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Ontogenic resistance to powdery mildew in hop cones: Implications for disease management

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ABSTRACT

Podosphaera macularis is the causal agent of hop powdery mildew and can cause substantial losses in crop yield and quality. Ontogenic resistance has been described in hop leaves, although ontogenic resistance has not been examined in detail in cones. Greenhouse-produced cone tissues were inoculated on a time course to assess their susceptibility to powdery mildew in different developmental stages. Field-based fungicide programs also were evaluated to determine the impact of omitting late-season fungicide applications on cone yield, levels of bittering acids, and quality factors. In greenhouse assays, young flowers were highly susceptible to powdery mildew, but susceptibility of bracts and bracteoles decreased linearly with increasing cone maturity. In fungicide trials conducted under high disease pressure, there was a tendency for later season fungicide applications (up to 24 August) to improve cone yield, alpha acid content, and quality. The incidence of diseased cones was correlated with alpha acid content (r = -0.62; P = 0.04), cone color (r = -0.73; P = 0.01), and aroma quality (r = -0.77; P = 0.01). Under low disease pressure, however, cone yield, alpha acid content, and quality were similar if fungicide applications were made through 27 July. Treatments that ended before this time had similar yield and alpha acid content, but cone color was negatively affected. Further characterization of ontogenic resistance in cones may enable control measures to be targeted to critical periods of cone susceptibility and potentially reduce unnecessary fungicide applications.

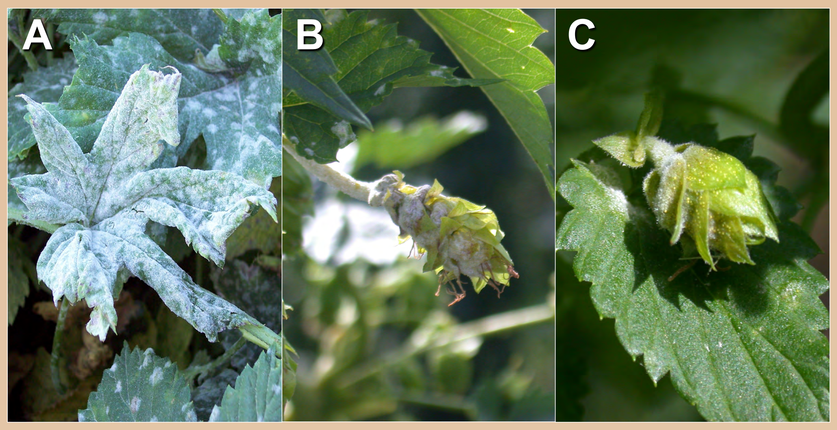

Figure 1. Powdery mildew on leaves (A) and cones (B and C).

MATERIALS AND METHODS

Detached cone tissue assays. Greenhouse-grown hop cones of a cultivar highly susceptible to powdery mildew were sampled at multiple phenological stages. Detached flowers (burrs), bracts, and bracteoles (Fig. 2 and 3) were placed onto moistened filter paper and inoculated in a settling tower. Disease incidence ratings were completed using a stereomicroscope after 1.5 latent periods (10 days). Field-grown hop cones were sampled and inoculated as described above (Fig. 3D), and background powdery mildew levels were recorded.

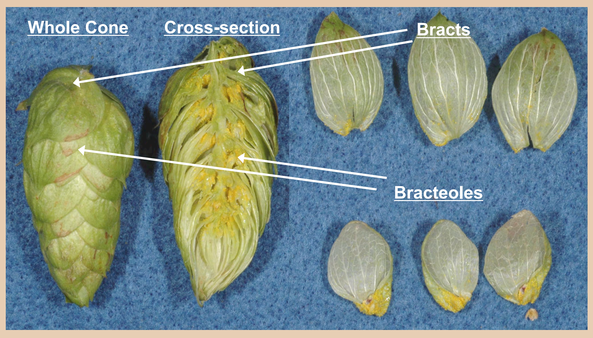

Figure 2. Hop cone tissues.

Field-assays. Juvenile susceptibility may have an impact on the timing and efficacy of fungicide programs. Treatments evaluating the effect of ceasing fungicide applications in mid-July, late-July, mid-August, and late-August were conducted in both a commercial and experimental hop yard. Treatments were arranged in a randomized complete block design with 4 to 5 replications. At harvest, plots were evaluated for cone yield, alpha acid content, and cone quality factors. Cone quality factors were determined by a commercial hop merchant.

Figure 3. Detached flowers (A), field-grown bracts and bracteoles (outer and inner surface) (B), greenhouse-grown bracts and bracteoles (outer and inner surface) (C), and detached field-grown lateral branch. These tissues were inoculated using a dry inoculation method and rated after 1.5 latent periods (10 days).

RESULTS AND DISCUSSION

- Ontogenic resistance was observed in detached cone tissues, with the detached bracts being the most susceptible in greenhouse-grown cones (Fig. 4).

- While there was enhanced juvenile susceptibility observed in the detached bracts and bracteoles, complete resistance was not observed at the point of crop maturation (BBCH-scale ~ 89) (Fig. 4).

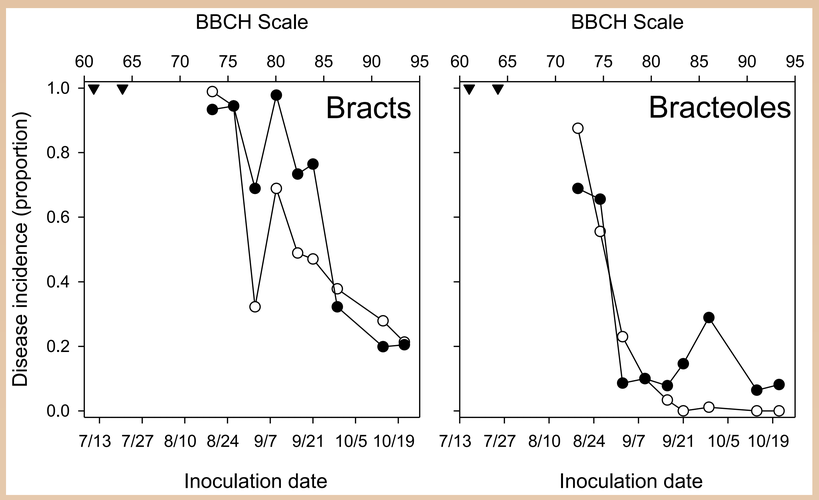

Figure 4. Incidence of powdery mildew on detached bracts and bracteoles inoculated at different phenological stages. BBCH scale refers to the phenological stage of the cones. Black triangles (▼) indicate detached flowers (see Fig. 3). Open circles refer to the inner surface of the tissue and closed circles refer to the outer surface of the tissue.

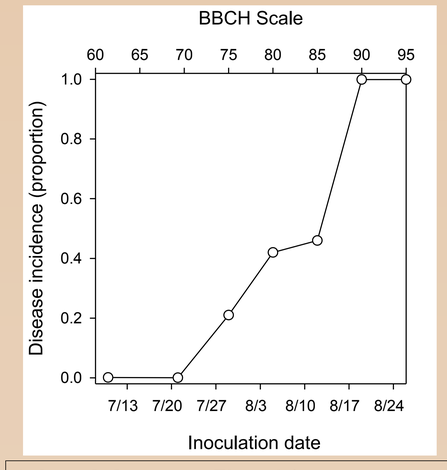

Figure 5. Powdery mildew incidence on field-grown hop cones sampled at multiple time points during crop development.

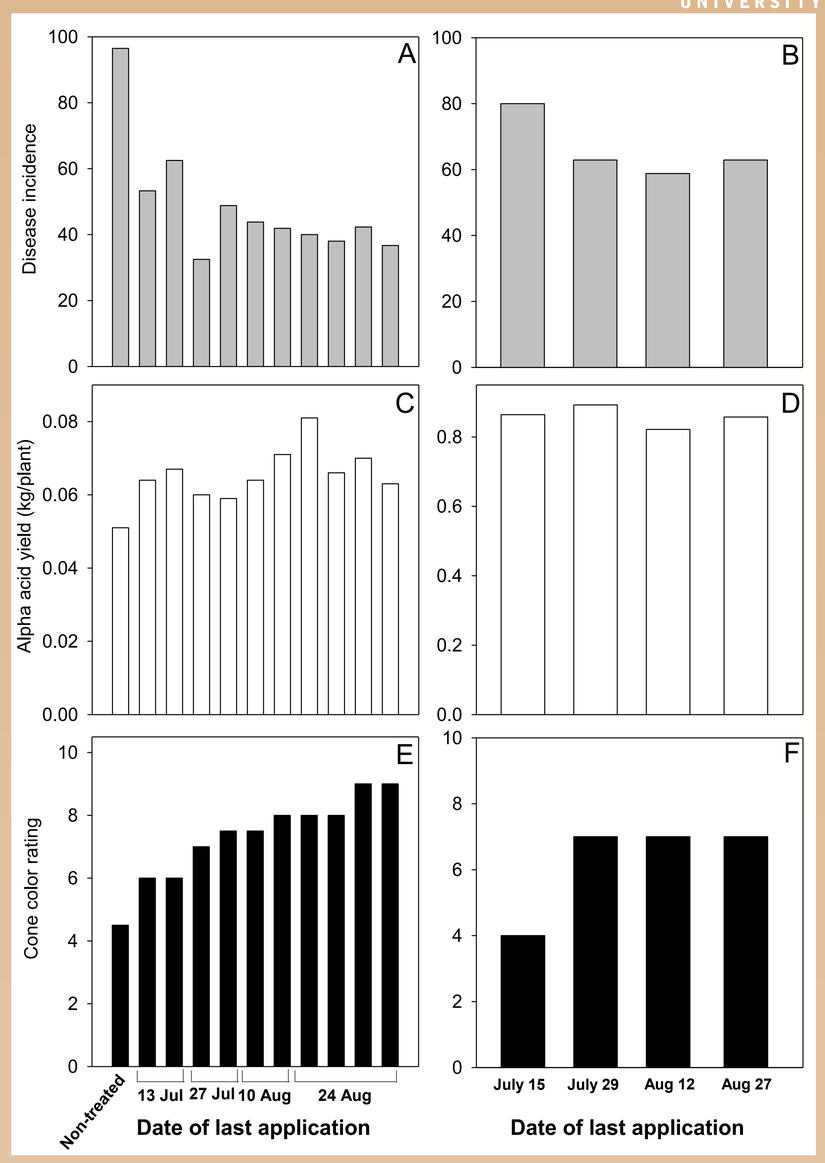

Figure 6. Disease incidence, alpha acid yield (kg/plant) and cone color rating in experimental plots (left column) and commercial plots (right column). Dates indicate the date when fungicide applications ceased.

- Powdery mildew incidence on cones in an experimental hop yard increased logistically (Fig. 5), suggesting secondary spread among cones.

- In both trials, disease control was not improved with fungicide applications made after July 27 (Fig. 6A, B). This may indicate a critical period for the timing of efficacious fungicides for powdery mildew on cones.

- However, under high disease pressure, cone yield, alpha acid content, and cone quality were improved with the application of fungicides made up to August 24 (Fig 6C, E). Disease incidence was correlated with alpha acid yield (r = -0.56, P = 0.08) and cone color (r = -0.73, P = 0.01).

- Under low disease pressure, there was no benefit to yield, alpha acid content, and cone quality from additional fungicide applications made after July 27 (Fig. 6D, F).

- Under high disease pressure, the trend for improved cone color with late season applications (Fig. 6E), may suggest a role of diffuse infections on cone color and yield.

LITERATURE CONSULTED

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