New Considerations for Controlling Bitter Rot on Apples

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Bitter rot, which can be caused by at least 18 different species of *Colletotrichum* worldwide, continues to be one of the more difficult summer diseases to control on some apple cultivars. Bitter rot is an especially severe problem on Honeycrisp and some of the other early-maturing cultivars. An update on what we know about the pathogens causing bitter rot was posted on my blog back in January (See http://blogs.cornell.edu/plantpathhvl/2017/01/20/recent-changes-in-our-understanding-of-bitter-rot-of-apples/). Based on available evidence, it appears that bitter rot in Northeastern United States and probably in much of the Midwest is caused primarily by *Colletotrichum fioriniae*, a species within the broader *C. acutatum* group. South of the Mason Dixon line, bitter rot may be caused by species that include representatives from the *C. gloeosporioides* group that have different fungicide sensitivities and a somewhat different life cycle. The rest of this article pertains primarily to controlling bitter rot in the northeast and Midwest where *C. fioriniae* seems to be the predominant pathogen on apples.

In previous commentary, fungicides recommended for control of bitter rot in the Northeast included captan, ziram, and QoI fungicides such as trifloxystrobin (i.e., as Flint or as one component in Luna Sensation) or pyraclostrobin (which is present in both Pristine and Merivon). It is becoming evident, however, that continued dependence on QoI fungicides for controlling bitter rot in apples is probably neither sustainable nor advisable.

Over the past few years, numerous scientists have been reporting that *Colletotrichum* species are developing resistance to QoI fungicides. Resistant isolates have been recovered from apples (Koenig et al. 2012, Kim et al. 2016, Munir et al. 2016) and other fruit crops around the world (Forcelini et al. 2016, Nita and Bly 2016). Because QoI fungicides applied to apples during summer are always recommended in combinations with captan (or perhaps Ziram), one might argue that the mixtures with these multi-site inhibitor fungicides should suffice as an anti-resistance strategy. However, mixtures with captan alone may not be effective for preventing development of QoI-resistant bitter rot due to the unique capabilities of *Colletotrichum* species within the *C. acutatum* group.

Researchers in both Norway (Børve and Stensvand 2007, 2016) and New Zealand (Everett et al. 2010) have shown that several species within the *C. acutatum* group can overwinter in bud scales (as well as in rotted fruit and dead twigs) and then can move into leaves during summer without causing any disease symptoms on these leaves. (Glomerella leaf spot, it now appears, is caused primarily by species in the *C. gloeosporioides* group.) It is not clear if the symptomless leaves that are inhabited by *C. acutatum* species play a significant role in producing inoculum for subsequent fruit infections, but *Colletotrichum* present in leaves may play a role in fungicide resistance development. The best evidence to date suggests that inoculum is probably coming from mummified fruit from previous years that survive on the orchard floor, thinned fruit that were dropped to the ground during early summer, and/or infected prunings that are left beneath trees (Everett et al. 2010). However, if *Colletotrichum* moves into apple leaves during summer, then the fungus present in leaves may get repeated doses of QoI fungicides (every time the orchard is sprayed with a QoI/captan mixture), but it will not be exposed to captan because the QoI fungicide can move into leaves but the captan cannot. It is important to note that I do NOT know for certain if this is occurring, but it seems possible based on the existing literature.

Fortunately, we may have at least a partial solution for improving resistance management strategies for *Colletotrichum* species in apples. Recent work by Yoder et al. (2016; see table below) and Ishii et al. (2016) have shown that two of the new SDHI fungicides, Fontelis and Aprovia, have reasonably good activity against pathogens in the *C. acutatum* group. (Ishii's group also showed that the SDHI components in Luna Sensation, Merivon, and Pristine are NOT effective against *C. acutatum*, so using one of those fungicides against bitter rot has the same effect as applying a QoI alone.) Fontelis and Aprovia have been promoted primarily for controlling early-season diseases, but including one or two sprays of either of these products, mixed with Captan or other fungicides, during July or early August might help to slow development of QoI-resistant *Colletotrichum* species in apple orchards. Neither

Fontelis nor Aprovia can be applied during the last month before harvest, so the window for using them would be in mid-summer when bitter rot begins to build up in leaves and forms quiescent infections on fruit. QoI-containing fungicides could then be used in mixtures with captan for sprays closer to harvest, thereby providing a rotation of products that are absorbed into leaves and protect fruit.

Bitter rot suppression is listed on the Aprovia label. Fontelis is not labeled for bitter rot, although it can be applied during summer to control apple scab. **Aprovia is not labeled in New York**, so New York growers seeking an alternative to QoI fungicides for bitter rot control will need to either use higher rates of Captan alone or include Fontelis to suppress secondary scab in mid-summer. Only limited quantities of Aprovia and Fontelis can be applied each year (three or four applications, depending on rates used), so growers who used these products in multiple early-season sprays may not be eligible to apply them during summer this year.

It is important to note that while Aprovia plus captan at the rates tested by Yoder's group provided excellent control of sooty blotch and flyspeck (SBFS) in addition to controlling fruit rots (see the table below), Fontelis plus captan did not provide adequate control of flyspeck. Thus, to protect against the full range of summer diseases (SBFS and fruit rots), NY growers who opt to use Fontelis in summer sprays may need to increase the rate of captan-80 in the Fontelis/captan mixture from 3 lb/A as used by Yoder to 4 or 5 lb/A. Or they may need to include a third fungicide in the tank mixture (e.g., a phosphite or Topsin M, if the latter is allowed by the sales group who will be handling the fruit). Since I have no first-hand experience in using a Fontelis/captan/phosphite tank mix, this option should be approached with caution. Fontelis/captan mixtures have caused some leaf injury when applied to lush foliage right after bloom, but it seems unlikely that Fontelis plus captan alone will cause problems when applied during summer. Yoder reported no phytotoxicity issues with either the Fontelis/captan or the Fontelis/Prophyt mixtures, but the three-way mix remains untested so far as I know.

In conclusion, the concept of using alternations of SDHI and QoI fungicides in tank mixes with captan to slow selection pressure for resistance in *Colletotrichum* species in apple orchards seems logical based on the published literature, but the effectiveness of this approach remains unproven, both as it relates to season-long control of bitter rot and as it relates to resistance management. I have presented the concept here primarily because I am concerned that QoI-resistant bitter rot may predominate in orchards before the concept can be fully field-tested, and alternative strategies may need to be implemented as soon as possible.

Literature cited:

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In the table below, I have abstracted some of the data from Dr. Yoder's 2015 field trial report. Note that he applied many of the tested products and tank mixes in eight consecutive sprays for research purposes only. Labels for both Fontelis and Aprovia limit the number of consecutive applications than can be used, as well as the total amount that can be applied per season. **The product concentrations in the table below are amounts per 100 gal of dilute spray: multiply by 4 to arrive at the amount/A that was evaluated in the trial.**

Results from a field trial conducted by Dr. Keith Yoder in Virginia in 2015 showing the effectiveness of Fontelis and Aprovia used alone and in various combinations for controlling sooty blotch, flyspeck, and summer fruit rots on 'Fuji' apples harvested 30 September. Data was abstracted from Yoder et al. (2016).

Trt. no.	Treatment and rate per 100 gal dilute spray	Spray timing	% fruit at harvest with: sooty blotch	% fruit at harvest with: flyspeck	% fruit with rot after 14 days of postharvest incubation at 70.7 F: bitter rot	% fruit with rot after 14 days of postharvest incubation at 70.7 F: any rot
1.	Control: No fungicide	- - -	100 g	100 g	20 e	52 f
2.	Fontelis 1.67SC 4 fl oz	Bl-6C	57 f	76 f	8 d	18 de
3.	Fon. + Manzate 12 oz Fon. + Ziram 76DF 12 oz	Bl-3C 4-6C	13 de	34 de	3 abcd	6 bc
4.	Fon. + Ziram 76DF 12 oz	Bl-6C	13 de	35 de	1 ab	5 bc
5.	Fon. + Captan 80WDG 12 oz	Bl-6C	3 abc	27 cde	3 abcd	4 b
6.	Fon. + ProPhyt 1 pt	Bl-6C	12 cde	11 b	2 abc	4 ab
7.	Aprovia 0.83EC 1.75 fl oz	Bl-6C	20 e	15 bc	2 abcd	6 bc
8.	Aprv. + Manzate 12 oz Aprv. + Ziram 76DF 12 oz	Bl-3C 4-6C	4 abcd	3 a	0 a	3 ab
9.	Aprv. + Ziram 76DF 12 oz	Bl-6C	8 bcde	2 a	4 abcd	4 ab
10.	Aprv. + Captan 80WDG 12 oz	Bl-6C	2 ab	2 a	0 a	0 a
11.	Aprv. + ProPhyt 1 pt	Bl-6C	4 abcd	3 a	2 abc	7 bc
12.	Manzate 12 oz Ziram 76DF 12 oz	Bl-3C 4-6C	2 a	2 a	6 cd	9 bcd
13.	Ziram 76DF 12 oz	Bl-6C	12 de	40 e	6 bcd	28 e
14.	Captan 80WDG 12 oz	Bl-6C	15 e	39 e	5 abcd	15 cde
15.	ProPhyt 1 pt	Bl-6C	10 bcde	25 bcde	1 ab	10 bcd

Mean separation by Waller-Duncan K-ratio t-test (p=0.05). Four single-tree replications, 25 fruit per tree picked 30 Sep. Application dates: 29 Apr (late bloom); 12 May (late petal fall); 1st-6th covers (1-6C): 27 May, 10 Jun, 24 Jun, 8 Jul, 22 Jul, 13 Aug.