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POWDERY MILDEW IN THE GREENHOUSE

Powdery mildew is one of the most common and widely distributed disease of plants in greenhouse production. This disease is responsible for significant economic losses in many greenhouse floricultural (e.g., roses, violas, African daisy, zinnias) and vegetable (e.g., tomatoes, cucumbers) crops. More recently, powdery mildew has been implicated as a serious threat to poinsettia production. Although infections usually do not result in plant death, they reduce crop aesthetics and value. With tomato, infections can significantly reduce fruit production. In the greenhouse, powdery mildew tends to be more problematic in the spring and fall when day-night temperatures favor high relative humidity (RH) but it can develop at any time during any production cycle. An understanding of the disease cycle, organisms involved, and factors that favor disease development will contribute to successful management of this disease.

SYMPTOMS:

Powdery mildews are easily recognized by the white, powdery growth of the fungus on infected portions of the plant host. The powdery appearance results from the superficial growth of the fungus as thread-like strands (hyphae) over the plant surface and the production of chains of spores (conidia). Colonies vary in appearance from fluffy and white to sparse and gray (Figures 1-3).

Figure 1. Powdery mildew of torenia.

Powdery mildew fungi usually attack young developing shoots, foliage, stems, and flowers, but can also colonize mature tissues. Symptoms often first appear on the upper leaf surface, but can also develop on lower leaf surfaces. Early symptoms vary and can appear as irregular, chlorotic, or purple areas, or as necrotic lesions, all of which are followed by the typical white, powdery appearance. Some infected leaves may shrivel, brown, and drop prematurely. Other symptoms include atypical scab-like lesions, witches'-brooms, twisting and distortion of newly emerging shoots, premature leaf coloration and drop, slowed

or stunted growth, and leaf rolling. In rare but extreme situations, heavy infections cause plant death.

Figure 2. Powdery mildew of gerbera daisy.

Although diagnosis of powdery mildew is not difficult, symptoms often escape early detection if plants are not periodically monitored, since symptoms can first develop on lower or middle leaves. The time delay from when infections begin and when disease is detected helps explain reports of sudden "explosions" of disease. This can occur when the percentage of infected leaves increases from 10% to 70% in one week.

Figure 3. Powdery mildew colonies on a cucumber transplant.

CAUSAL ORGANISMS AND DISEASE DEVELOPMENT:

Although the symptoms of disease are similar, the fungi responsible for powdery mildew fall into a number of different genera. The most common genera include *Erysiphe*, *Golovinomyces*, *Phyllactinia*, and *Podosphaera*. These fungi are all obligate parasites that require living hosts to complete their life cycles so they readily infect healthy, vigorous plants. Some powdery mildew fungi have broad host ranges whereas others are fairly host-specific. For example, *Podosphaera macularis* can infect many hosts such as coreopsis, geranium, heuchera, delphinium, phlox, and potentilla, whereas *Sphaerotheca sparsa* is limited to asclepias. It is important to know the identity of the fungus in order to determine the potential for spread to other crops that might be present in the greenhouse.

Powdery mildew fungi have fairly simple life cycles on most plants. Spores (conidia) are produced in chains on stalks (conidiophores) (Figure 4). Conidia are "powdery" and are readily disseminated by air currents.

Figure 4. Chains of powdery mildew conidia on conidiophores growing the surface of a leaf (arrows).

After the conidia land on the plant surface, they germinate, penetrate the tissues, and send food-absorbing projections (haustoria) into the epidermal cells. Thread-like strands of the fungus (hyphae) then grow over the surface of the infected plant part and eventually produce more conidiophores and conidia. The time from when conidia land to the production of new conidia can be as short as 72 hours, but is more commonly 5-7 days. Powdery mildew conidia are unique since, unlike most fungal spores, they do not require free moisture (e.g., guttation, dew, rain, overhead irrigation) on plant surfaces in order to penetrate and infect.

In greenhouses, powdery mildews usually survive between crops as hyphae or fungal strands in living crop plants or in weedy hosts. Under certain circumstances, some powdery mildew fungi produce small, black, pepper-like resting structures called chasmothecia (formerly called cleistothecia) (Figure 5). These structures allow the fungus to survive in the absence of a suitable host. However, the role of these resistant structures is probably insignificant in greenhouse situations since continuous cropping provides a constant source of living hosts.

Figure 5. Chasmothecia of different ages of maturity, from immature yellow to mature dark brown or black.

Development of powdery mildew in the greenhouse is influenced by many environmental factors including temperature, RH, light, and air circulation. Unfortunately, greenhouses usually provide optimum levels for all of these conditions. Optimum conditions include moderate temperatures (68-86° F), high humidities (>95% RH), and fairly low light intensities or shade. However, these requirements vary with the specific powdery mildew fungus. There is an inverse relationship between temperature and RH which influences both the production and spread of powdery mildew conidia. As temperatures fall at night, RH increases. High RH stimulates conidia to germinate and also encourages the production of chains of conidia in existing infections. In the morning after sunrise, the temperatures warm and RH levels fall. These conditions help to dry the chains of conidia. Since conidia function as the primary means for new infections in the greenhouse, air movement and circulation in the house are very important for development and spread of disease. Dry, "powdery" conidia are easily dislodged and disseminated by air movement from grower activities in the house as well as by opening and closing doors.

STRATEGIES FOR DISEASE MANAGEMENT:

Although chemical control continues to be a key component of management of powdery mildew in the greenhouse, other strategies complement and enhance control efforts.

1. Culture and Pathogen Identification-

- Maintain adequate plant spacing to reduce RH levels in the plant canopy. This also helps to obtain good coverage with fungicide sprays.
- Maintain RH levels below ~ 93% by properly timed venting and heating.

- Identify the particular powdery mildew fungus in order to anticipate the potential for spread to other plants in the house.
- Syringing or applying water directly to leaves of some greenhouse crops discourages germination of conidia and helps to wash conidia off leaf surfaces. This procedure works for some crops provided other types of foliar diseases favored by leaf wetness are not common problems for that crop.

2. Monitoring and Sanitation-

- Carefully examine and inspect new cuttings, seedlings, and plugs upon arrival. Never use diseased plant material.
- Scout for disease on a regular schedule to identify outbreaks before they become widespread. This typically involves examining one out of 30 plants each week. It is helpful to concentrate on the middle and lower leaves since infections often start in these leaves. Once disease is detected, examine one out of 10 plants every week. Continue with this schedule until plants are free of disease for at least three weeks. Thereafter, resume weekly scouting of one plant out of 30.
- All diseased tissues should be removed as soon as they are detected and immediately placed in a plastic bag to avoid carrying infected material through the house.
- All production areas should be thoroughly cleaned and plant debris removed between crops and production cycles. This includes removing all weeds in and around the greenhouse.

3. Resistance-

- Genetic resistance is very effective for powdery mildew control but it is unfortunately of limited availability for most floricultural crops. For example, the "Profusion" series of *Zinnia elegans* is resistant to powdery mildew and pansy cultivars "Delta Pure Rose" and "Bingo Deep Purple" are highly resistant to some powdery mildews.

4. Chemical-

Control with chemicals is targeted at eradication of existing infections and protection of healthy tissues. Once disease is detected, the first sprays should be aimed at eradication. These are usually followed by sprays for protection. The efficacy of specific compounds can vary significantly with the particular powdery mildew fungus and host, so knowledge of the host-pathogen combination is helpful. Attention to spray delivery and coverage is also very important. Other factors for consideration are fungicide classes (MOA--FRAC Code) for resistance management, REI, environmental parameters (e.g., T, RH), compatibility, residue, and stage of the crop production cycle.

- Eradication sprays should be applied as soon as symptoms are first observed since early control is *critical!!!*
- Monitor and rotate the types of compounds used to avoid development of fungicide resistance in the powdery mildew population. The diversity of products currently registered and effective for greenhouse use makes fungicide resistance management much easier than in the past. Since pesticide registrations vary with state, check with the appropriate agency and consult the label before applying any pesticide.
- General categories of compounds
  - Biologicals:
    - *Bacillus subtilis* (Cease, Rhapsody, Serenade)
    - *Trichoderma harzianum* Rifai strain KRL-AG2 (PlantShield)
  - Systemics:
    - Strobilurins [QoI] (Compass O, Cygnus, Insignia, Heritage)
    - DMIs (Terraguard, Eagle, Hoist, Strike)

    - Thiophanates (Cleary's 3336, OHP 6672)
    - Carbamate and Strobilurin (Pageant)
- Contacts (*Biorationals):
    - Bicarbonates (Milstop, Kaligreen) *
    - Coppers (Camelot, Kocide, Phyton 27)
    - Hydrogen dioxide (ZeroTol, Oxidate)
    - Sulfur (Microthiol Disperss)
    - Oils: Horticultural & Neem (Ultra-Fine Oil, Triact) *
    - Soaps (Insecticide Soap) *

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