Title: Biology and Management of Anthracnose and Botrytis in Strawberry Production in the Southeast

Research or Extension Project: Research

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Objectives: To discover basic information on the biology of Colletotrichum and develop tools to manage anthracnose and Botrytis or to reduce disease risk in strawberry fruit production fields.

Justification: Anthracnose of strawberry can be the most destructive disease on specific farms. Three species have been associated with anthracnose of strawberry including *Colletotrichum gloeosporioides*, *C. acutatum*, and *C. fragariae*. *C. acutatum* is more commonly associated with the ripe fruit rot problem. The disease has been associated with asymptomatic plants imported from transplant supply nurseries, either as tips or bare root plants. The use of "disease-free" plants is the most important management strategy to control this disease. However, once contaminated plants are imported, growers need to know how best to manage the problem. In particular, the primary goal is to protect developing fruit in the spring. We are uncertain if transplant treatments or fall fungicide applications have economic utility. A key question to answer relates to the dynamics of the pathogen during the winter and spring, prior to fruit set. Does the pathogen undergo reproduction during this time period? Do newly emerged leaves (since transplanting) become infected and function as a reservoir of inoculum? Answering basic questions about the biology of *C. acutatum* is particular will allow us to make informed and directed decisions about research strategies needed for field management of this devastating disease.

Botrytis cinerea, causal agent of gray mold, is a recurrent problem in plasticulture strawberry production systems. Most growers rely on fungicides for effective management and several new fungicides have been developed. We often can secure funding to evaluate new products but there is a real need to determine how these products can be incorporated into a program that manages disease and minimizes the risk of pathogens developing resistance.

We have had high levels of success evaluating novel chemistry or management tactics to limit anthracnose fruit rot problems in fruiting fields during the spring. There is a need to evaluate fungicide application strategies to manage anthracnose ripe fruit rot. Likewise, we have some preliminary data that early sprays are essential and perhaps such early will timed sprays may offer sufficient suppression such that a season long program is not needed. For both anthracnose and Botrytis, there is a need to evaluate fungicide use strategies that are efficacious and more economical.

Methodologies:
TRIAL 1: A trial was initiated to look at the dynamics of *C. acutatum* during the winter and early spring season. Plug plants were established and grown according to standard industry practices. At 7-14 days prior to field setting, plug plants were inoculated with field isolates (3 strains) of *C. acutatum*. These plants were field set 23 October and non-inoculated plants functioned as a control. The inoculated and non-inoculated plants were arranged spatially to minimize inter-plot interference

and as a RCBD with four replications. Plants were evaluated several times to determine if stunting occurred and to monitor the dynamics of the pathogen on transplant leaves and newly emerged leaves, with a final analysis on fruit rot incidence. We used a paraquat assay to determine the incidence and frequency of latent infections.

TRIAL 2: Plants were field set in October 2003 in 12-plant plots with 2 inoculated (3 *C. acutatum* strains) plants at each end of each plot to allow "natural" spread. The experimental design was a randomized complete block with 4 replications on standard black plastic beds. Plots were inundated by seasons end and interplot interference unavoidable. No fungicides were applied and weekly harvests sorted fruit into marketable and diseased categories. 'Camarosa' and 'Chandler' are commercially standard cultivars; Bish and NCSU numbered lines are products of the NCSU breeding program. Data are sorted based on anthracnose ripe fruit rot incidence.

TRIAL 3: The test was located at the Horticultural Crops Research Station in Castle Hayne, NC. The test was initiated 23 Sep 03 by planting tips into 60-cell trays and immediately placing them under a mist system in an enclosed screen house located on site. Four week-old plug plants were arbitrarily selected and removed from the enclosed screen house and inoculated using a conidial suspension (10^6/ml) of *C. acutatum*. Inoculum was applied until runoff using a hand mister. Individual trays were then placed in clear plastic bags and sealed. Plants were then incubated at room temperature (25^{o}C) for 48 hr then removed from the bags and incubated for 5 more days. Field plots were established 23 Oct 03 with non-inoculated plants. Plot size consisted of single, 6-in. tall, 27-in. wide, plastic mulched beds on 60- in. centers, 12 ft long and contained 24 plants on a 12-in. spacing staggered in two rows 12 in. apart. Two inoculated plants were inter-planted 27 Oct 03 between plots to increase disease pressure throughout the growing season. Commercially recommended fertilization and insect management practices were followed. Treatments were randomized in four complete blocks. Fungicide sprays were initiated on 25 Mar 04 at 10% bloom. Nine sprays were applied weekly from 25 Mar through 20 May using a CO_2 back-pack sprayer equipped with a 2-nozzle, hand-held boom centered over the row, with fan nozzle tips and operating at 90 psi (100 gal/A). Fruit were harvested weekly from 22 Apr through 27 May. Total yield and percent of marketable and cull fruit (undersized, misshapen) were calculated based on weight. Weather conditions were unseasonably cold throughout winter and late into the growing season with frequent temperatures below normal which adversely affected fruit quantity.

TRIAL 4: The test was located at the Horticultural Crops Research Station in Castle Hayne, NC. The test was initiated 23 Sep 03 by planting tips into 60-cell trays and immediately placing them under a mist system in a enclosed screen house located on site. Plots were established 23 Oct 03, and consisted of single, 6-in. tall, 27-in. wide, plastic mulched beds on 60- in. centers, with a 2-ft spacing between adjacent plots. Plots were 12 ft long and contained 24 plants on a 12-in. spacing staggered in two rows 12 in. apart. Commercially recommended fertilization and insect management practices were followed. Treatments were randomized in four complete blocks. Fungicide sprays were initiated on 25 Mar 04 at 10% bloom. Sprays were applied weekly (9 apps) from 25 Mar through 20 May using a CO_2 back-pack sprayer equipped with a 2-nozzle, hand-held boom centered over the row, with fan nozzle tips and operating at 90 psi (100 gal/A). Fruit were harvested weekly from 22 Apr through 27 May. Total yield and percent of marketable and cull fruit (undersized, misshapen) were calculated based on weight. Weather conditions were unseasonably cold throughout winter and late into the growing season with frequent temperatures below average limiting fruit quantity and resulting in low yields. Plots were not inoculated with the anthracnose pathogen but inoculum migrated from adjacent experiments.

Results:

TRIAL 1: Leaf samples (12/plot) were collected 24 Nov and 18 Dec, exposed to Paraquat, and total spore counts assessed using a Hemacytometer (Table 1). On 24 Nov, all inoculated plots had infected leaves, as anticipated, with a high sporulation index. Values were not zero, but low in non-inoculated plots, with only one plot with infected leaves. By 18 Dec, the newly emerged leaves in all plots were infected with a high sporulation index. Apparently, the inoculum rapidly spread from inoculated to non-inoculated plots and successfully infected newly emerged leaves by 18 Dec. (The problem= visual leaf assays did not suggest colonization occurred to the same extent). Differences in plant vigor (i.e. stunting effects) were not noted based on monthly plot evaluations from Nov to Mar.

Total yield and incidence of anthracnose ripe fruit rot did not differ among the 2 treatments (Table

2). The pathogen had spread sufficiently to mask all treatment effects, even though plots were arranged to minimize cross-contamination.

Table 1: Incidence of sporulation and conidia concentration on leaves

Data/Treatment		Initial leaf evaluation (24 Nov)	Old Leaves (18 Dec)	New Leaves (18 Dec)
% Plots With Sporulating Leaves	Inoculated	100%	75%	100%
	Non-inoculated	25%	75%	100%
Average Conidia/ml (SE)	Inoculated	18.2 X 10^3 (6.5 x 10^3)	4.8 X 10^3 (3.6 x 10^3)	3.6 X 10^3 (1.0 x 10^3)
	Non-inoculated	1.4 X 10^3 (1.4 x 10^3)	7.8 X 10^3 (2.7 x 10^3)	2.5 X 10^3 (0.7 x 10^3)

Table 2: Yield values based on 6 weekly harvests

Treatment	Total Yield	Anthracnose incidence (%)	Average berry wt (g)
Inoculated	2041 g/plot	41.0	18.8
Non-inoculated	2798 g/plot	36.4	18.8

TRIAL 2: The emphasis of this trial was to determine if new strawberry lines have effective field resistance to anthracnose ripe fruit rot. Anthracnose pressure was high and inter-plot interference was prominent. All lines had less anthracnose fruit rot than the standard cultivars (Table 3). Bish, D15.01, NCS 99-27 and NCS 93-05 had the lowest incidence of anthracnose ripe fruit rot. Incidence of gray mold varied amongst the cultivars evaluated but fruit were sorted for anthracnose as a primary category. Thus Botrytis incidence data may not reflect differences in cultivars since this data is not independent of anthracnose incidence. NCS 99-27 had the highest yield combined with large berry weight and low anthracnose incidence. Bish performed well but is not best suited to eastern
NC.

Table 3: Evaluation of standard cultivars and breeding lines for field incidence of Anthracnose ripe fruit rot and Botrytis fruit rot in 2004.

Selection	Total yield (kg/plot)	Marketable yield (%)	Botrytis incidence (%)	**Anthracnose Incidence (%)**	Average berry weight (g)
Bish	3.3 a	59.7 d	2.6 ab	**11.9 a**	14.2 a
D15.01 (Araza)	5.6 bc	56.8 d	8.7 e	**18.4 ab**	18.2 bc
NCS 99-27	12.5 e	66.8 d	4.3 bc	**18.4 ab**	18.6 bc
NCS 93-05	5.7 cd	59.4 d	4.2 bc	**22.7 bc**	20.4 cd
Allstar	3.5 a	40.3 bc	6.2 cd	**31.6 c**	16.3 ab
Festival	4.3 ab	43.1 c	2.2 ab	**42.5 d**	16.3 ab
Chandler	3.5 a	30.1 ab	0.7 a	**57.5 e**	18.6 d
Camarosa	3.2 a	29.3 a	1.2 a	**60.6 e**	22.6 d
LSD	3.5	10.6	2.3	10.4	3.3
***P* value**	0.0001	0.0001	0.0001	0.0001	0.0013

TRIAL 3:
The emphasis of this trial was to evaluate different fungicide spray strategies and their effect on management of anthracnose fruit rot. Gray mold incidence was low throughout the fruiting season

(Table 4). Anthracnose fruit rot incidence was heavy throughout the harvest season among all treatments. All fungicide programs decreased the incidence of anthracnose ripe fruit rot and increased the percent of marketable fruit. There were no dramatic differences amongst spray strategies, particularly with regard to the final percent of marketable fruit harvested. Total yields were not impacted. These spray strategies represent effective options for growers to rotate fungicides that belong to different fungicide groups.

Table 4: Effective of fungicide spray strategies on anthracnose ripe fruit rot during spring harvests.

Treatment and rate/A	Timing	Gray mold (%)	Anthracnose (%)*	Total yield (g/plot)	Marketable fruit (%)*
No spray ……		2.7	22.6 e	7258	65.7 a
TM45002 5.25 lb ..……...…….....	1 - 9	1.4	12.9 cd	7723	76.2 b
Captan 50WP 4.0 lb + Topsin M 70W 1.1 lb.....	1, 3	1.2	7.4 ab	7715	82.0 c
Elevate 50 WGD, 1.5 lb + Quadris 12 oz	2, 6				
Pristine 1.45 lb	4, 8				
Captan 50 WP 4.0 lb	5, 7, 9				
Captan 50 WP 4.0 lb + Topsin M 70 W 1.1 lb.....	1,3,5,7,9	0.7	8.5 abc	7268	79.0 bc
Elevate 50 WGD, 1.5 lb + Quadris 12 oz	2, 6				
Pristine 1.45 lb	4, 8				
Captan 50 WP 4.0 lb + Pristine 1.45 lb…….....	1	0.4	12.4 bc	7678	77.3 bc
Captan 50 WP 4.0 lb + Quadris 12 oz	2, 4, 6, 8				
TM45002 5.25 lb	3, 5, 7, 9				
Captan 50 WP 4.0 lb + Pristine 1.45 lb…….....	1, 5, 9	1.6	7.7 ab	7608	80.9 bc
Captan 50 WP 4.0 lb + Quadris 12 oz	2, 6				
TM45002 5.25 lb	3, 7				
Captan 50 WP 4.0 lb + Quadris 12 oz	4, 8				
Captan 50 WP 4.0 lb + Topsin M 70 W 1.1 lb.....	1,3	1.3	6.3 a	7542	82.7 c
Pristine 1.45 lb	2,4,6, 8				
TM45002 5.25 lb	5, 7, 9				
LSD (*P*=0.05) …….....		NS	5.1	NS	5.8

* Values followed by the same letter within a column are not significantly different according to Fisher's protected LSD.

TRIAL 4: The emphasis of this trial was to evaluate seven spray strategies for management of gray mold and anthracnose fruit rot. Gray mold incidence was low throughout the fruiting season and treatment differences were not observed. Thus the relative contribution of Elevate component in the CaptEvate (TM45002) formulation could not be determined. Anthracnose fruit rot incidence was heavy throughout the harvest season among all treatments. Inoculum originated from adjacent plots in an anthracnose study. BAS 516 (Pristine) suppressed anthracnose incidence if used 4 times within the spray strategy. Multiple applications of Switch, in the absence of a strobilurin-type fungicide, did not appear to impact anthracnose fruit rot incidence. These strategies were designed for Botrytis control primarily. With the heavy anthracnose pressure, no fungicide strategy enhanced percent marketable yields.

Table 5: Effective of fungicide spray strategies on Botrytis and anthracnose ripe fruit rot during spring harvests.

Treatment and rate/A	Timing	Gray mold (%)	Anthracnose (%)*	Total yield (g/plot)	Marketable fruit (%)*
No spray ……		1.9	15.0 bc	6701	71.1 abc
TM45002, 5.25 lb ..……...…….....	1 - 9	0.4	8.0 ab	7045	76.6 bc
Elevate 50 WGD, 1.5 lb…….	1 - 9	0.9	18.8 c	7126	62.0 a
Captan 50 WP, 4.0 lb + Topsin M 70 W, 1.1 lb.....	1	1.7	12.8 abc	6948	71.6 abc
Elevate 50 WDG, 1.5 lb	2, 4, 7				
Switch 62.5 WG, 11 oz	3, 6, 9				
Captan 50 WP, 4.0 lb	5, 8				
Captan 50 WP, 4.0 lb + Topsin M 70 W, 1.1 lb.....	1	0.8	17.8 c	7336	70.3 ab
Elevate 50 WDG, 1.5 lb	2, 4				
Switch 62.5 WG, 11 oz	3				
Captan 50 WP 4.0 lb + Topsin M 70 W, 1.1 lb.....	1	1.0	9.1 ab	6504	78.6 bc
Pristine, 1.45 lb	2, 4				
Switch 62.5 WG, 11 oz	3				
Captan 50 WP, 4.0 lb + Topsin M 70 W, 1.1 lb.....	1, 3	0.7	6.3 a	7734	81.4 c
Pristine, 1.45 lb	2, 4, 6, 8				
TM45002, 5.25 lb	5, 7, 9				
LSD (*P*=0.05) ……....		NS	7.0	NS	11.0

* Values followed by the same letter within a column are not significantly different according to Fisher's protected LSD.

Conclusions:

TRIAL 1: This was the second year of the study. We documented that the anthracnose pathogen multiplies on green leaves and spreads to new foliage even prior to fruit development. Inter-plot interference limited the value of the study but we gained sufficient information for extension impacts (the first year study was more straight forward to interpret). This represents important information concerning the biology of this serious pathogen.

TRIAL 2: This was a very productive trial and we were highly impressed by the field resistance demonstrated by several of the NCSU selections. These selections had a low incidence of anthracnose ripe fruit rot (inoculum pressure and inter-plot interference was excessive, unlike commercial fields would experience). Integrating host resistance and our other management tactics holds considerable promise for Southeastern strawberry growers.

TRIAL 3: Effective fungicide programs were implemented that limit ripe fruit rot problems and should minimize risk of the pathogen developing resistance to any one product (particularly the strobilurins or Group 11 fungicides).

TRIAL 4: Botrytis incidence was low and conclusions about the best strategies could not be made. We need to do more analysis to look at the anatomy of the epidemic (early incidence of gray mold may have been impacted even thought total season effects were not noted. Botrytis spray programs without the use of strobilurin products are not sufficient to suppress anthracnose.

Impact Statement: Developing basic biology about the anthracnose pathogen directs our recommendations for management. Since the pathogen is active in early spring, we recommend anthracnose fungicide applications commence earlier, at 10% bloom, similar to the botrytis spray program. Host resistance offers considerable promise as an IPM component of anthracnose ripe fruit rot control. Future work should seek to develop fungicide spray strategies with reduced intervals combined with host resistance. Effective fungicide spray strategies were developed that minimize disease risk and the potential of resistant strains emerging (to the fungicides) within the anthracnose pathogen population.

Citation(s) for any publications arising from the project:

Louws, F.J., J.G. Driver. 2005. Evaluation of fungicides for anthracnose fruit rot management, 2004. Fungicide and Nematicide Tests. 60:submitted.

Louws, F.J., J.G. Driver. 2005. Evaluation of fungicides for gray mold and anthracnose fruit rot management, 2004. Fungicide and Nematicide Tests. 60:submitted.