UNIVERSITY OF GEORGIA
College of Agricultural & Environmental Sciences
Department of Plant Pathology

Blueberry Disease Management: Fungicide Resistance Findings And Tools for Managing Fruit Rots

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Blueberries affected by Anthracnose Fruit Rot

Outline

- Blueberry Fruit Rots & New Fungicide Resistance Findings
- New Predictive Tool for Anthracnose
- Blueberry Disease Management Resources

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- **Blueberry Fruit Rots & New Fungicide Resistance Findings**
- New Predictive Tool for Anthracnose
- Blueberry Disease Management Resources

Fruit Rots

- Fruit rotting pathogens can infect blueberries at diverse stages of berry development – including postharvest – but eventually lead to a rot of ripe fruit.
- Field infections often remain latent until the berry ripens (these can be difficult to detect until it is too late).
- The most devastating fruit rot pathogens are those that can be readily transferred to healthy berries in packing lines or within clamshells to induce rot.
  - "One bad ~~apple~~ blueberry can spoil the whole ~~barrel~~ clamshell"

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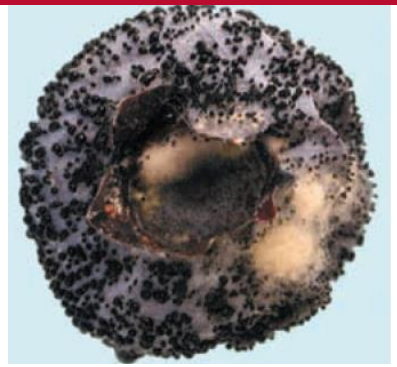
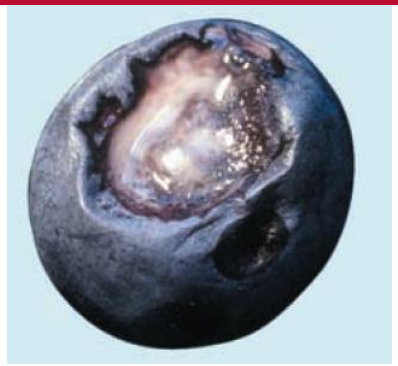
Fruit Rot Diseases



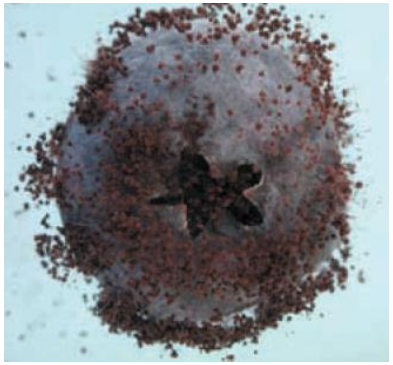
Pestalotia Rot



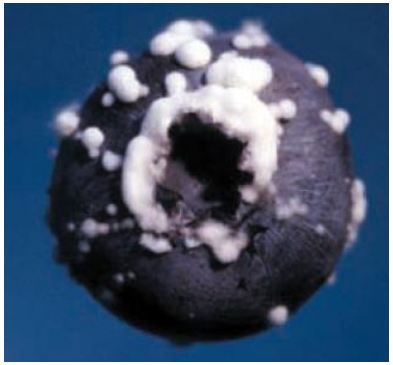
Yeast Rot

Rhizopus Rot

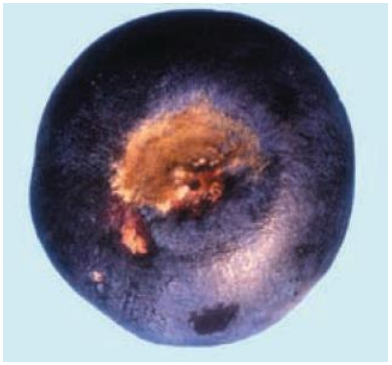
Hainesia Rot



Aspergillus Rot



White Mold



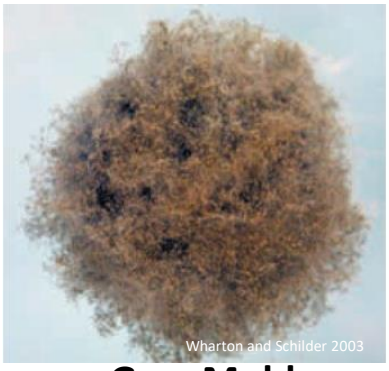
Epicoccum Rot

Mummy Berry

Phomopsis Rot

Anthracnose Rot

Alternaria Rot



Gray Mold

Fruit Rot Pathogens

- Important fruit rotting pathogens of blueberry include:
  - *Colletotrichum* spp. - Anthracnose Rot (aka "Ripe Rot")
  - *Alternaria tenuissima* - Alternaria Leaf Spot & Fruit Rot
  - *Botrytis cinerea* – Botrytis Flower Blight and Fruit Rot (aka "Gray Mold")

All three of these diseases can cause significant losses pre- and postharvest on blueberry

Colletotrichum spp.

Anthracnose Rot

Alternaria tenuissima

Alternaria Rot

Botrytis cinerea

Gray Mold

Anthracnose Fruit Rot (Ripe Rot)

- Anthracnose fruit rot is caused by two different fungi: *Colletotrichum gloeosporioides* and *C. acutatum*
- Fruit infections begin at bloom, remain latent until ripening.
  - Can be major issue postharvest
- Warm, wet weather during bloom and just before harvest favors disease development.

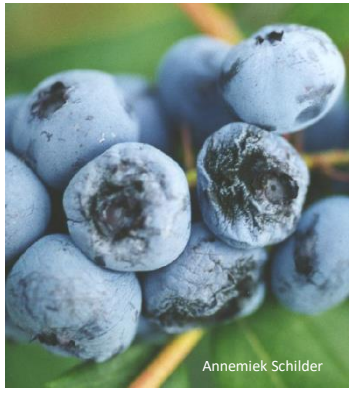
Shriveling Ripe berries

Sporulation on infected berry

Orange spore masses on berries

Alternaria Fruit Rot

- Caused by *Alternaria tenuissima*
- Symptoms develop when fruit ripen: infected fruit become leaky and may be covered in grey-green fungal mycelium
- This fungus can also cause a (minor) leaf spot on blueberry
- Cool, wet conditions favor disease development and infection of berries in the field



Ripe berries shriveling and sporulating on bush

Grey-green mycelium

Leaf spots

Botrytis Flower Blight and Fruit Rot

- Disease caused by the fungus *Botrytis cinerea*
- Symptoms include blights of blossoms, twigs, and young leaves as well as a rot of fruit (aka "Gray Mold")
  - Blossom blight causes the most losses

Blighted Blossoms

Masses of conidia on rotting fruit

- Particularly problematic when wet weather occurs near bloom or when freeze-damaged tissues are present

Chemical Control of Fruit Rot Diseases

Recommendations below are based on the 2023 SE Regional Blueberry Integrated Management Guide

Trade Name	Active Ingredient	FRAC MoA	Anthracnose Ripe Rot	Alternaria Rot	Botrytis Gray Mold
Quash	metconazole	3	+++++	+++++	
Quilt Xcel	propiconazole azoxystrobin	3 11	+++++	+++++	
Abound	azoxystrobin	11	+++++	+++++	
Pristine	pyraclostrobin boscalid	11 7	+++++	+++++	+++++
Switch	cyprodinil fludioxonil	9 12	+++++	+++++	+++++
Miravis Prime	pydiflumetofen fludioxonil	7 12	+++++		
Elevate	fenhexamid	17			+++++
Omega	fluazinam	29	+++	+++	++
Ziram	ziram	M3	++	++	++
Captan	captan	M4	+++	+++	++

Fungicide Resistance

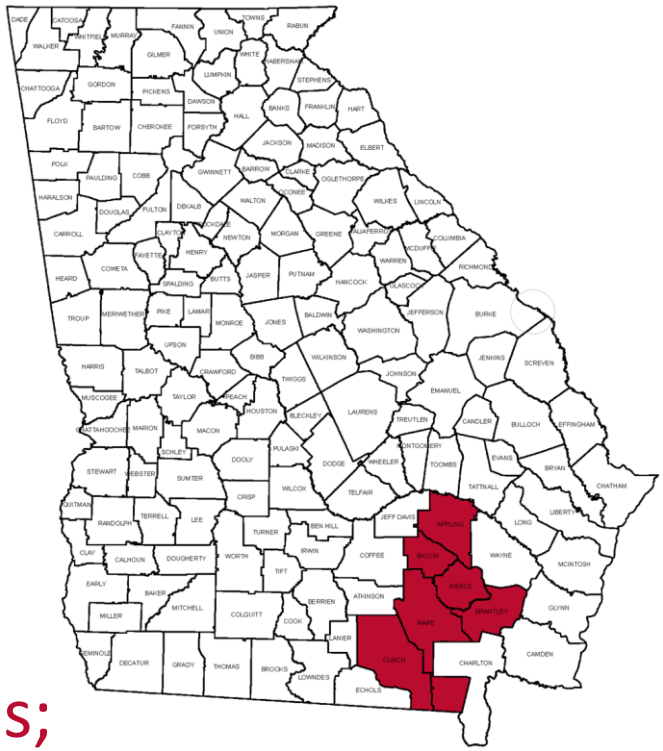
- Several important fruit rot pathogens are known to rapidly develop fungicide resistance.
- Anthracnose resistance to QoI fungicides (Abound and Pristine) has been documented previously in Florida, and in 2019 three isolates of *C. gloeosporioides* **highly resistant** to Pristine were isolated from blueberries near Blackshear, GA.
- These isolates possessed a mutation known to confer resistance in *Colletotrichum sp.* to all QoI fungicides.

2021 & 2022 Fruit Rot Survey

- A blueberry fruit rot survey was conducted during the 2021 and 2022 growing seasons to assess the prevalence of fungi on blueberry fruit and screen fruit rot fungi for fungicide resistance.

- Symptomatic SHB and RE fruit samples were collected from 46 sites in 6 major blueberry-producing counties.

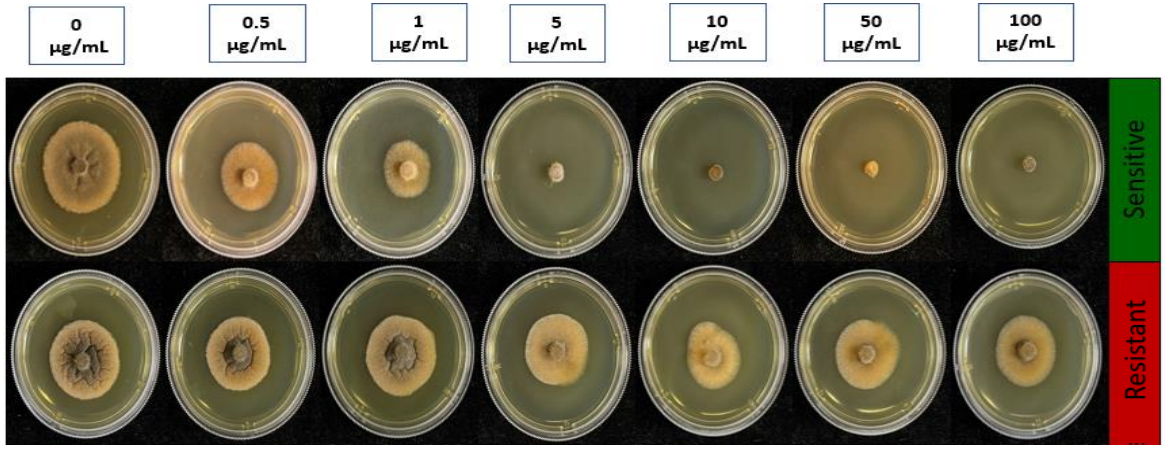
- *Colletotrichum* and *Alternaria* were the most prevalent species among SHB sites; *Botrytis* was more prevalent on RE sites.



Counties surveyed for blueberry fruit rots

Fungicide Resistance Screening

- *Alternaria*, *Botrytis,* and *Colletotrichum* blueberry isolates were screened for resistance to common fungicides.
- 46 *Alternaria* isolates (from 16 sites in 4 counties), 117 *Botrytis* isolates (8 sites in 3 counties), and 50 isolates of *Colletotrichum* (16 sites in 4 counties) were screened.
- A mycelial growth inhibition assay and genetic testing were used for isolate screening.



Mycelial Growth Inhibition Assay; Fungicide Resistant Isolate Shown on Bottom

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Fungicide Resistance Screening

Fungicide (trade name)	FRAC MoA	Screening Results		
		Alternaria	*Botrytis*	*Colletotrichum*
pyraclostrobin (Pristine)	11	10 of 46 (22%)	12 of 117 (10%)	9 of 50 (18%)
boscalid (Pristine)	7	21 of 46 (46%)	10 of 117 (9%)	All Resistant
pydiflumetofen (Miravis Prime)	7	All Sensitive	not tested	All Resistant
fludioxonil (Switch & Miravis Prime)	12	All Sensitive	7 of 117 (6%)	18 of 50 (36%)
cyprodinil (Switch)	9	All Sensitive	30 of 117 (26%)	All Resistant
fluazinam (Omega)	29	All Sensitive	All Sensitive	All Sensitive
fenhexamid (Elevate)	17	not tested	7 of 117 (6%)	not tested
metconazole (Quash)	3	All Sensitive	not tested	All Sensitive

Red = # (%) of fungicide resistant isolates | **Orange = Moderate Resistance** | **Green = Sensitive**

Note: *Colletotrichum* isolates were *insensitive* to boscalid, pydiflumetofen, & cyprodinil.

6/46 (13%) *Alternaria* isolates [3 of 16 locations] were resistant to BOTH components of Pristine.

5/117 (4%) *Botrytis* isolates [4 of 8 locations] were resistant to BOTH components of Switch.

9/50 (18%) *Colletotrichum* isolates [5 of 16 locations] were resistant BOTH components of Pristine.

18/50 (36%) *Colletotrichum* isolates [10 of 16 locations] were resistant to ALL components of Switch and Miravis Prime.

8/50 (14%) *Colletotrichum* isolates [4 locations] were resistant to Pristine, Switch, & Miravis Prime!

Fungicide Resistance Conclusions

- *Alternaria* isolates w/resistance to QoI-fungicides and boscalid, and *Botrytis* & *Colletotrichum* isolates w/multiple fungicide resistances have been ID'd in Georgia blueberries.
- To ensure that fungicides remain effective against fruit rots, it is more essential than ever to utilize good fungicide resistance management practices.
  (Rotate available MoAs; tank mix w/multisite fungicides [Captan or Ziram])
- No resistance to fluazinam (Omega) was observed in any tested isolate; as such, Omega may be a good rotation option - likely best utilized around petal fall (30 day PHI).
  - All *Alternaria* and *Colletotrichum* isolates were also sensitive to Quash.

Outline

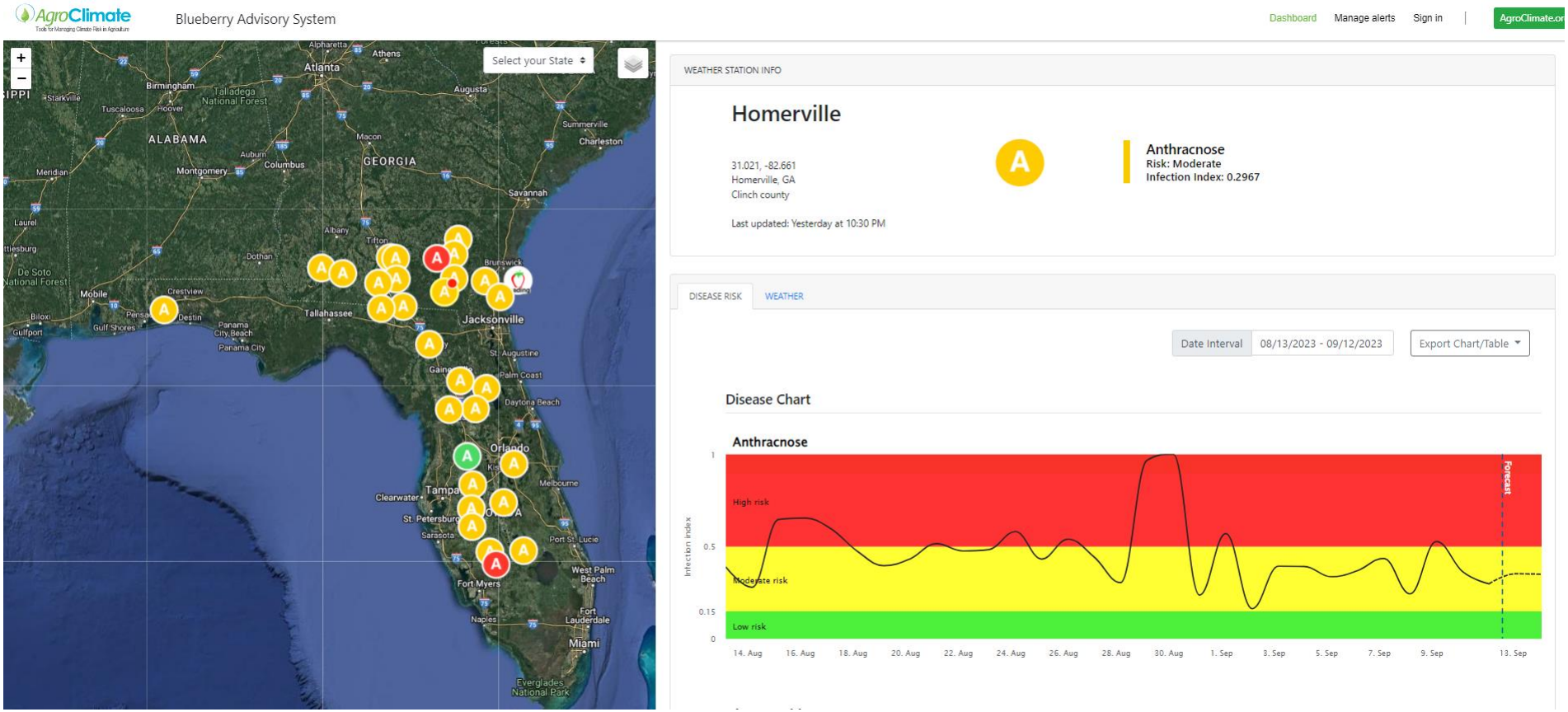
- Blueberry Fruit Rots & New Fungicide Resistance Findings
- **New Predictive Tool for Anthracnose**
- Blueberry Disease Management Resources

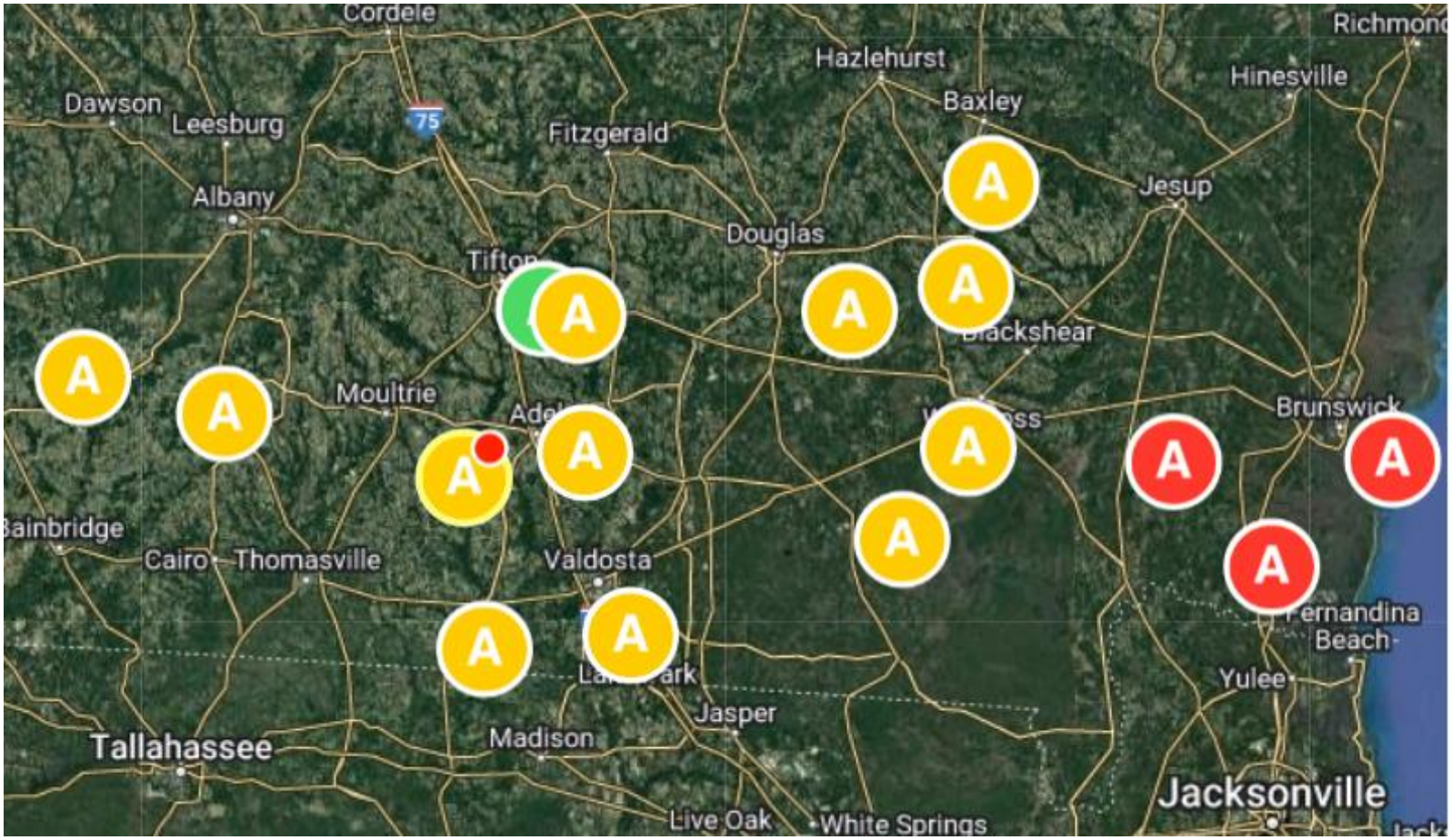
Predictive Tool for Anthracnose

- In March 2022, 16 UGA weather stations in SE Georgia were incorporated into the **Blueberry Advisory System** (BAS) through AgroClimate (http://agroclimate.org/).
- BAS was adapted from the Strawberry Advisory System (SAS) to **predict the risk of infection** of blueberry with anthracnose (*Colletotrichum* spp.) based on weather parameters (primarily leaf wetness and temperature).
- Freely accessible through AgroClimate. By creating a free account, subscribers can receive anthracnose risk alerts based on their nearest/chosen weather station. **New BAS App released in November 2023 (App Store & GooglePlay).**

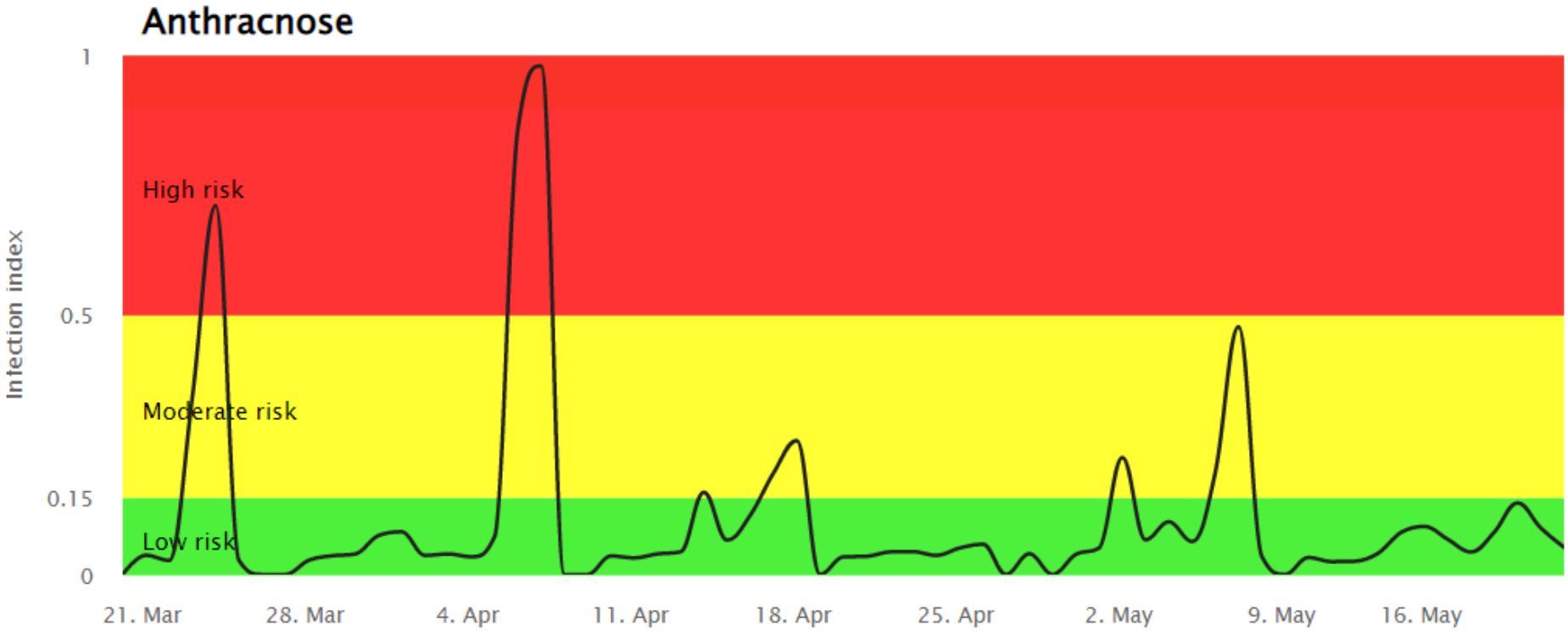
Predictive Tool for Anthracnose

http://cloud.agroclimate.org/tools/bas/dashboard/disease





- Red circles indicate high risk, yellow circles indicate medium risk, and green indicate a low risk of NEW infections with anthracnose occurring at this time at a specified location.



- The model was field tested by UF over three field seasons. They recommend fungicide applications within 48 hours* of a high/medium risk event.

***Ideally, fungicide applications should be made PRIOR to a high/medium risk event for optimum efficacy.**

Anthracnose

Potential "Critical" Fungicide Application Timings

Other Potential Fungicide Application Timings

<u>Note:</u> For illustration purposes only. Other factors, including past application history and plant developmental stage should also be considered before making spray decisions. Refer to specific fungicide labels for minimum retreatment interval and other information. Remember, <u>the label is the law</u>.

Utilizing Predictive Tools

- Predictive models, such as the Blueberry Advisory System, are useful for assessing risk of infection with Anthracnose
- Model information will likely be most useful for:
  - ***Extending*** spray intervals in some years (versus a standard calendar-based approach)
    - Calendar: Spray for Anthracnose every 10-14 days from bloom to harvest
    - Model: Delay additional sprays until moderate/high risk conditions reoccur
  - ***Targeting*** the use of the most effective chemistries to the highest infection risk periods
    - Current Practice: Use the most effective chemistries whenever possible
    - Model Informed: Use “Excellent” or “Very Good” materials (Switch/Miravis Prime) when high/moderate risk conditions occur and use “Good” or “Fair” materials alone (Omega/Captan/Ziram) during moderate/low risk conditions

Utilizing Predictive Tools

A couple caveats:

- This model does not "make spray decisions". Rather, it provides information to allow growers to make more informed decisions regarding anthracnose management. *Sometimes conditions at the nearest weather station will differ from on-farm conditions!*
- Prior to 2023, this system had been validated in Florida only. During the 2023 growing season, we conducted field trials using this system with the hopes of understanding how best to utilize this system for anthracnose fruit rot management on SHB and rabbiteye in Georgia.

2023 Blueberry Advisory System Trials

Methods:

- At 7 sites (6 commercial blueberry farms and one research farm), fruit rot trials were conducted during 2023.
- Sites chosen, in part, due to their proximity to UGA weather stations.
- At four sites, SHB 'Farthing' was used and at the other three sites RE 'Brightwell' was used.
- At the trial conclusion, fruit was collected and evaluated for rots (including anthracnose ripe rot) immediately prior to the first grower harvest.

2023 Blueberry Advisory System Trials

Methods:

- Two spray schedules ('Standard' [based on plant development] and 'BAS' [based on the Blueberry Advisory System]) were compared to an untreated control.
- For the BAS program, "Excellent" fungicides (Switch/ Miravis Prime) were used for high risk events and "Good" materials (Omega/Captan) were used for moderate events.
- The standard program consisted of 5 sprays:

Treatment/Timings				
10% Bloom	Petal Fall	10 days after Petal Fall	3 weeks after Petal Fall	Pre-harvest
Switch	Omega	Miravis Prime	Captan	Miravis Prime

2023 Blueberry Advisory System Trials

Hypotheses: [things we thought might happen]

- Total number of sprays would be reduced using the BAS program ("extending spray intervals") while providing equivalent control to the standard program.
- The BAS system would likely recommend more applications for rabbiteye blueberries vs. SHB (hotter and wetter during rabbiteye season)

2023 Blueberry Advisory System Trials

Results:

- At all sites, both spray schedules ('Standard' and 'BAS') resulted in numerically less anthracnose fruit rot and all rots versus the untreated control.

		Fruit Rot Incidence (%)						
		Southern Highbush 'Farthing'				Rabbiteye 'Brightwell'		
		Research Farm	Alma	Homerville	Nahunta	Alma	Homerville	Nahunta
Anthracnose Fruit Rot	Untreated	2.7	1.5	2.7	7.2	0.6	1.2	26.8
	Standard	0	0.2*	0.2*	1.1	0	0.4	10.2
	BAS	0.2	0*	0*	1.2	0	0	1.6*
Alternaria Fruit Rot	Untreated	5.2	0.9	0.4	1.6	3.2	0.8	5.2
	Standard	0.2*	0.4	0	0.6	0.2*	0.7	3.8
	BAS	0.5*	0.4	0.4	0.2*	1.6	0.6	0.2
All Rots	Untreated	6.2	2.7	3.4	9.2	6.2	1.6	28.6
	Standard	0.4*	0.9*	0.2	1.7*	0.8*	0.7	10.6
	BAS	1*	0.6*	0.8	1.4*	2.2*	0.6	2.4*

*indicates significantly less than the untreated control according to the least significant difference test (LSD) (α=0.05).

Red = Max Disease **Orange/Yellow/Light Green = Less Disease** **Green = No Disease**

2023 Blueberry Advisory System Trials

Results:

- Using the BAS program did not result in fewer sprays per season versus the standard schedule.
- However, utilizing Captan or Omega ("Good" efficacy) during "Moderate" risk events often resulted in the BAS program being cheaper overall.

Location	Program	Sprays	Est. $/Acre
Research Farm SHB	Standard	5	$262
	BAS	5	$184
Alma SHB	Standard	5	$262
	BAS	5	$184
Homerville SHB	Standard	5	$262
	BAS	6	$312
Nahunta SHB	Standard	5	$262
	BAS	5	$262
Alma RE	Standard	5	$262
	BAS	5	$184
Homerville RE	Standard	5	$262
	BAS	5	$204
Nahunta RE	Standard	5	$262
	BAS	6	$216

2023 Blueberry Advisory System Trials

Results:

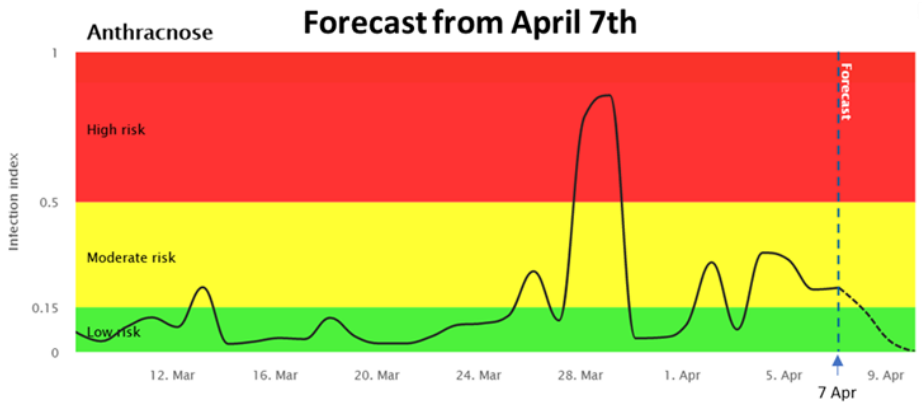
- Nearly twice as many "Moderate" and "High" risk events were recorded during the RE season vs. SHB season; however, since sprays were never made to the same plants <7 days apart, overall spray numbers were comparable for RE vs. SHB trials.

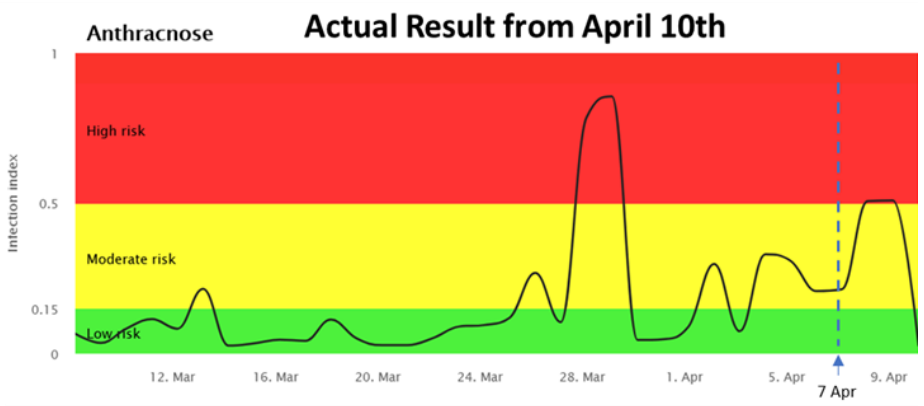
		Locations								
		Homerville			Alma			Nahunta		
	Time Period	Moderate	High	Mod+High	Moderate	High	Mod+High	Moderate	High	Mod+High
SHB	Bloom	3	3	**6**	0	4	**4**	2	2	**4**
	Harvest	15	2	**17**	13	0	**13**	16	0	**16**
	Season	29	7	**36**	18	4	**22**	21	3	**24**
RE	Bloom	3	0	**3**	3	0	**3**	0	0	**0**
	Harvest	21	9	**30**	17	4	**21**	25	4	**29**
	Season	39	13	**52**	28	6	**42**	42	5	**47**

2023 Blueberry Advisory System Trials

Results:

- The risk forecast provided by BAS was not accurate enough at predicting future risk events to use for spray scheduling





Homerville Blueberry Advisory System Results (April 7th and April 10th)

Blueberry Advisory System Conclusions

- Georgia blueberry growers can utilize BAS for timing sprays for anthracnose fruit rot control.
- Utilizing BAS to time sprays did not result in fewer sprays being made versus the standard program in 2023.
  - In drier years [↓high/moderate events], fewer sprays may be recommended.
- Using "good" materials (Omega/Captan) during moderate risk events provided equivalent control w/lower costs.
- A minimum retreatment threshold (ours was 7 days), may be necessary to avoid excessive sprays with BAS.
- The forecast function of BAS has major shortcomings.

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Southeast Regional Blueberry Guide

Southern Region Small Fruit Consortium

Home | SRSFC Activities | Crops | News | Regional Experts | IPM/Production Guides | Agent Training | Weather

Southeast Regional Guides

- 2023 Blueberry IPM Guide
- 2023 Bunch Grape IPM Guide
- 2023 Caneberry IPM Guide
- 2023 Muscadine Grape IPM Guide
- 2023 Organic Blueberry Pest Management
- 2023 Strawberry – Plasticulture Production

IPM/Production Guides

Available at: www.smallfruits.org

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BLUEBERRY IPM GUIDE

Seasonal 'at a glance' fungicidal spray schedule options for blueberry

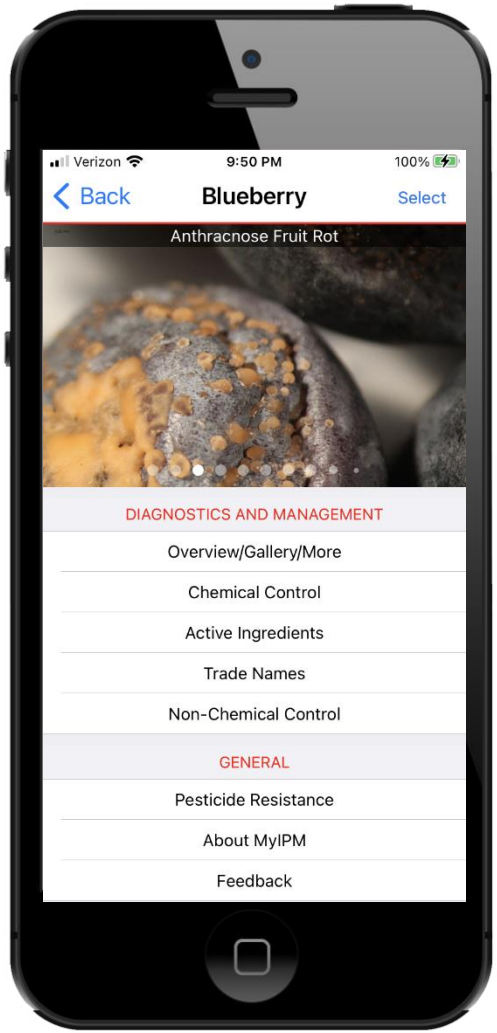
Developmental Stage	Late Dormant	Green tip	Bloom (2-3 applications)[b]	Petal Fall	10 to 14 Days after Petal Fall	20 to 24 Days after Petal Fall	Pre-Harvest[g]	After Harvest
Disease (Fungicides)	**Exobasidium** (Lime Sulfur, Sulforix or Lime Sulfur Ultra)[a]	**Twig Blight** (Pristine or Indar)	**Alternaria and Ripe Rot** (Abound, Pristine, Switch, Captan, Miravis Prime, Omega, or Quilt Xcel)[c]	**Alternaria and Ripe Rot** (Abound, Pristine, Switch, Captan, Miravis Prime, Omega, or Quilt Xcel)	**Alternaria and Ripe Rot** (Abound, Pristine, Switch, Captan, Miravis Prime, Omega, or Quilt Xcel)	**Alternaria and Ripe Rot** (Abound, Pristine, Switch, Captan, Miravis Prime, Omega, or Quilt Xcel)	**Alternaria and Ripe Rot** (Abound, Pristine, Switch, Captan, Miravis Prime)	**Anthracnose Leaf Spot** (Abound, Pristine, Switch, Aliette, ProPhyt, K-Phite, Quash, Quilt Xcel, Indar, or Bravo)
		Mummy Berry and Twig Blight (Pristine, Indar,Tilt, Quash, Proline, Quilt Xcel, Cevya, or Luna Tranquility)	**Mummy Berry and Twig Blight** (Pristine, Indar[d] + Captan, Tilt, Quash, Proline, Quilt Xcel, Cevya, or Luna Tranquility)	**Septoria Leaf Spot** (Abound, Pristine, Switch, Aliette, ProPhyt, K-Phite, Quash, Quilt Xcel, Tilt, Indar or Proline)[e]	**Septoria Leaf Spot** (Abound, Pristine, Switch, Aliette, ProPhyt, K-Phite, Quash, Quilt Xcel, Tilt, Indar or Proline)[e]	**Septoria Leaf Spot** (Abound, Pristine, Switch, Aliette, ProPhyt, K-Phite, Quash, Quilt Xcel, Tilt, Indar or Proline)[e]		**Septoria Leaf Spot** (Abound, Pristine, Switch, Aliette, ProPhyt, K-Phite, Quash, Quilt Xcel, Tilt, Indar, Proline, or Bravo)[e]
			For serious **Botrytis** problems, add (Elevate, Pristine, or Switch)	**Rust** (Proline, Quash, Tilt, Indar, or Quilt Xcel)[f]	**Rust** (Proline, Quash, Tilt, Indar or Quilt Xcel)[f]			**Rust** (Proline, Quash, Tilt, Indar, Quilt Xcel, or Bravo)[f]
	Phytophthora Root Rot (Ridomil, Orondis Gold, Orondis Gold 200)			**Phytophthora Root Rot** (Ridomil, Orondis Gold, Orondis Gold 200, Aliette, ProPhyt, or K-Phite)				**Phytophthora Root Rot** (Ridomil, Orondis Gold, Orondis Gold 200, Aliette, ProPhyt, or K-Phite)
		If **Exobasidium** has been a problem, add Captan	If **Exobasidium** has been a problem, add Captan	If **Exobasidium** has been a problem, add Captan	If **Exobasidium** has been a problem, add Captan	If **Exobasidium** has been a problem, add Captan		

[a]Exobasidium is not specifically on the label. However, when applied for other diseases, suppression of Exobasidium has been observed.
[b]Bloom times vary, due to varietal differences and the environment, and as a result the number of applications may vary from 1-3. Bloom sprays should provide protection against the primary pathogens of blooms for the entire bloom period.
[c]Many of the fungicides which are registered for rot control may also have activity against twig dieback organisms, such as Phomopsis species.
[d]When using Indar during bloom, always tank-mix with Captan. Captan provides some control of mummy berry, twig blight, Botrytis, and fruit rots. However, it is mainly of value for resistance management and to prevent increased rots due to use of Indar.
[e]Septoria leaf spot is generally controlled with 2-4 fungicide applications. This disease is more problematic on highbush blueberry varieties, but some rabbiteye varieties may experience premature defoliation from Septoria as well. For leaf spot, Aliette and other phosphites (ProPhyt, K-Phite, etc.) are best utilized after harvest, since they are not as efficacious against the fruit rots, and they serve as a resistance management tool.
[f]Rust is problematic on some blueberry varieties, especially in far southern areas such as south Georgia, and it can result in complete, premature defoliation on susceptible varieties. Scout for rust in mid to late July. Applications of fungicides (2-3) from August to mid-September will generally result in good rust management. Some varieties may require yearly rust control.
[g]In wet years, pre-harvest and post-harvest rots may be a potential problem. Under these conditions, 1-2 applications of a pre-harvest material may be necessary for rot control.

MyIPM App

MyIPM App

- Contains basic disease (and pest) info for Apple, Blackberry, **Blueberry**, Cherry, Cranberry, Grape, Peach, Pear, & Strawberry
- Includes management and pesticide efficacy info
- Available for **free download**



MyIPM

Available on the App Store

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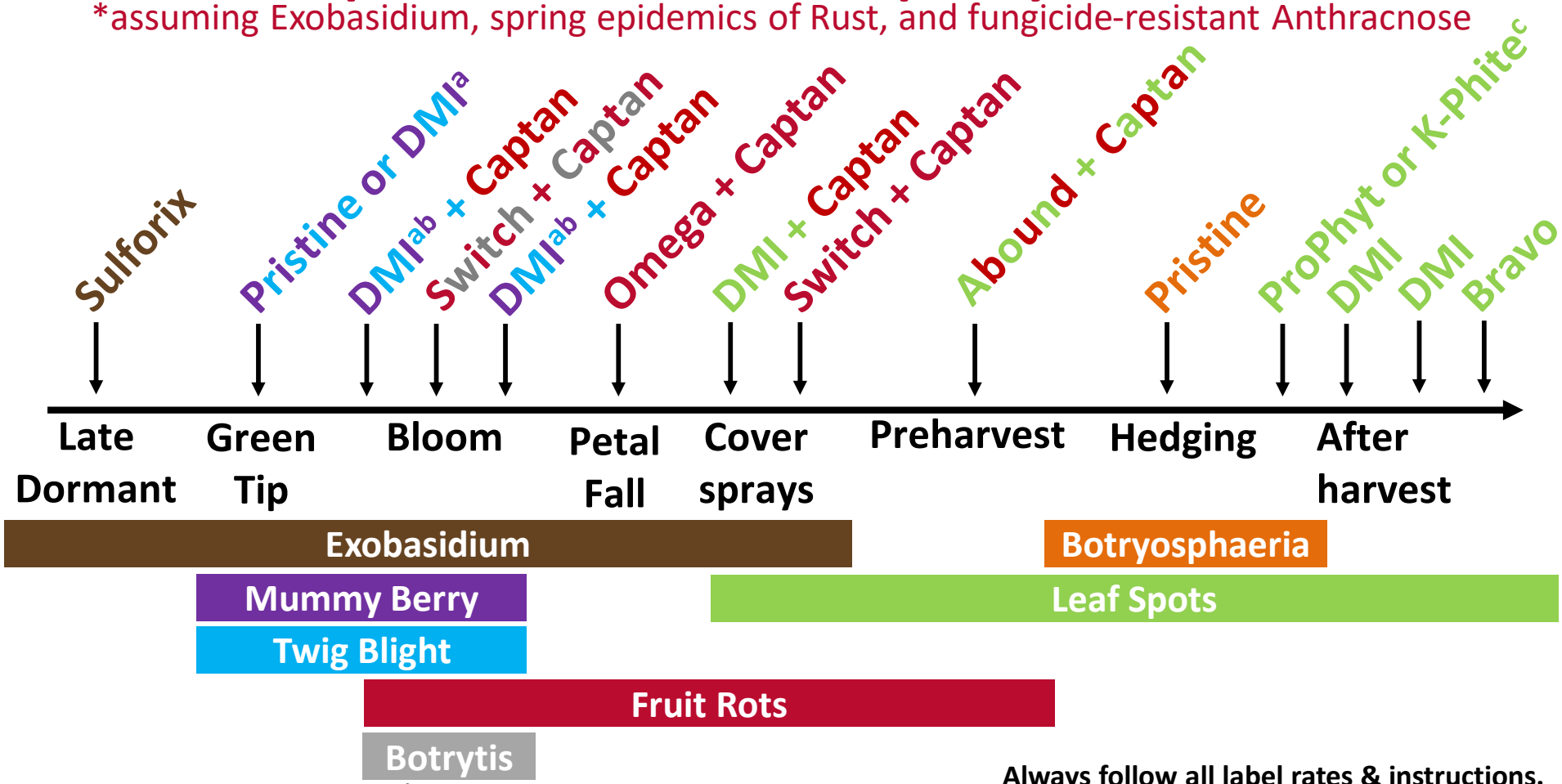
Thank you for your attention!

Example Seasonal Spray Schedule

*assuming Exobasidium, spring epidemics of Rust, and fungicide-resistant Anthracnose



Always follow all label rates & instructions.

[a]DMIs include Indar, Tilt/generics, Quash, and Proline.

[b]Elevate can be added for additional Botrytis control, if resistance is not an issue.

[c]Phosphonate fungicides (ProPhyt, K-Phite, Reliant) are also effective for Phytophthora control