Why do we are discussing the efficacy of fungicides today?
One of the main reasons is fungicide resistance.

But why do we need to care about it?
Chemical companies will produce more products to sell!

Well, not really...
Here is a list of recently introduced materials.

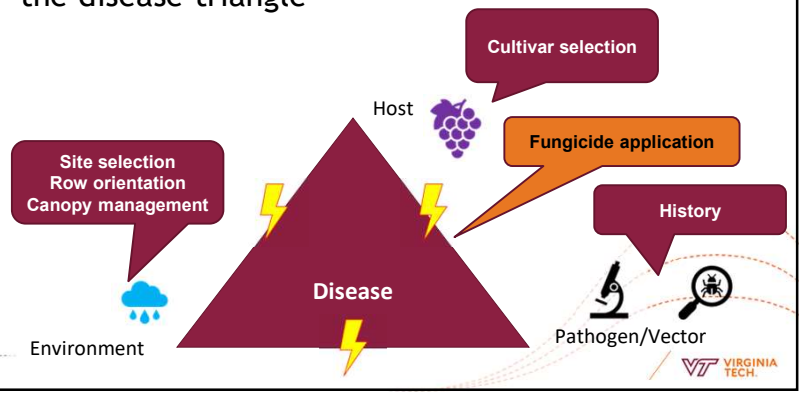
Examples of relatively new fungicides for grape production and their mode of action

Trade name	Chemical name	FRAC group	Year introduced	Materials in the same FRAC group
Aprovia	Benzovindiflupyr	7	2018	Boscalid, Luna
Miravis	Pydiflumetofen	7	2019	Boscalid, Luna
Kenja	isofetamid	7	2018	Boscalid, Luna
Rhyme	flutriafol	3	2019	Rally, Elite, etc.
Ceyva	mefentrifluconazole	3	2021	Rally, Elite, etc.
Intuity	mandestrobin	11	2018	Abound, Flint, etc.
Oso	Polyoxin-D	22	2016	Ph-D. The same chemical was available since 80's
Prolivo	Pyriofenone	50	2018	Vivando

Not all fungicides in the same group made equal.

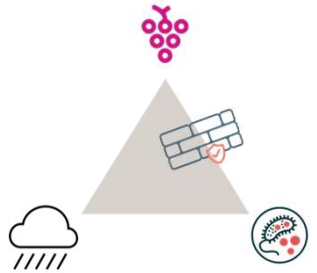
- Newer generations of group 7 materials (Luna, Aprovia, Kenja, Miravis, etc) have different way to attach to the target site
- These differences were enough to make each chemical unique
  - I.e., Not all the boscalid-resistant isolates (previous generation group 7 material) are resistant to Kenja or Luna, or Aprovia
  - Aprovia and Miravis work differently too.
- However, fundamentally, these materials work the same way.

The management of disease = aiming to break the disease triangle



Biofungicides: Biologicals control agents and plant defense activators (not the main focus for today)

- These are different from conventional fungicides in many aspects.
  - Competition, interruption, predation, antagonistic, or turn on plants' defense mechanisms
- **Preventative application is the best practice**.
  - We need to set the stage for them before pathogens come in contact with the host.
  - Both biofungicides and conventional materials won't work after you see diseases.
  - We need to know the target pathogen(s) for each product



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Phomopsis cane and leaf spot of grape

- It can infect shoots, leaves, berries, and rachis, and the pathogen is active in spring (i.e., 40-50 F and wet condition).
- Protection of young shoots (~ 1 to 3 inches) is important.

Protective application at 1-3 inch shoot growth is the best for management of Phomopsis cane and leaf spot

- Good materials (*Note: Group = FRAC group = Mode of action*)
  - Mancozeb (Group M3), Ziram (Group M3), and Captan (Group M4)
- Fair to Good
  - QoI/Strobilurins (Abound, Flint, Intuity, Group 11), Topsin-M (thiophanate-methyl, Group 1), Pristine (pyraclostrobin + boscalid (Group 11 and 7), and some SDHI (Aprovia, Miravis Prime, etc. , but you probably want to keep these for other diseases)
- Poor
  - Fixed copper (Group M1), sulfur (Group M2), **lime sulfur** (Group M2)
    - For organic production use either fixed copper or lime sulfur (for foliar application, use a low rate (1 pt/100 gal water, see label)

Dormant application of lime sulfur against Phomopsis (and very effective on anthracnose!)

- Phomopsis survives in infected woody tissues from the previous years.
- If you have a serious Phomopsis issue, a dormant application of lime sulfur (10 gal/A or 1 gal/A with Sulforix) is recommended
  - Sulforix seems to be better due to its low rate
- Its efficacy is "fair", and even with the dormant fungicide application, in-season applications of mancozeb to protect young shoots (from 1 inch to several inches, until your downy mildew treatment starts) is very important.

Downy Mildew

- It can infect leaves and berries, berry infection can cause serious damage
- Heavy leaf infection can cause defoliation

Oily spot appearance on the upper surface

Picture on the center: Organic grape production guide: OSU, Ellis and Nita 2004

Humidity drives downy mildew

- **Canopy management**
- Pre-bloom: Consider not only infection event (=rain), but also warm and humid nights (>60F and 80-90%) that promote spore production (2009, 2013, and 2018…)
- After bloom: Critical time for the cluster runs about 4-6 weeks.
- After critical time: Leaves are still susceptible to the infection.
  - Late summer infections

Downy Mildew
Timing: all season
Clusters are susceptible from bloom to 4-6 wks after bloom

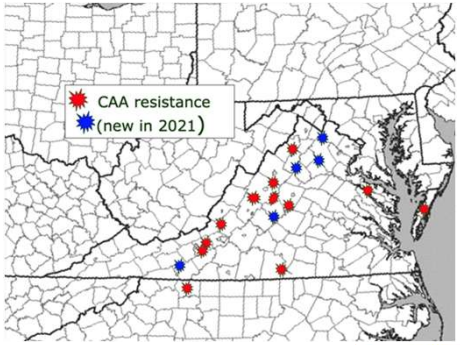
- Preventative fungicide application
  - **Good:** Mancozeb, ziram (Dithane, Penncozeb, Gavel, etc. Group M3), Ranman (Group 21), captan (Group M4), copper (Group M1)
  - **Good, but…: Revus/Forum (Group 40 – resistance spreading quickly)**, Zampro (Group **40** + 45),
  - **Don't know:** Lifeguard and Zonix (defense activators) - inconsistent reports, please use them with a caution (can be a good rotation or tank mix partner)
  - **Bad:** Any QoI (Group 11) fungicides (e.g., Aboud, Pristine, etc.)

Downy Mildew
Timing: all season
Clusters are susceptible from bloom to 4-6 wks after bloom

- Curative fungicide application (**after the rain, not after you see downy!)**
  - **Good:** Phosphonate (Prophyt, Phostrol, etc. Group P07 (used to be 33)), Ridomil products (Group 4),
  - **Poor:** Tanos (Group 11 + 27) note: we did not find a good result with Tanos in VA), Tanos need a mixing partner

Group 40 (Revus, Forum, and part of Zampro)

- Dr Anton Baudoin's lab at VA Tech has been tracking resistance isolate against dimethomorph (the a.i of Revus), and results are not promising…
- If you suspect that Revus is not working for you, it is probably better not purchase in the future.
- If you have some, my recommendation is to use it early in the season as **protectant** and **mix** with captan, mancozeb, or copper.



Black Rot

- It is a fungal disease caused by *Guignardia bidweillii*.
- The fungus tends to be active in relatively higher temperature ranges, and it takes about 7-8 hours to complete infection = good air circulation helps!!
- It can infect leaves and berries, berry infection can cause serious damage

Black rot
Timing: pre-bloom to 4-6 wks after bloom
Clusters are susceptible from bloom to 4-5 wks after bloom

- Preventative fungicide options
  - **Good:** Mancozeb, SDHI (Pristine, Luna Experience, Aprovia, Kenja, Miravis Prime, etc. Group 7)
  - **Good, but…:** Sterol-inhibitors (Rally, Mettle, Rhyme, Luna Experience, Top Guard EQ, etc., Group 3), Strobilurins (QoI, Pristine, Abound, Flint, Intuity, Group 11): **There may be resistance issue with group 3 fungicides…**
  - **Poor or not working: Captan and copper**

Black rot curative fungicide options

- Myclobutanil (Rally) is known to have a good curative (kick-back) activity against black rot fungus. It has an efficacy up to 6 days after infection.
- Azoxystrobin (Abound) does have some curative activity against black rot fungus; however, the efficacy is not as good as that of myclobutanil.
- **Note: Rally is group 3 and Abound is group 11…**

VIRGINIA TECH

Powdery Mildew

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Powdery Mildew Management

- Canopy management for
  - Good air circulation
  - Good light penetration
- Timing for chemical management is pre-bloom to harvest
  - However, the risk of infection is low when the temperature hits 90F or higher, so, if you keep the vines clean until mid-July or so, you may not need to worry about powdery mildew.
- Young berries infected by the powdery mildew pathogen tend to crack open later, thus, early season PM management will be important for Botrytis, sour rot, and fruit fly management too!!

VIRGINIA TECH

Powdery Mildew
Timing: pre-bloom to harvest
Clusters are susceptible from bloom to 4-6 wks after bloom

- **Good:** Sulfur (Group M2), Vivando (50 (used to be U8)), SDHI (Pristine, Endura, Luna Experience, Kenja, Aprovia, Miravis Prime, etc. Group 7),
- **Good, but…:** DMI (Sterol-inhibitor, Rally, Mettle, Rhyme, Top Guard EQ (3+11), etc., Group 3), Quintec (Group 13, one case of resistant isolate found in VA)
- **Fair:** Fixed copper (Group M1), Torino (Group U6), etc.
  - DMI: there are evidence of chemical resistance in Europe, AND good evidence of resistance development among VA isolates
  - Torino works, but not as strong as others. Good mixing partner to sulfur to have an extra kick
- **Bad:** QoI (group 11) or Topsin-M most likely not going to be help

VIRGINIA TECH

Powdery Mildew Management "Curative" fungicide options

- Stylet Oil (Group M) [early season, some varieties may show phytotoxicity when applied on premature fruits]
  - Efficacy = Good
  - **DO NOT mix oil with sulfur or captan!!!**
  - **Cannot spray within two weeks of each other**
    - You may be able to spray a certain oil product then sulfur after one week (try in a small area first!)
- Potassium salt products (Group M, Kaligreen, Milstop, etc.)
  - Efficacy = Good
  - Requires through coverage, and it is expensive!

Botrytis management

- Timing: At bloom, bunch closure (the last opportunity to deliver fungicides inside of the cluster), and at veraison (spore availability)
- Canopy management is critical because the outbreak is often associated with a long wetness event.
- Injury management (***GBM***, Birds, PM) is also important

Botrytis Management Preventative fungicide options

- **Fair to Good:** Group 2: iprodione (Rovral/Meteor – resistance = low/mod risk),
- **Good, but…:** Group 7 (SDHI): ~~boscalid (Endura),~~ Luna Experience, Kenja, Miravis Prime (– resistance = high)
- **Good:** Group 9: cyprodinil (Vanguard, Inspire super, Switch- resistance = mod)
- **Good:** Group 12: cyprodinil + fludioxinil (Switch – resistance = mod)
- **Good:** Group 17: fenhexamid (Elevate – resistance = unknown)
- **Fair:** Group 19: polyoxins (Oso, Ph-D – resistance = mod)
- **Fair:** Group M4: captan – fair activity, but it will be a good mixing partner!
- **Fair:** Group M1: copper (the same comment as above)
- **Bad:** QoI fungicides, Pristine (7 + 11), Topsin-M

Ripe rot

- Caused by *Colletotrichum* species.
- We found the average of 2.7 species per vineyard in our previous survey.
- They vary in the level of susceptibility against fungicides.
- We tested 10 modes of action, but **none** produced satisfying results consistently.

Mixing multiple MOA is probably the key for ripe rot management

Mixing partners for mancozeb/ziram or captan (Timing: bloom, veraison, + 7-10 days after veraison)		
Moderate level of reduction	**Low level of reduction**	**No or limited effect**
• **Aprovia** (Benzovindiflupyr, FRAC= 7) • **Cueva** (Copper (M1)) • **Intuity** (mandestrobin, (11)) • **Viathon** (Phos acid (33) + tebuconazole (3)) • **Switch** (cyprodinil (9) + fludioxonil (12))	• **Elevate** (fenhexamid (17)) alt. w/ **Rovral** (iprodione (2)) • **PhD** (polyoxin-D (19)) • **Luna Experience** (Fluopyram (7) + tebuconazole (3))	• **Endura** (Boscalid (7)) • **Oso** (polyoxin-D (19)) • **Rally** (myclobutanil (3)) • **Miravis** (Adepidyn (7))

The same MOA provided different level of control…

Mixing partners for mancozeb/ziram or captan (Timing: bloom, veraison, + 7-10 days after veraison)		
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Resistance issue with QoI fungicides…

Ripe rot application timing: at bloom, veraison, plus you may need one or two more, if you have susceptible cultivars with a history of outbreak…

- All materials are "fair" in efficacy by itself
- MIX mancozeb (M3), captan (M4) or a fixed copper (M1) with
  - a QoI (Pristine, Flint, Abound, FRAC = 11), Rovral (2), Switch (9 + 12), tebuconazole (3),
  - or Howler (not as good as Switch)
  - Copper is not as effective as mancozeb or captan
- In 2022 trial, Mancozeb or Aprovia Top applied at bloom, then Howler plus captan or Switch plus captan applied at veraison and on provided good controls.
  - Another successful treatment was Switch plus Howler applied three times

Bitter rot

- Timing: after veraison
- Materials: captan (M4) or a QoI fungicide (Abound, Flint, Pristine, Intuity, etc., FRAC = 11)
  - Copper (M1) seems to be not effective

Photo courtesy of Mike Ellis (OSU)
Note the characteristic concentric rings of black fruiting bodies

Sour rot management

- Timing: ~ 15 Brix
- Current recommendation is **TWO** applications of an insecticide (to control fruit flies, e.g., Mustang MAXX) plus a fungicide [Oxidate (NC) or Switch (9 + 12), or Oso (19)], 7 to 10 days apart
  - Do not use Mustang Maxx more than twice a season!
  - Captan did not work in our trials
  - Ph-D (19), which has a higher concentration of polyoxin, probably works better.

Alternative to Mustang MAXX

Spotted-wing Drosophlia	Azera	1.0-2.0 p	Spotted-wing drosophila is more important in some varieties than others; growers should incorporate block history. Berries become most vulnerable at about 15 degrees Brix. It is critical to rotate among differing modes of action in order to delay the development of resistance. PyGanic has a short residual life which limits its efficacy. Surround, Entrust and PyGanic are organic alternatives. Be watchful for flare-ups of secondary pests (mealybugs, spider mites) following application of pyrethroids. When available, flowable (F) formulations pose less risk of phytotoxicity that emulsifiable (EC; oil-based) formulations. Avoid using captan and oil-based pesticides within 14 days of each other. For more information on SWD, visit www.virginiafruit.ento.vt.edu/SWD.html.
	~~Entrust 2SC~~	~~4.0-8.0 fl oz~~	
	Baythroid XL 1EC	2.4-3.2 fl oz	
	Delegate 25WG	3.0-5.0 oz	
	Malathion 8F	1.88 pt	
	Malathion 5EC	3.0 pt	
	Mustang Maxx	4 fl oz	
	PyGanic 1.4EC	64.0 fl oz	
	Tombstone 25EC	2.4-3.2 fl oz	
	Surround WP	25.0-50.0 lb	
	Sevin XLR Plus	1.0-2.0 qt	

Please check the IRAC code!

Tank-mix to reduce fungicide resistance development risk

Mix one of them with other material with "number-only" FRAC group (e.g., 3, 7, etc.)

- Black rot: mancozeb (M3), ziram (M3)
- Downy mildew: mancozeb (M3), copper (M1), captan (M4), ziram (M3), phosphite (P07 - please do not overuse!)
- Powdery mildew: sulfur (M2) [some growers use stylet oil, but the oil cannot be used with sulfur or captan - make sure to have at least two weeks in between sprays!]

Tank-mix to reduce fungicide resistance development risk

- Botrytis: captan (M2) or copper (M1) (both are poor-to-fair materials for Botrytis, but I think they are good mixing partners)
- Ripe rot and bitter rot: mancozeb (M3), captan (M4), or copper (M1) (copper products do not list ripe rot as a target, but provided moderate reduction in some of our trials)

Limit the use of "number-only" FRAC group to twice a season

Captan and Iprodione

- Both are constantly under EPA reviews…
  - Captan is still good with grapes
  - Iprodione (Metor, Rovral, etc.) will be limited to one application per year, and most likely with a longer PHI.
    - The change will happen soon.

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