Title: Web-Based In-Service Agent Training Modules In Disease Management And Diagnosis.

Progress Report

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Objectives:
The objectives of this proposal is to: 1) develop web-based training modules in disease management targeted at agents and 2) develop more advanced web-based information for diagnosticians and other professionals to implement protocols for diagnosis of strawberry diseases.

Methodology: Training materials were proposed to be developed on the primary disease problems encountered with strawberries. These would include Botrytis, Colletotrichum and Phytophthora problems. Several outlets for the training products were proposed including web access to PDF and possibly PowerPoint presentations. A second level of web-based training modules were proposed to be targeted at diagnosticians and other advanced professionals. This would provide detailed information on how to diagnose specific disease problems.

Results: We have updated and written a specific disease note on every major disease in strawberries as well as "diagnostic keys" for specific problems such as crown rot identification. This is has over 45 pages of content. We of course do not intend to publish this all together (although it forms a very good IPM manual for agents/growers) but will post each disease separately. The material needs to go through peer review/feedback and then we will start posting it on websites (e.g. NCSU plant pathology; the strawberry Grower Information Portal (http://www.ncsu.edu/enterprises/strawberries) and/or the Small Fruit Center. We need to sort out the details how best to do this, there is no effective infrastructure in our department to do web-based activity. Therefore, a no-cost extension is requested so we can complete this work. It is our goal to have near publication ready products for the Savannah agent training program on in early January 2011. An Example of our Botrytis note is attached (Appendix A)

Conclusions: Ready access to strawberry disease information will aid our growers, agents and clinicians well. In depth and comprehensive extension products have been developed and need to be finalized as part of our goal to serve our clientele well. These products will best be used through web-based access and through a no-cost extension we will accomplish this in the coming months.

Impact statement: IPM-based information will help growers better manage diseases. We integrate novel and established knowledge about the biology, ecology and management of the major strawberry diseases into practical disease management programs that hopefully will serve our stakeholders well.

Publications from this project: None other than we put out several extension newsletter publications that are based on these disease diagnostic notes.

Appendix A:
Gray Mold; Botrytis Rot (*Botrytis cinerea* (de Bary) Whetzel)

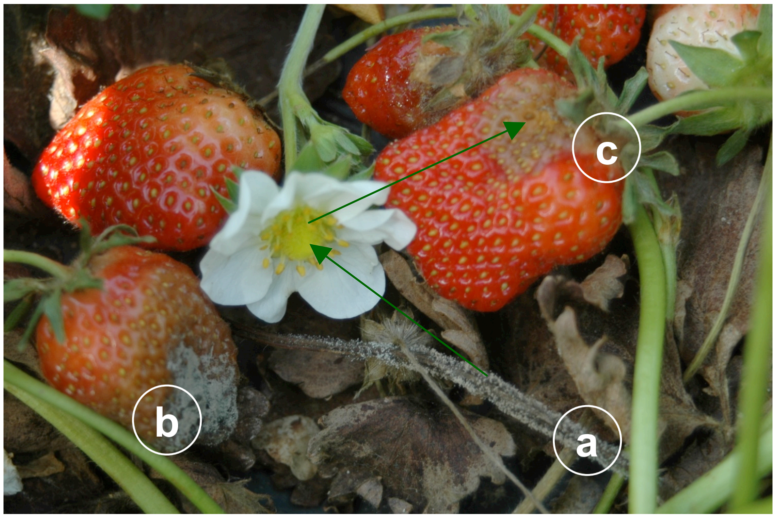


Fig. 1. Gray mold on different parts of strawberry; a) Sporulation on dead petiole and leaf; b) fruit infection from colonized dead tissue; c) lesion appearance from internal infection that have occurred through flower parts such as stigma.

Causal Organism [on separate page with detailed images]
Botrytis cinerea (anamorphic state *Botryotinia fuckeliana* (deBary) Whetzel) hyphae are branched, septate, hyaline. Conidiophores are long (2-5 mm), dark brown, branched primarily near the apex, determinate with swollen terminal cells that form ampullae. Conidia (8-14 x 6-9 μ m) are one-celled, multinucleate, obovoid, colorless or pale brown, and are born on denticles protruding from each ampulla giving it a grapelike cluster appearance. In mass, conidia appear gray to grayish-brown. Sclerotia are black, irregular in shape, and can be up to 5 mm long.

Symptoms and Signs

Gray mold may be prevalent during all stages of strawberry fruit development. Infected leaves and flowers turn brown and may die. Light brown lesions usually develop on the stem end of the fruit or on sides of fruit where soil, standing water, or infected berries are in contact, and can spread over the entire surface. Infected berries may remain firm, yet become covered with gray spores and mycelium, giving the fruit a velvety gray appearance. High humidity favors mycelial formation that is visible as a white cottony mass. On undeveloped fruit, lesions may develop slowly and fruit may become misshapened and die before maturity. Fruit that are completely rotted through become dry, tough and mummified.

Disease cycle

Botrytis primarily enters the field on transplant foliage. The fungus can live in the green tissue but be latent, or dormant, and not cause symptoms. Botrytis can affect many different crops and therefore weeds surrounding a field could be an important source of the pathogen. However, in our recent experiments conducted in eastern North Carolina, we found no signs of

Botrytis on surrounding vegetation, and found no indication of sclerotia (the overwintering form of *Botrytis*) in the soil, suggesting that those sources may be of limited importance in the spread of disease. As the infected strawberry leaf begins to die, the pathogen goes into an active stage, colonizing the leaf and obtaining its nutrients from the dead tissue. Spores then form and, once environmental conditions are appropriate (between 65-75 F and damp or rainy weather), they are dispersed by water splash and/or wind onto newly emerging leaves or blossoms. Immature fruits become infected primarily through blossom infections. Once the berries begin to ripen, the fungus is able to colonize them and sporulate, producing the mold often seen in the field.

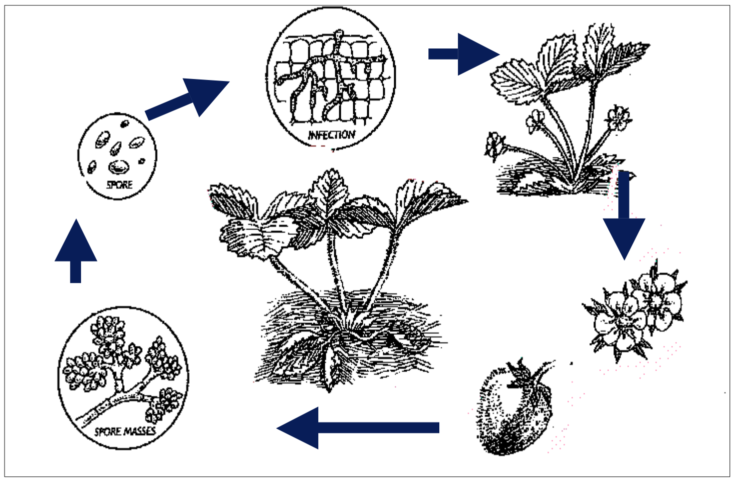
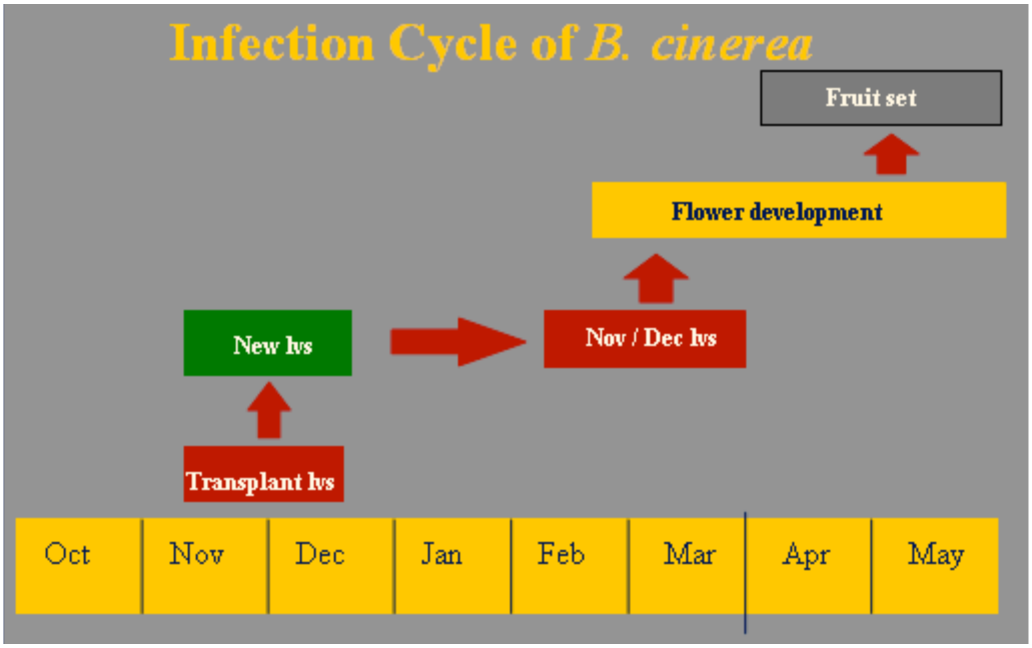


Figure 2: Infection cycle of B. cinerea in strawberry plantings from Cooley et al. 1996.

Factors of plant growth that are most important for disease development in annual planting systems:

1. Leaf senescence - Death of transplant foliage results in release of the initial inoculum introduced at planting. *Botrytis* will produce its spores on the dead leaf tissue and infect the leaves emerging during this time. Those newly infected leaves may then senesce two to three months later, during primary flower development.
2. Leaf emergence - Newly emerging leaves are extremely susceptible to infection. Upon infection in the fall, leaves will appear healthy until senescence occurs in the spring and the secondary inoculum is released.
3. Floral development - Release of secondary inoculum results in the infection of flowers and subsequent infection of the fruit. Rarely are the fruit themselves infected by an airborne spore, rather, *Botrytis* will stay dormant in the developing flower/fruit until factors such as increased ethylene production (ripening) and high humidity/rainfall allow for growth of the fungus.



Control

1. USE DISEASE-FREE PLANTS.

B. cinerea is commonly associated with transplant leaves and two years of research has demonstrated that there are no differences due to plant source. Currently, it is not possible to obtain disease free plants. However, plug production practices may favor crown rot problems and this is addressed elsewhere. Likewise, excess use of certain fungicides during the propagating phase results in resistant populations and poor control with these fungicides in fruit production fields.

2. MONITOR AND MANAGE

Excess nitrogen has been shown to increase fruit rot when weather conditions are favorable. To avoid over-fertilization, base fertilizer programs on leaf tissue nutrient analysis reports (see leaf sampling). Research has demonstrated increasing nitrogen levels beyond an optimum level does not increase yield but does increase fruit rot incidence.

Allow adequate spacing between plants to improve airflow in the canopy. Planting in raised beds improves drainage and also increases airflow, resulting in lower disease levels. Plastic mulch helps keep down rain splash, plant and soil-surface contact, weeds that may harbor *Botrytis* inoculum, and reduces moisture within the canopy. Drip irrigation provides a direct source of water and eliminates excess moisture from fruit and leaves. Removal of senescing tissue from the field may be helpful in the fall, but is likely of most benefit in the early spring, just prior to bloom, to help lower inoculum levels. Harvested fruit should be monitored for disease, and infected berries removed. Keeping fruit at around 34 F and increasing carbon dioxide levels during shipping (12-15 % concentration in gastight storage bags) when harvested will help keep *B. cinerea* down.

3. CHEMICAL CONTROL

Fungicides play a major role in the management of this disease. Fungicide applications are critical in problem fields during early and full bloom. These fungicides are targeted to limit flower infection that leads to fruit infection, and should limit the need for late season applications to the fruit. A few well-timed sprays are less costly and more effective in controlling gray mold than frequent fungicide applications through harvest. See extension publications for current recommendations.
http://www.smallfruits.org/SmallFruitsRegGuide/index.htm

4. BIOLOGICAL CONTROL

Antagonistic fungi such as *Trichoderma harzianium* Rifai and *Gliocladium roseum* Bainier have been used in Europe and Brazil as alternatives to fungicides.

Remember, *Botrytis* is in the field all season long. Don't wait until peak bloom or fruit set to begin control practices. Plan ahead and design your management program to inhibit disease progression at critical points in the season.