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Mildews of Hops:

Podosphaera and Pseudoperonospora

Introduction

Hops are an essential component in the brewing process, providing the hallmark bitterness of IPA's, as well as the subtle hints of herbal, pine, or citrus throughout the beer. New York was once the hop production capital of the North American Industry. However, production was pushed westward into the favorable drier climate of the PNW largely due to epidemics of Downy Mildew and Powdery Mildew in the early 1900's. Demand for locally produced hops has grown in parallel with the recent boom of the craft brewing industry.

As hop yards re-emerge to meet these demands, it is important to recognize that the pathogens that destroyed the industry of the 20th century are still present, and must be managed to ensure a stable hop industry. This fact sheet highlights Downy Mildew and Powdery Mildew, with the intention of aiding diagnosis and management of these pathogens.

Figure 1: Characteristic white colonies of hop powdery mildew. (B. Weldon)

Powdery mildew is caused by the ascomycete *Podosphaera macularis*. It is one of the most destructive and widespread diseases of hops worldwide.

Downy mildew is caused by the oomycete *Pseudoperonospora humuli*.

Signs and Symptoms

Powdery mildew can occur on all green tissue of the hop bine, including the stems, leaves, flowers, and hop cones. The most telling sign of the pathogen is white, powdery colonies that can be found on either side of leaf tissue, as well all other plant parts. Infections on the underside of the leaf are also possible, and the host plant usually expresses chlorotic spots on the corresponding topside of the leaf as a symptom.

Figures 2: Typical foliar signs and symptoms of Downy Mildew. (L) Yellow lesions on upper leaf, typical early symptom. (R) Brown necrotic lesions, typical later stage symptom. (B. Weldon)

Figure 3: Black masses of sporulation found exclusively on underside of leaf. (B. Weldon)

As colonies age, they develop a grey, granular appearance, which over time can develop into a necrotic lesion on the leaf. Infected cones also contain the characteristic white powdery colonies at the tip of the cone and within each of the bracteoles. These colonies will eventually cause brown, necrotic lesions on the hop cones. Additionally, infected cones are commonly physically distorted and growth is typically stunted from the point of infection and thereafter. Infected cones have distorted alpha and beta acid content, disturbing the essential components of hops for brewing purposes.

Figure 4: (L) Powdery mildew infected hop cone. (B. Weldon) (R) Brown discoloration of hop cone bracteoles with severe downy mildew. (B. Engelhard)

Downy Mildew: The most characteristic symptom of the disease in hops is the presence of systemically infected shoots, called "spikes". This tissue arises from either the hop crown (primary spikes) or from apical meristems (secondary spikes). In both cases, the bines are stunted with short internodes and possess brittle, downward curling, chlorotic leaves.

In the case of secondary spikes, these symptoms are not observed in tissue below the site of infection on the bine. Often infected spikes lose the ability to wind around the training strings of the trellis. On the lower surface of the leaf, lesions appear angular and localized to regions around the veins. These lesions quickly develop from chlorotic, water soaked spots to necrotic lesions that readily desiccate in dry conditions.

Figure 5: Downy mildew basal spikes. (L) A cluster of basal spikes emerging from the hop plant. (R) A single basal spike pulled from a downy mildew infected hop plant. Note the shortened internodes between leaves, chlorotic tip of the shoot, and downward curling leaves. (B.Weldon)

Sporangia form only on the underside of the leaves, emerging through stomata, and in masses that appear purple-grey. Cones are highly susceptible to infection and will quickly turn brown, hardened, and stunted. Downy mildew significantly reduces the carbohydrate reserves the hop rhizome, making the disease capable of fully killing systemically infected hills.

Disease Cycle

Both hop powdery mildew and hop downy mildew are host specific. As an example, this means that the powdery mildew that occurs on grapes cannot infect hops, and vice versa. Both organisms are obligate parasites, meaning that they can only grow upon living plant tissue. Both pathogens can cause complete loss of the marketable hop cone.

Powdery Mildew: In the spring, a small percentage of hop shoots can emerge systemically infected with powdery mildew, termed flag shoots. The number of flag shoots is correlated with the amount of disease present the previous season, but is often less than 1% of emerging shoots.

Flag shoots are often strikingly white, with stunted growth, short internodes and distorted leaves. Conidia are the primary dispersal agent of the disease during the growing season, commonly landing on the top of the leaf through aerial dispersal. Powdery mildew spores do not require water for infection,

making the pathogen destructive even in dry climates and dry years.

Figure 6: Hop powdery mildew flag shoot. (D.H. Gent)

Should both mating types of the fungus be present, black, winter-hardy overwintering structures termed chasmothecia can form within these colonies. Along with flag shoots, the spores released by chasmothecia can be a second source of inoculum in the following year.

Figure 7: Chasmothecia of hop powdery mildew. (B. Weldon)

Downy Mildew: The organism overwinters in infected dormant buds and crowns beneath the soil line. It will spread into a small percentage of developing buds, and give rise to primary basal spikes when shoots begin to emerge in the spring. Sporangia are produced from the underside of the leaf when humidity levels reach above 90%, and are aerially dispersed to new host tissue. Sporangia indirectly germinate to release zoospores that require water to be able to swim into host stomata and cause infection. Should shoots near the crown become infected, downy mildew mycelia can grow through the shoot and systemically invade the rhizome crown.

Management Strategies

Powdery Mildew: Factors that promote succulent growth of host plant tissue also promote high disease pressure. So, factors such as long spans of cloud cover, high canopy density, excess fertilizer (especially nitrogen), and high soil moisture are all conditions that favor the success of hop powdery mildew. Additionally, temperature appears to be a very important factor in the development of the disease. Infection is possible during temperature ranges of 8-28 C, while optimal infection and growth temperature spans from 18-21 C. The disease is polycyclic, and there is the potential for up to 40 disease cycles to occur within a growing season. Latency periods typically span from 5-10 days, and get longer as the temperature strays from the optimal 21 C in either direction. Infection and sporulation is reduced by more than 50% when temperatures exceed 30 C for more than 3 hours during the day.

Downy Mildew: Sporangia cannot be produced when temperatures drop below 5 C, and production is optimal between 16-20 C. Zoospore release from sporangia is greatest mid-afternoon and during rainy events, in which the zoospores can be widely dispersed via raindrops and enter new host sites through the stomata. Downy mildew requires a water film to infect its host, so severe disease generally requires multiple rain events spaced over the growing season. It is one of the worst pathogens of hop in wet, humid production regions.

Combined Management Practices

1) Select resistant varieties and carefully consider the source of the planting material. Strains of powdery mildew exist in the PNW that can cause disease on hop varieties typically considered resistant; includes Nugget, Cascade, Mt. Hood, and TriplePearl.

2) In the spring, when hop shoots are first emerging, rigorously scout for the presence of flag shoots (powdery mildew) and basal spikes (downy mildew). Remove all infected shoots.

3) Prune yards as late as possible without negatively affecting yield. How late you can prune depends on the length of growing season. The PNW has longer growing seasons, so growers can get away with

pruning later in the season than can growers in the Northeast.

4) Break the green bridge, i.e. the green leaf tissue along the ground that connects from hill to hill. Strip lower leaves from bines after training (~ 4 feet and below). This removes basal foliage as an inoculum source and increases airflow in the hop yard, which reduces humidity levels that promote these diseases.

5) Rotate and tank mix fungicide modes of action to delay development of resistance. Be aware the downy mildew and powdery mildew are in distinctly different classes of organisms, and therefore typically require different fungicides for successful management.

Citations:

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READ THE LABEL BEFORE APPLYING ANY PESTICIDE! Changes in pesticide regulations occur constantly. All pesticides distributed, sold, and/or applied in New York State must be registered with the New York State Department of Environmental Conservation (DEC). Questions concerning the legality and/or registration status for pesticide use in New York State should be directed to the appropriate Cornell Cooperative Extension Specialist or your regional DEC office.

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