished product.

The first symptoms of white rust are yellow spots on upper leaf surfaces, up to 4 mm in diameter (figs. 1 and 2). These may become sunken and necrotic. At first glance, to someone unfamiliar with this chrysanthemum pathogen, the yellow spots may be mistaken for some type of spray injury, insect damage, or even plant virus. Any sign of yellow spotting should be closely examined for further evidence of this disease. The subsequent development of prominent pustules on the lower surface of leaves is diagnostic for a rust type pathogen. Pinkish or buff colored at first (fig. 3), pustules mature to waxy white (fig. 4). Pustules may also develop on stems, bracts, or even flowers. Severely infected leaves dry up and hang along the stem (fig. 5). Microscopic observation of two-celled teliospores (fig. 6) in pustules is required to confirm a diagnosis for white rust.

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OCCURRENCE AND CURRENT SITUATION
White rust is native to east Asia. It is now widespread in Australia, Africa, Europe, and South and Central America. The USDA Animal and Plant Health Inspection Service (APHIS) regularly intercepts white rust on cut chrysanthemum flowers imported from infested countries.

While local outbreaks of white rust in North America during the last two decades have included incidents associated with smuggling of cuttings by amateur growers and handling of off-shore cut flowers inside greenhouses where chrysanthemums were grown; the source of disease has not been determined in every incident. Since detection and eradication action in California in 1991 there have been repeated incidents of white rust in several coastal California counties. There have been outbreaks in commercial nurseries in New Jersey, Oregon and Washington State (1995 - 1997), and in dooryard or hobbyist plantings in New York and New Jersey (1997). Additional incidences have been reported in nurseries in Hawaii, Rhode Island, Pennsylvania, Maryland and Delaware in 2004 and again in Pennsylvania in 2006. In 2007, CWR was found in surveys or trace forwards / trace backs in Connecticut, New York, Pennsylvania, Rhode Island, Maine, Delaware, Massachusetts, Maryland and North Carolina. Any incidence of confirmed white rust will result in state and federal action to determine source, movement of infected plants, and activation of both quarantine and eradication protocols. These protocols, while quite disruptive and costly to a commercial nursery, are designed and enforced to prevent further spread of this serious pathogen throughout the flower industry.

DISEASE CYCLE
New infections are initiated by basidiospores (see life cycle on page 6) released from pustules during periods of high relative humidity (96 to 100%) when temperatures are between 40 and 73°F (optimum 63°F). Spores landing on a plant surface can germinate and penetrate in as little as two hours at optimum temperatures (63 to 75°F). A film of free water is required for infection.

For 5 to 14 days after infection the fungus grows within the plant as a latent infection, after which chlorotic (yellow) spots, and ultimately pustules, appear.

Teliospores (fig. 6) produced in pustules remain attached to leaves, germinating in place to produce the next generation of basidiospores when conditions of temperature and humidity are favorable.

DISPERAL
Long distance dispersal of white rust depends on movement of infected plant material. Because cuttings may not display symptoms for as long as two weeks after infection, apparently healthy cuttings are no guarantee of safety. This is the basis for the requirement for a six-month post entry quarantine for cuttings imported into the United States.

Basidiospores can be carried short distances by wind currents. These spores are so short-lived that even under ideal conditions (100% humidity, cool temperatures) they only survive long enough to be carried a short distance before dying due to desiccation. In spite of their very brief lives, basidiospores are responsible for the explosive character of local epidemics when conditions are right.

Infested debris carrying viable teliospores may also play a role in dispersal.

SURVIVAL
White rust survives for extended periods only in association with host plant tissue. Basidiospores (the airborne spores) are thin walled and subject to rapid desiccation. They are thus extremely short-lived, surviving only 5 minutes at 80% relative humidity and less than one hour at 90% relative humidity. Teliospores (the spores that remain attached to the leaf) survive associated with dried plant debris for at most two weeks when buried in air dried soil. Where white rust becomes established on hardy outdoor plantings of chrysanthemums it can overwinter with the host. Many varieties of chrysanthemums survive readily in climates as cold as those found in USDA hardness zones 5 and 6 (average minimum temperatures ranging from -10 to 10°F).
ENVIRONMENT
Basidiospores are only produced and released during periods of high relative humidity (96 to 100%) and temperatures from 40 to 73°F (optimum 63°F). A film of free water is required for infection and penetration. Optimum temperatures for infection range from 63 to 75°F.

White rust is commonly most severe in greenhouse environments but it can also be destructive outdoors when temperature and humidity permit.

HOST RELATIONS
The host range of white rust extends to a number of species of chrysanthemum and their close relatives. Since 1990 white rust has been detected in the United States in commercial and residential plantings of the florist’s chrysanthemum and chrysanthemum (Chrysanthemum x morifolium) Ramat. or Dendranthema x morifolium (Ramat.) Tzvelev, the perennial garden plant Chrysanthemum pacificum Nakai (synonym Ajania pacifica (Nakai) K. Bremer & Humphries), and also the Nippon or Montauk daisy (Nipponanthemum nipponicum (Franch. ex Maxim.) Kitam.

Some cultivars of chrysanthemum appear to be resistant to some races of white rust. When exposed to other races, however, they may be quite susceptible. Thus, cultivar selection is not a reliable approach to control of this disease.

DISTINCTION FROM BROWN RUST OF CHRYSANTHEMUM
Brown rust of chrysanthemum, caused by Puccinia tanaceti DC, is present in the U.S. but rarely causes heavy losses. Chocolate brown pustules on both surfaces of leaves contrast with white rust (fig. 9). Uredospores found in common rust pustules are easily distinguished from the teliospores of white rust.

WHITE RUST PREVENTION WITHIN THE UNITED STATES

- Plant cuttings from a reputable commercial source.
- Do not handle imported chrysanthemum cut flowers in or near production facilities. Cut mums from any country known to have CWR are a threat to chrysanthemum crops.
- Maintain low humidity and dry foliage. Use fans, vents, plant spacing and heat to move air and reduce humidity. Use drip rather than overhead irrigation to minimize free water on foliage. Beware of impermeable barriers that retain humidity if using black cloth to control day length.
- Schedule regular applications of fungicides. Commonly used fungicides that are known to be effective protectants are Daconil Ultrex and fungicides containing mancozeb, including Dithane 75 DF and Fore and Protect DF. See the Protectant Fungicides section. Always read and follow label directions when using pesticides. The label is the law.
- Federal quarantines require:
  - Six-month post entry quarantine of imported cuttings.
  - Prohibition of cutting import from infested countries.
  - Inspection of imported cut chrysanthemums at port of entry.
- Certification programs for offshore cut flower producers wishing to export to the U.S.
- Eradication when white rust is found.

IF YOU FIND WHITE RUST:
Inform USDA, state, or county officials.
Regulatory officials will supervise eradication and treatment programs that may include:

- Destruction of infected plants and those immediately surrounding them.
- Treatment with eradicant fungicides.
- Survey of surrounding premises.
- Trace back to attempt a determination of source and distribution.
- Trace forward to track incidence in shipments.
- More extensive action may be taken if infection is generalized in an operation.

PROTECTANT FUNGICIDES AND A PREVENTATIVE SPRAY SCHEDULE

Exclusion is our first and best means of defense against CWR. Always obtain cuttings from a reliable supplier who does not have CWR. Do NOT mix cut chrysanthemums with growing plants. This means do not have them in the same facility or within 400 m (preferably >700m). Cut chrysanthemums, especially from off shore countries where CWR is established, are a major threat to growing plants because they can bring inoculum and not show symptoms.

In addition to following exclusion principles, a fungicide program should be used for protection against CWR. Some fungicides are better for CWR eradication while others are better for protectants. Keep this in mind when you apply fungicides. Myclobutanil (Eagle, Systhane) which acts as a sterol biosynthesis inhibitor, can be used to eradicate early infections of CWR. Routine use of this fungicide on chrysanthemums is not recommended. It is not as effective as some other fungicides as a protectant for CWR and resistance to this class of pesticides is a high risk.

The following fungicides can be used in the protectant program for CWR as sprays:

*Always read and follow label directions. The label is the law.*

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Rate</th>
<th>Effective Against</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Azoxystrobin (Heritage)</strong></td>
<td>1-4 oz/100 gal water every 7-28 days</td>
<td>Puccinia rusts and also Alternaria, Cercospora, Peronospora, Septoria, powdery mildew, Botrytis, Phytophthora, Rhizoctonia, Sclerotium, Fusarium.</td>
</tr>
<tr>
<td><strong>Chlorothalonil (Daconil Ultrex, Spectro 90 WDG with thiophanate-methyl)</strong></td>
<td>1-2 lb/100gal water every 7 days (minimum)</td>
<td>Puccinia rusts and also Alternaria, Ascochyta, Botrytis, Cercospora, Septoria, powdery mildew (Erysiphe, Microsphaera).</td>
</tr>
<tr>
<td><strong>Kresoxim-methyl (Cygnus)</strong></td>
<td>3.2-6.4 oz/100gal water at 7-10 day interval</td>
<td>Puccinia rusts and also Alternaria, Ascochyta, Botrytis, Cercospora, Septoria, powdery mildew (Erysiphe, Microsphaera).</td>
</tr>
<tr>
<td><strong>Mancozeb (Fore, Dithane75DF, Protect DF)</strong></td>
<td>1.5 lb/100 gal water at 7-10 day interval</td>
<td>Puccinia rusts and also Ascochyta, Botrytis, Cercospora, Septoria, powdery mildews, Alternaria, Septoria, Peronospora.</td>
</tr>
<tr>
<td><strong>Triadimefon (Strike)</strong></td>
<td>1-2 oz/100 gal water at 7-14 day interval</td>
<td>Puccinia rusts and also Sclerotinia, Cercospora, powdery mildew.</td>
</tr>
<tr>
<td><strong>Triflumizole (Terraguard)</strong></td>
<td>2-8 oz/100 gal water at 7-14 day interval</td>
<td>For rusts, Rhizoctonia, Botrytis, Alternaria, powdery mildew, Fusarium.</td>
</tr>
</tbody>
</table>

Additional fungicides NOT known to control rust diseases, but which can be used in a chrysanthemum prevention program for other chrysanthemum diseases are:

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Rate</th>
<th>Effective Against</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Etridiazole (Truban)</strong></td>
<td>3-10 oz/100 gal water per 400 sq. ft. (equivalent to 1 quart/sq ft soil surface).</td>
<td>Controls Pythium and Phytophthora.</td>
</tr>
<tr>
<td><strong>Fludioxonil (Medallion)</strong></td>
<td>1-2 oz/100 gal water at 7-14 day interval</td>
<td>Controls Rhizoctonia, Alternaria, Botrytis, Cercospora, Septoria, Fusarium, and Sclerotium, all of which can cause chrysanthemum diseases.</td>
</tr>
<tr>
<td><strong>Iprodione (Chipco 26019, 26GT)</strong></td>
<td>1-2.5 lb/100gal water at 7-14 day interval</td>
<td>Controls Rhizoctonia, Alternaria, Botrytis (can have resistance), Fusarium, Ascochyta, all of which can cause chrysanthemum diseases.</td>
</tr>
<tr>
<td><strong>Thiophanate methyl (3336, OHP 6672)</strong></td>
<td>Systemic 20 oz/100 gal water OHP 6672 4.5L at 10-14 day interval</td>
<td>Controls Ascochyta, Fusarium, Rhizoctonia, Septoria and Sclerotinia, all of which can cause chrysanthemum diseases.</td>
</tr>
</tbody>
</table>
PREVENTION SCHEDULE FOR CWR AND OTHER CHRYSANTHEMUM DISEASES
(Pythium* not included):

Since we have not had CWR at our Yoder facility, this program has not been practically trialed under CWR pressure. All of these fungicides can be used on chrysanthemums, and Heritage, Daconil Ultrex, and Dithane 75 DF are specifically labeled for *Puccinia* rust prevention. The active ingredients of Heritage and Dithane are used in European programs to protect against CWR. Thorough coverage is critical.

Begin this schedule in propagation on day 3, 4, or 5 after stick; apply at night when mist not on.

- **Week 1** Heritage (azoxyrstrobin) spray
- **Week 2** Daconil Ultrex** (chlorothalonil) spray
- **Week 3** Dithane 75 DF (mancozeb) spray
- **Week 4** Daconil Ultrex (chlorothalonil) spray
- **Week 5** Medallion (fluadoxinol), Chipco 26019 (iprodione), or 3336 or OHP 6672 (thiophanate methyl) spray or drench for other chrysanthemum diseases

Repeat this schedule weekly until color break. Then use Heritage (azoxybstrobin) when color can be seen. Repeat the azoxybstrobin weekly until the crop ships if the conditions are 63°-75° F (17°-24°C) and wet. Do not apply chlorothalonil or mancozeb after color break since burn and residue, respectively, can occur. Please note that Heritage (azoxybstrobin) can cause growth regulator effects in chrysanthemum.

*To include Pythium control in this program, drench Truban or other fungicides labeled for this oomycete in addition to the suggested schedule.

**Daconil Ultrex is a safe formulation.

USE ALL CHEMICALS ACCORDING TO LABEL RECOMMENDATIONS AND PLANT TOLERANCE. THE LABEL IS THE LAW. APPLY TO A SMALL NUMBER OF PLANTS FIRST WHEN IN DOUBT OF PHYTOTOXICITY.

THE YODER BROTHERS, INC., CHRYSANTHEMUM SYSTEM

Yoder Brothers maintains an exacting exclusion system to assure that the cuttings we deliver are free of certain diseases transmitted through propagation. All chrysanthemum materials entering our system for any purpose (trial, breeding, or introduction) are first put in tissue culture to provide a period of observation under glass. This assures that problems brought in from the outside will be contained and that established crops are not exposed. While in tissue culture and during the rest of the chrysanthemum outside sources program all lines are tested for systemic fungi and bacteria and for viruses and viroids by the Yoder Indexing and Certification Department. When a variety is coded for introduction it passes on to the certification program, a six-month testing and observation process that qualifies it for entry into our elite nucleus. The elite nucleus is now kept in tissue culture except for a few varieties kept as entire plants in a nucleus facility in Parrish, Florida. This facility is an insect and disease exclusion greenhouse with dedicated staff and infrastructure, assuring no contamination or insect infestation from the outside. All Yoder chrysanthemum products are increased from the elite nucleus in tissue culture after acclimatization, or from the entire plants in the Parrish Nucleus on a regular schedule in a support area. This support area is operated with precise sanitation practices to assure that systemic diseases are not introduced into chrysanthemum stock production. Yoder chrysanthemum cutting production facilities in south Florida are isolated from concentrations of finished chrysanthemum production, further reducing exposure to disease problems.

REFERENCES


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For further information, contact:

Dr. Joe Bagley or Dr. Jane Trolinger, Yoder Brothers, Technical Services Group, 2201 Owarita Road, Alva, Florida 33920; 239-728-2535, ext. #150.

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Life cycle of *Puccinia horiana* Henn. (after Firman and Martin 1968)

**Teliospores**
- Produced in pustules and remain in pustules unless they are aggressively brushed off
- Produce basidiospores if under moist conditions for at least 3 hours (optimum temperature=63°F (17°C))
- May survive attached to dried leaves for 8 weeks at 50% relative humidity or less; die sooner under moist conditions
- Survive ONLY one week if infected tissue is buried under soil

**Basidiospores**
- Can cause epidemic if conditions are right
- Spread from plant to plant by splashing water
- Must have film of water on plant surface for infection
- Infection (host penetration) can occur in 2 hours at optimum temperature of 63°F (17°C)
- Can travel short distances of 700 meters = about 1/2 mile by wind currents during moist weather (less than 1/2 mile in most situations)
- Survive 5 minutes when relative humidity is 80% or less and less than 60 minutes when relative humidity is 90%