Ontogenic Resistance of Leaves, Leaf Folding and the Distribution of Mildew Colonies in Strawberry Powdery Mildew (*Podosphaera macularis*)

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Is Strawberry Powdery Mildew a Late-Season Disease?

Symptoms and signs of strawberry powdery mildew are often not observed until late in the growing season and growers may not intervene to manage the disease before mildew colonies are seen. However, our most recent studies indicate that primary infection from ascosporic inoculum may occur soon after overwintered plants begin to regrow in early spring. Why then does the early development of the epidemic pass unnoticed?

Fig. 1 (right). Typical matted-row culture of strawberries in early spring. Semi-persistent leaves (insert) from the previous season often survive winter and are interspersed within new growth once regrowth of the canopy resumes.

Fig. 2. Upward curling of leaves and marginal reddish blotches reveal extensive mildew colonies on the lower surfaces of strawberry leaves. The upper leaf surfaces appear comparatively mildew-free.

Why Is Colonization More Prevalent on the Lower Leaf Surface?

Many previous reports indicated that colonies of *Podosphaera macularis* are distributed most abundantly on the lower surface of strawberry leaves. Differential susceptibility of the upper vs lower epidermis, differential conditions of temperature and humidity, and direct damage to colonies by UV light have all been postulated, but not conclusively demonstrated, to be involved.

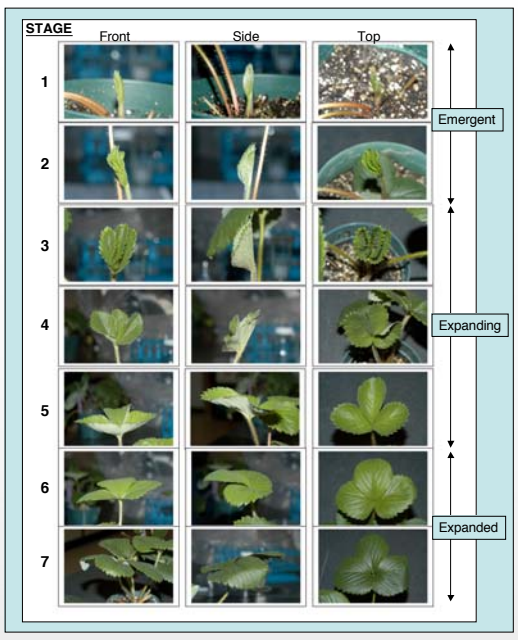

Fig. 3. Front, side, and top views of leaves representing 7 numerical stages assigned to different aged strawberry leaves.

Ontongenic Resistance to Powdery Mildew in Strawberry Leaves

Strawberry leaves begin as folded trifoliate leaves wherein the leaf blade is greatly reduced and only the lower leaf surface is exposed as they emerge from the crown (emergent leaves). As leaves age, the blade expands and the upper surfaces become exposed (expanding). Later, the leaflets flatten and reach full size (expanded). We assigned 7 numerical stages to leaves as depicted in Fig. 3. We inoculated the upper or lower surfaces of leaves at each numerical stage. For emergent leaves (stages 1 and 2), this required prying the leaf open to gain access to the upper leaf surface and inserting the conidia. Plants bearing the inoculated leaves were incubated for 7 to 10 days at 20 C and 70% RH.

Is the Lower Leaf Surface More Susceptible?

Probably not. When we simultaneously inoculated the upper and lower surfaces of young leaves on the cultivars Earliglow and Elan (both of which are regarded as highly susceptible to powdery mildew) and incubated the plants at 20 C and 70% RH, there was no significant (P = 0.05) difference in either the diameter of colonies, density of sporulation, or latent period on the upper vs lower leaf surface.

Fig. 3. Earliglow 10 days after inoculation.

How Does Ontogenic Resistance Affect Pathogen Development?

Susceptibility of strawberry leaves declined exponentially as they aged, whether the response recorded was latent period, colony expansion, or the number of conidia produced (Fig. 5). By the time the emergent leaves began to unfold (stage 3), they had already lost much of their susceptibility (Fig. 5). Only the lower leaf surface was exposed during the period that the leaves were highly susceptible.

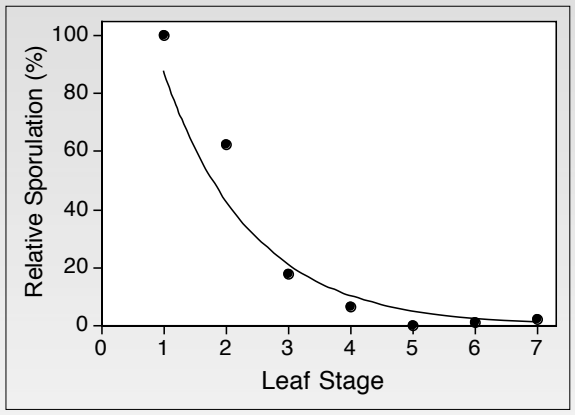

Fig. 5. Relative sporulation on different aged leaves of 'Elan' strawberries 7 days after inoculation.

Fig. 6. Earliglow leaf at developmental stage 2.

Combined Effect of Ontogenic Resistance and Leaf Folding

We released conidia of *P. macularis* upwind of potted Earliglow and Elan plants bearing leaves at developmental stages 1-7 (Fig. 3). Seven to 10 days later, over 90% of all colonies observed occurred on the lower surface of leaves that were at stage 1 or 2 (Fig. 6) at the time of inoculation, and were thus highly folded at the time of exposure.

Powdery Mildew on Older and More Resistant Leaves

We placed potted mildewed plants at the center of a new and mildew-free planting of Elan strawberries. One month later, only the potted plants showed macroscopically-visible mildew colonies. However, the lower surface of older fully-expanded (and healthy-appearing) leaves throughout the planting supported an extensive network of non-sporulating hyphae of *P. macularis* (Fig. 7). The duration of colonization without sporulation far exceeded reported latent periods for the pathogen, although sporulation has often been observed on old leaves late in the growing season in many regions where the crop is grown.

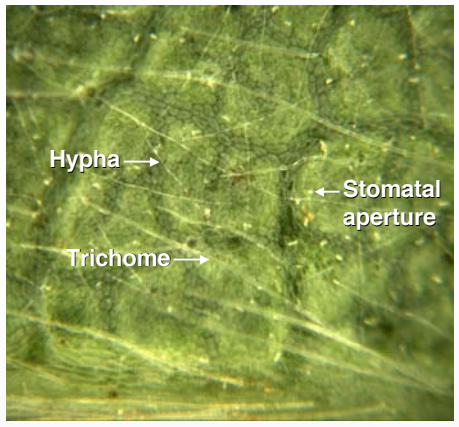

Fig. 7. Diffuse colonization of the lower surface of a stage-7 Elan leaf by *Podosphaera macularis*.

Conclusions

At least in part, the more-common appearance of *P. macularis* on the lower leaf surface reflects escape of the upper epidermis from infection due to leaf folding during a critical susceptible phase.

Leaves rapidly acquire substantial ontogenic resistance, although they never become completely resistant and may support extensive diffuse colonization.

Although symptoms and signs of powdery mildew may not become conspicuous until later in the growing season, primary infection can occur immediately upon resumption of growth after winter and extensive spread of the pathogen may occur without macroscopically-visible symptoms or signs.

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