Pre-harvest disease management of *Botrytis cinerea* on blueberries

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Photo by Kelly L: https://www.pexels.com/photo/close-up-photo-of-blueberries-2539170/

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PRE-HARVEST DISEASE MANAGEMENT

DISEASE MANAGEMENT TOOLBOX

What?
The pathogen that needs to be controlled

When?
Conditions necessary for infection (disease cycle and epidemiology)

Where?
What plant organs are susceptible and when (disease cycle and epidemiology)

Disease management toolbox

How?
Available control methods

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Botrytis blossom, twig blight and post harvest rot

Causal agent: *Botrytis cinerea*

- **Aggressive coloniser of injured and senescing plant tissues**
- **Wide host range (not host specific)**
  - **Survives well as a saprophyte on dead host and non-crop material**
  - **Inoculum load and transition to susceptible material**

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

What plant organs are susceptible and when? (disease cycle and epidemiology)

- **Can infect shoot tips, blossoms**
- **Tender green twigs/stems**
- **Leaves**
- **Fruit (soft decay mature fruit)**

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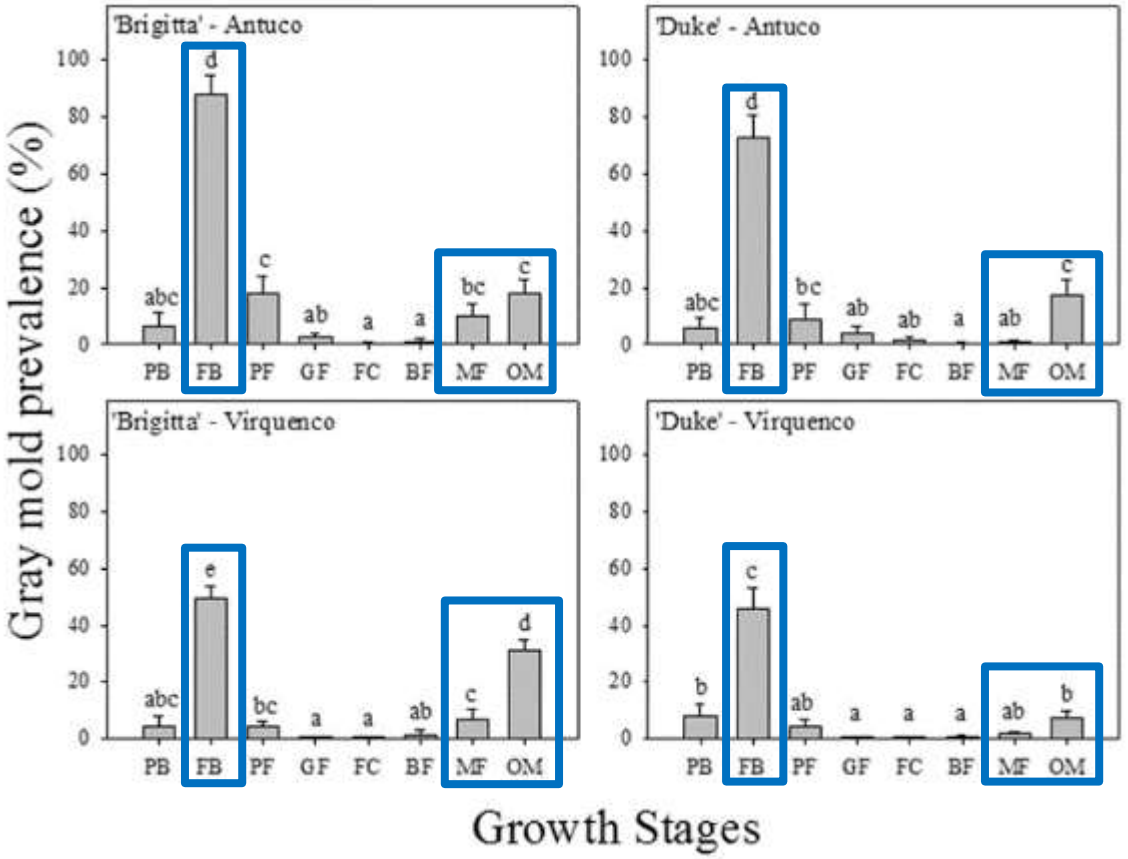
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Susceptibility

- **Natural occurring inoculum**
- **Full bloom**
- **Mature fruit**
- **Green fruit??**
- **Over-mature fruit**
- **Cultivar dependent**



Rivera et al., 2013; Plant Dis. 97:1069-1074

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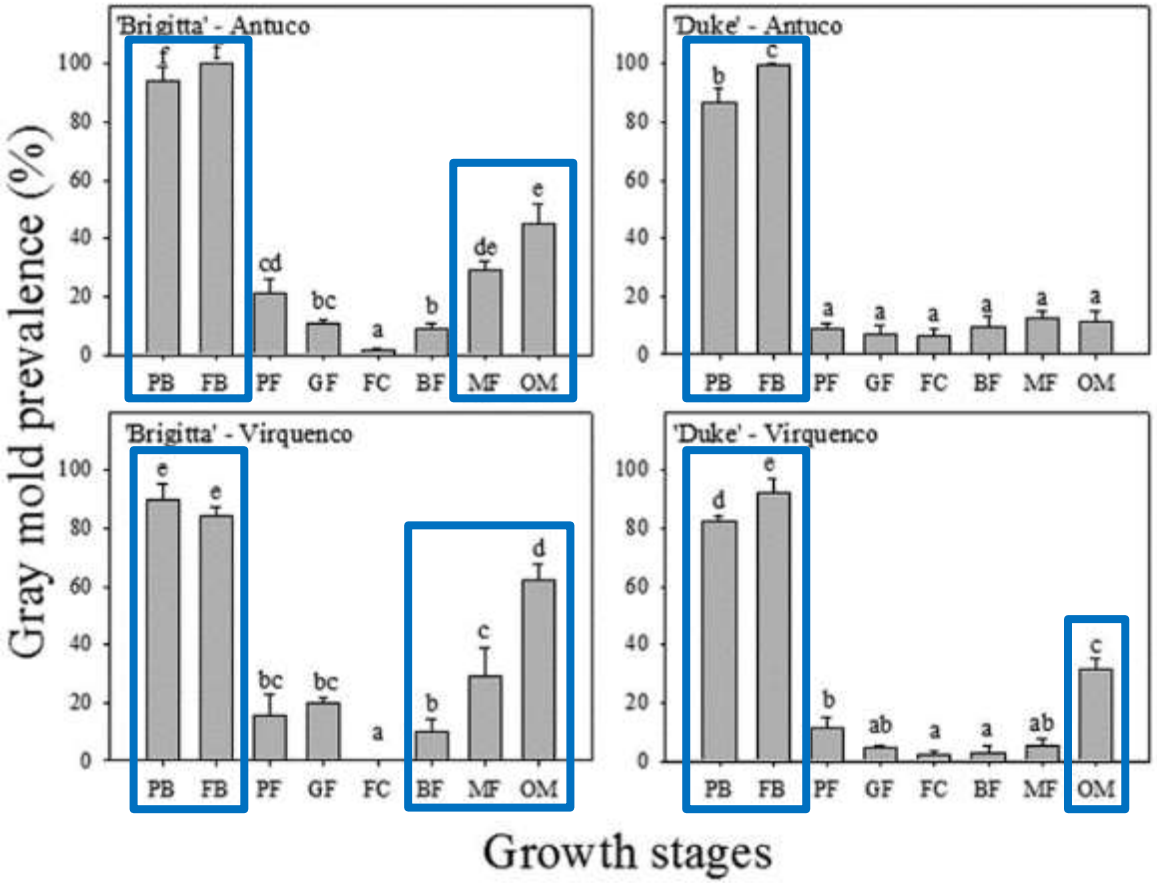
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Susceptibility

- **Late pink bud**
  - **Spread from corolla to peduncle**
  - **Possible latent fruit infection**
  - **Cluster abortion**
- **Green stem infection**
  - **Usually seen on long canes**
  - **Not covered by the sprayer**
  - **Narrow rows – overlapping issues**
  - **Inadequate nozzle orientation**



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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND H

Susceptibility

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    - **Inadequate nozzle orientation**

Growth stages

Rivera et al., 2013; Plant Dis. 97:1069-1074

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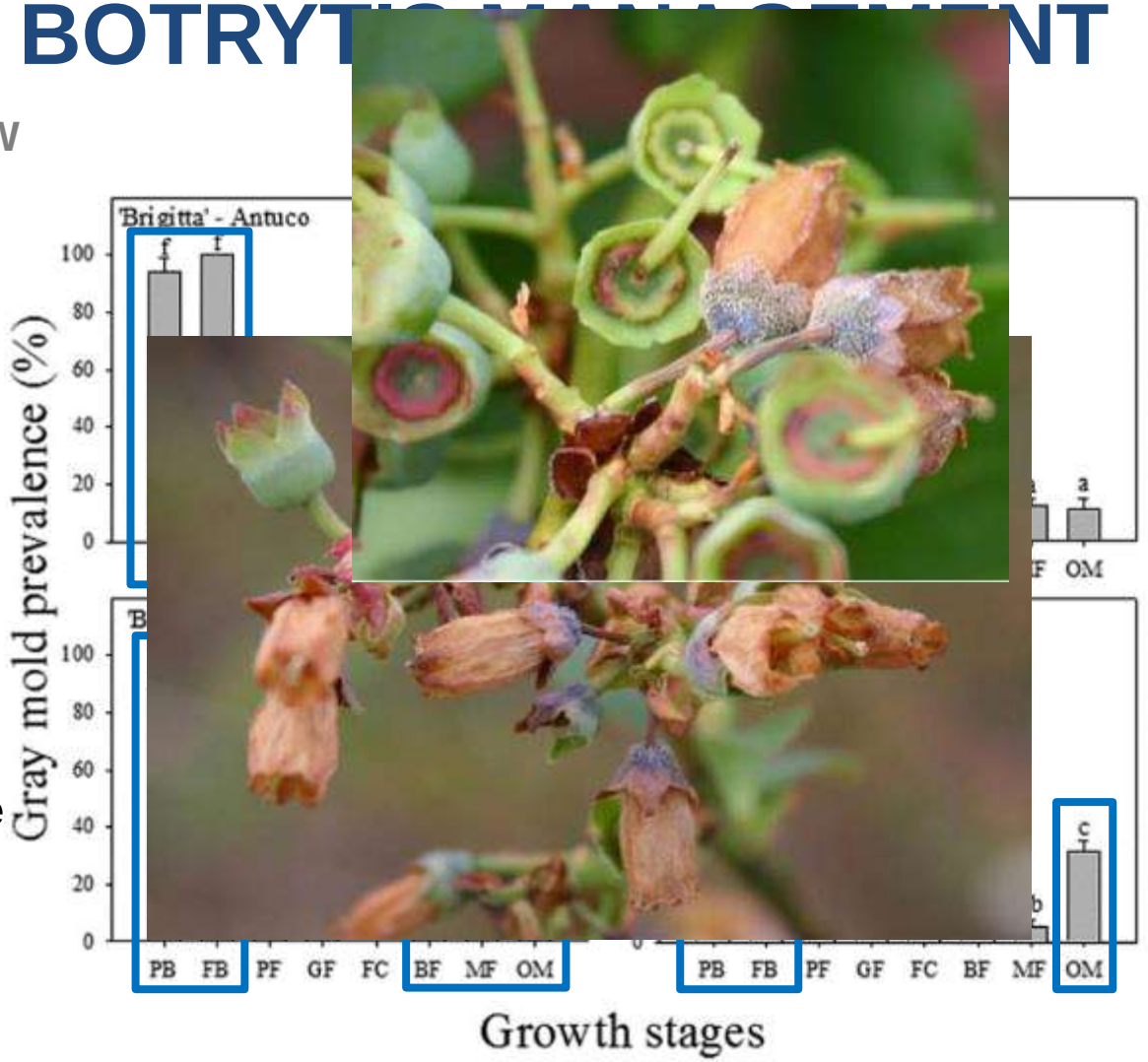
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Susceptibility

- **High inoculum pressure**
- **Full bloom**
  - **Blossom blight**
  - **Spread from corolla to peduncle**
  - **Possible latent fruit infection**
  - **Cluster abortion**
  - **Can be economical unde severe pressure**



Rivera et al., 2013; Plant Dis. 97:1069-1074

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PRE-HARVEST BOTRYTIS MANAGEMENT

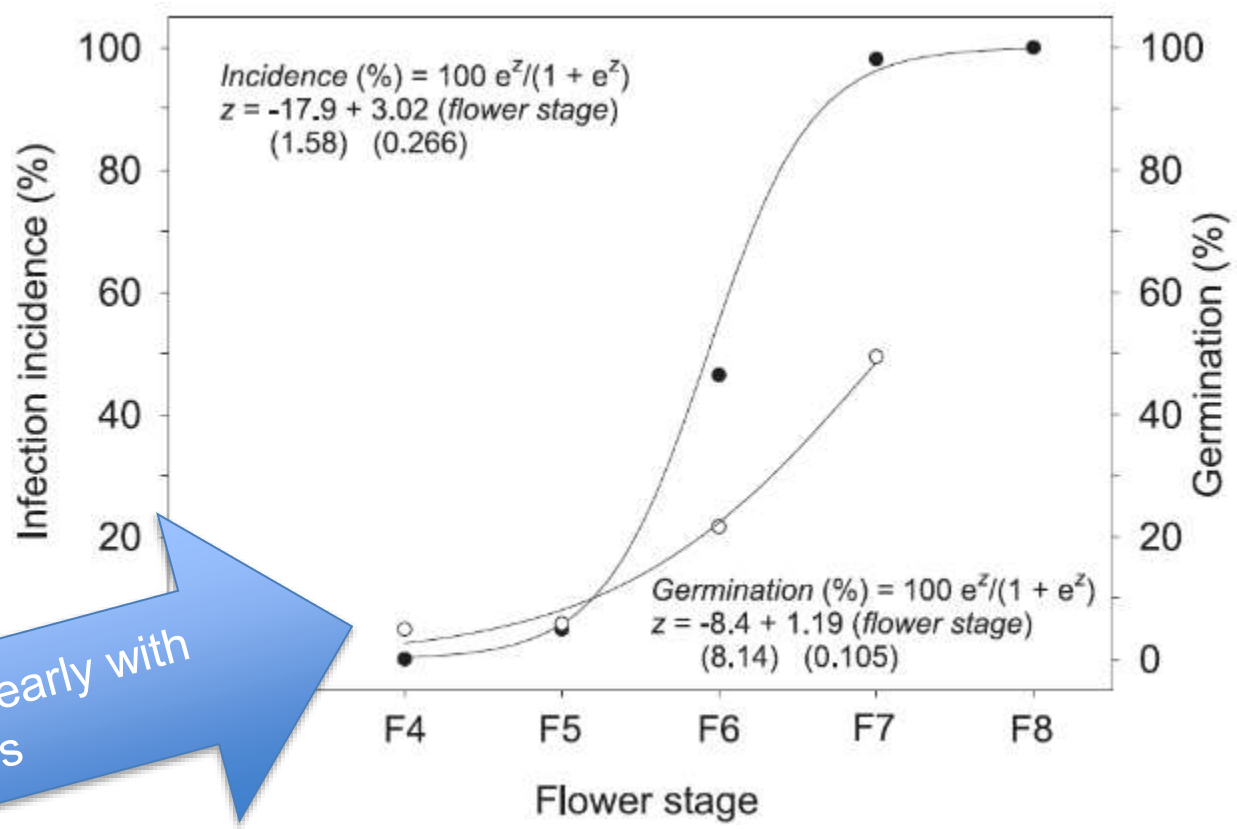
WHAT, WHEN, WHERE AND HOW

Susceptibility

- **Early flower stages low susceptibility**
- **Lack of exogenous nutrients inhibits spore germination**

Increase in susceptibility

- **F6 – Pink/White bud (pre-bloom)**
- **F7 – Full bloom**
- **F8 senesced corolla**



Do not start to early with sprays

Hildebrand et al., 2001; Can. J. Plant Pathol. 23: 364–370

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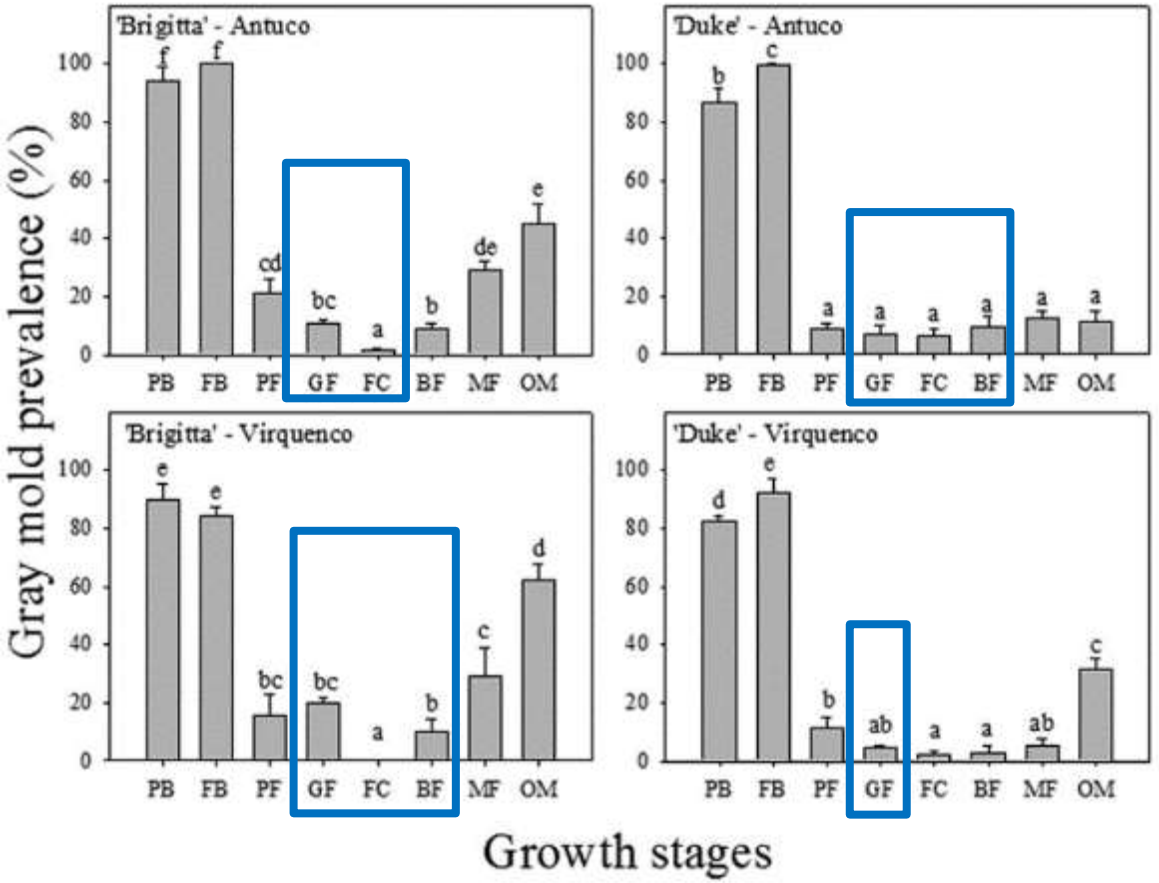
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Susceptibility

- **Green fruit – low susceptibility**
- **Cultivar dependent**



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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

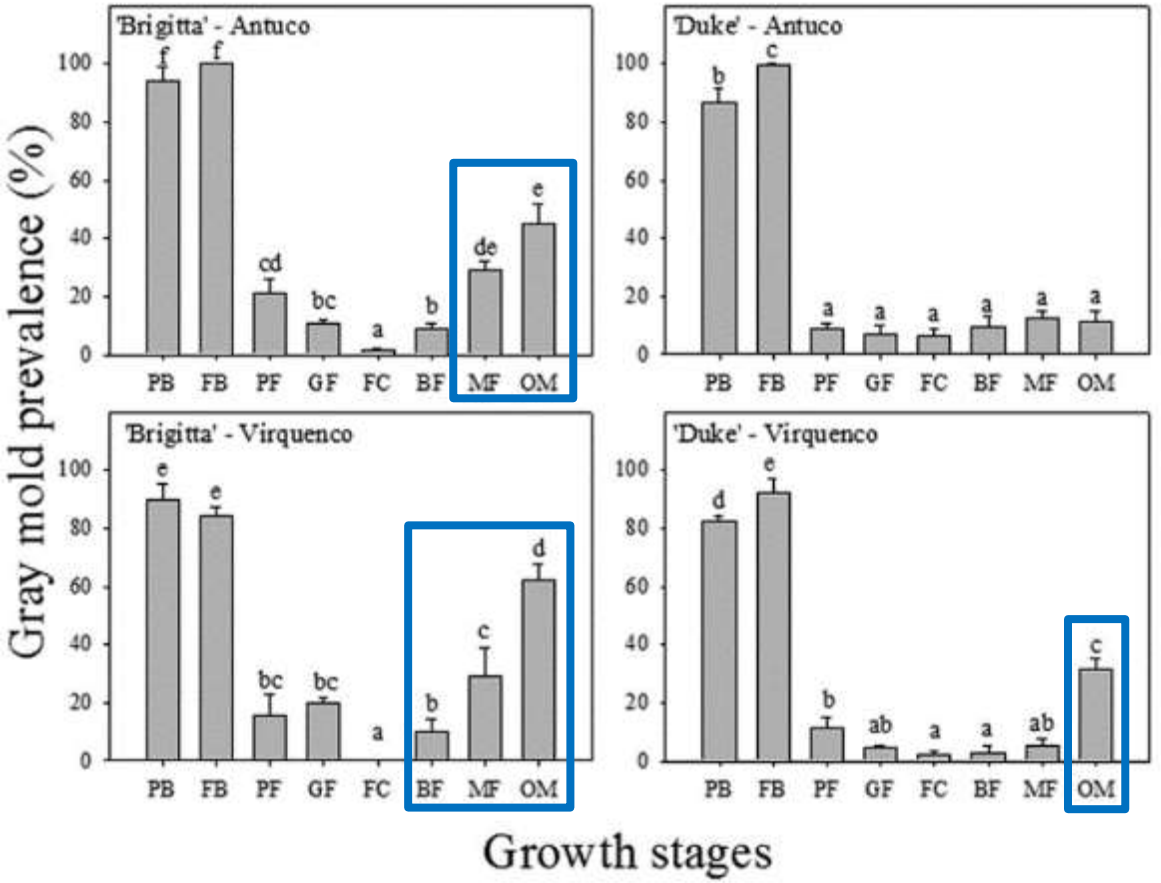
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Susceptibility

- **Mature – over mature fruit**
- **Wounding, especially stem-end scars increases infection**
- **Cultivar dependent**
- **Cappellini & Ceponis 1978**

- **Inoculum pressure during harvest?**



Rivera et al., 2013; Plant Dis. 97:1069-1074

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WHERE = PROTECTION NEEDED

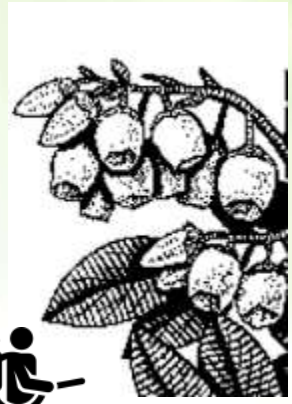

Dormant

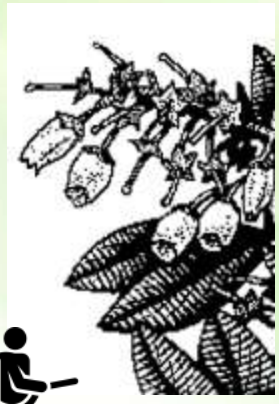

Bud swell


Green tip


Bud cluster


Pink bud


Bloom


Petal fall


Calyx


Green fruit


Fruit ripening

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Postharvest can be initiated at flowering or during the early stages - remaining latent until harvest and postharvest – Inoculum build up

Conditions favourable for infection (disease cycle and epidemiology)

- **Infection is possible 0-30 ˚C**
- **Optimum conidium germination 20-25 ˚C**
- **Optimum infection 16-20 ˚C**
- **Wetness period of 6h needed for infection**
  - **6h @ 20 ˚C**
  - **8h @ 16 ˚C**
  - **13h @ 8-12 ˚C**
  - **24h @ 4 ˚C**
- **3-4 days visible infection**

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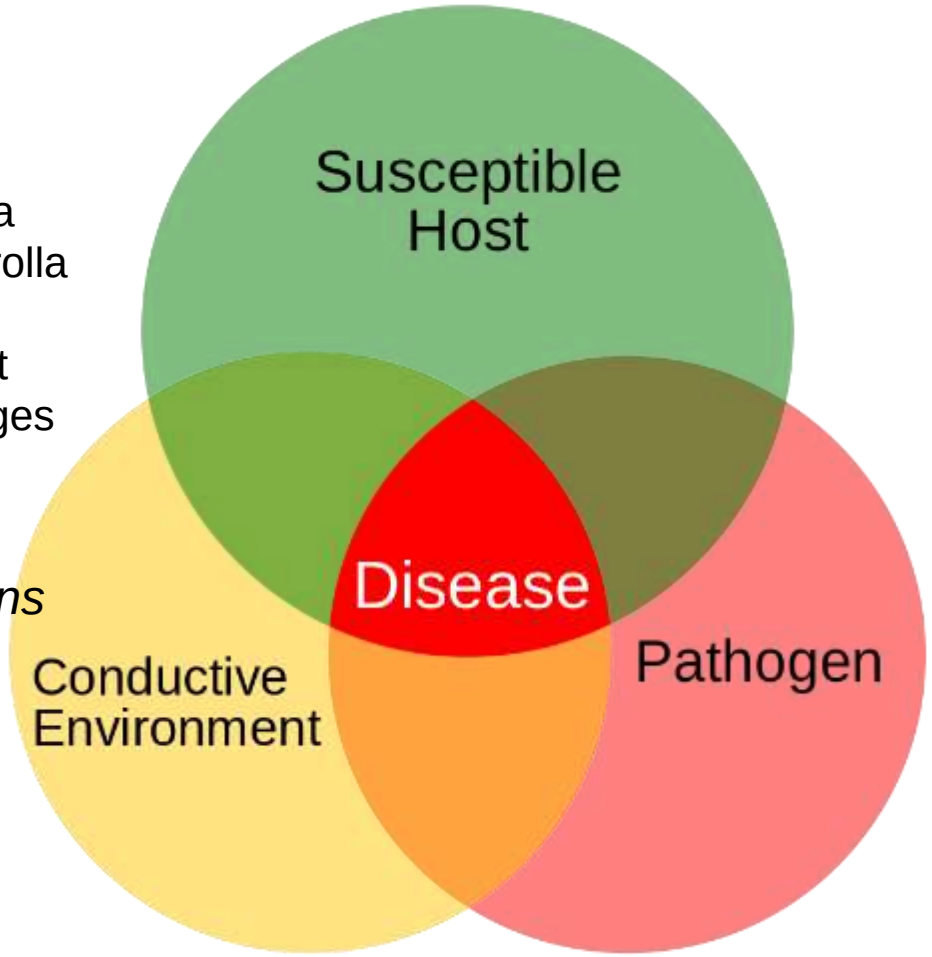
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

Susceptibility

- Late pink bloom
- Senesced corolla
- Green fruit - corrolla
- mature fruit
- Over mature fruit
- Overlapping stages



Favourable conditions

- Wetness period
- Temperature

Inoculum load

Area
Sanitation
Time of season

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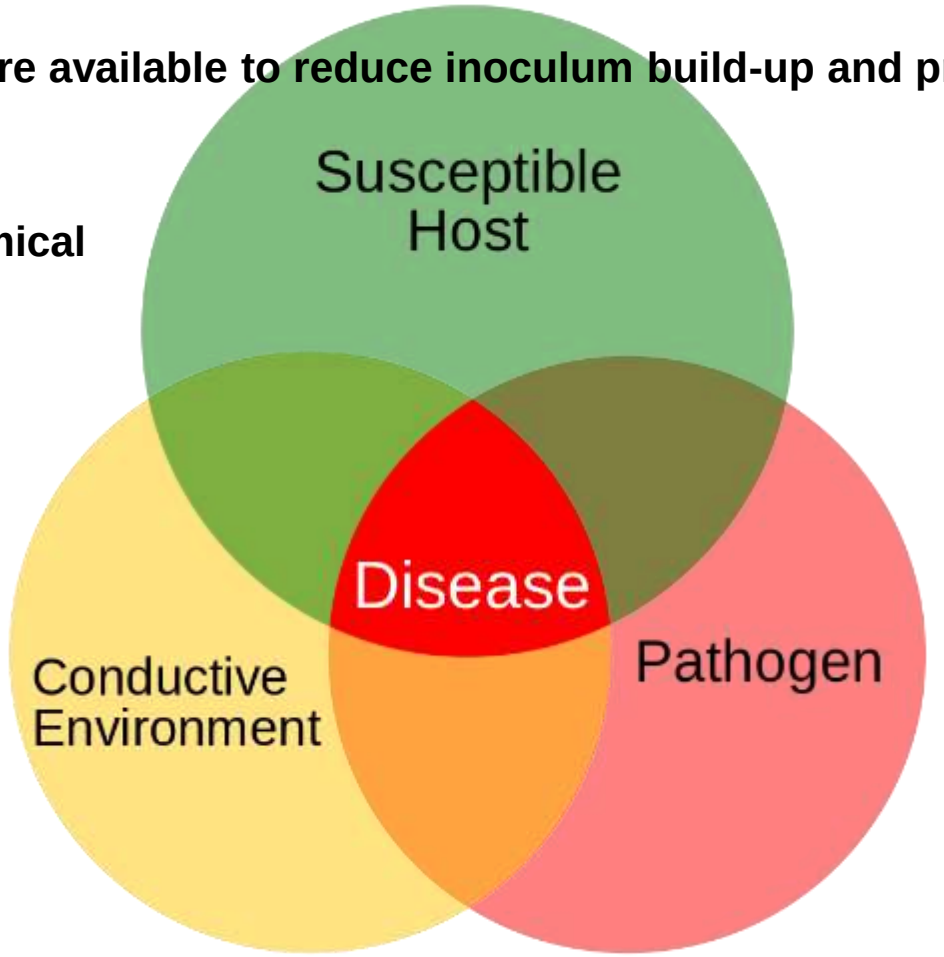
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

HOW?

What strategies are available to reduce inoculum build-up and prevent infection…

Cultural and chemical



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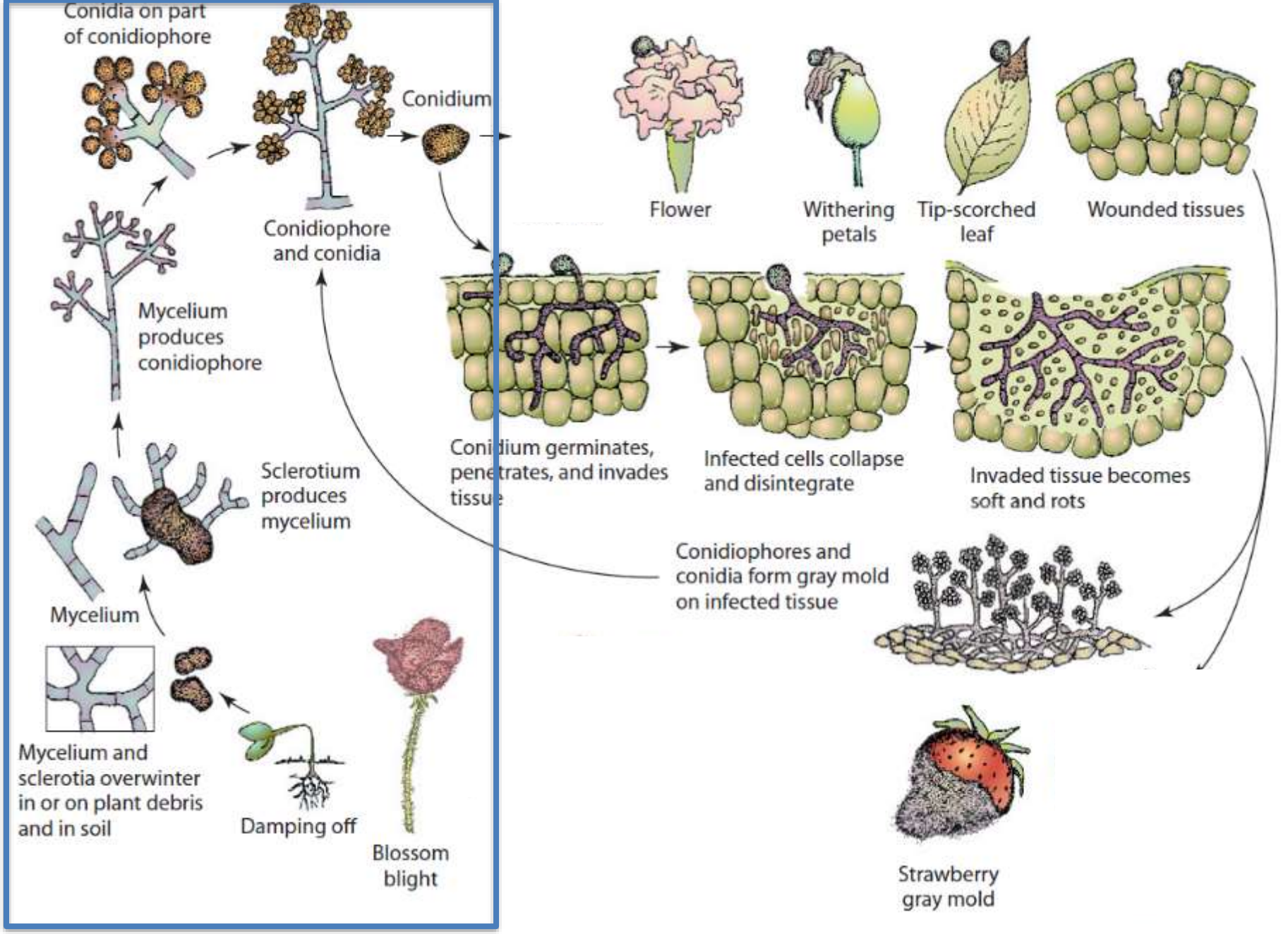

Inoculum load reduction

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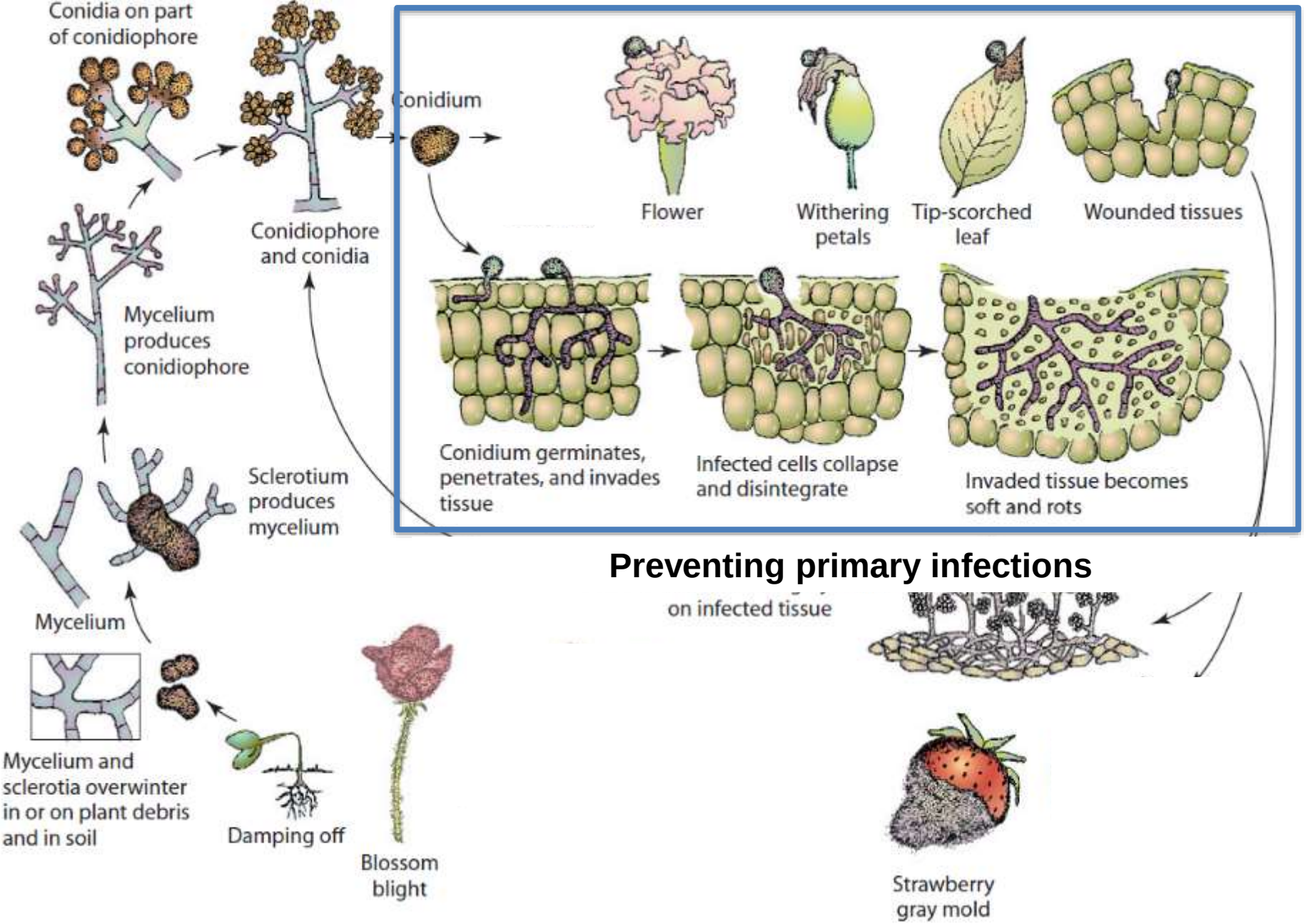

Preventing primary infections

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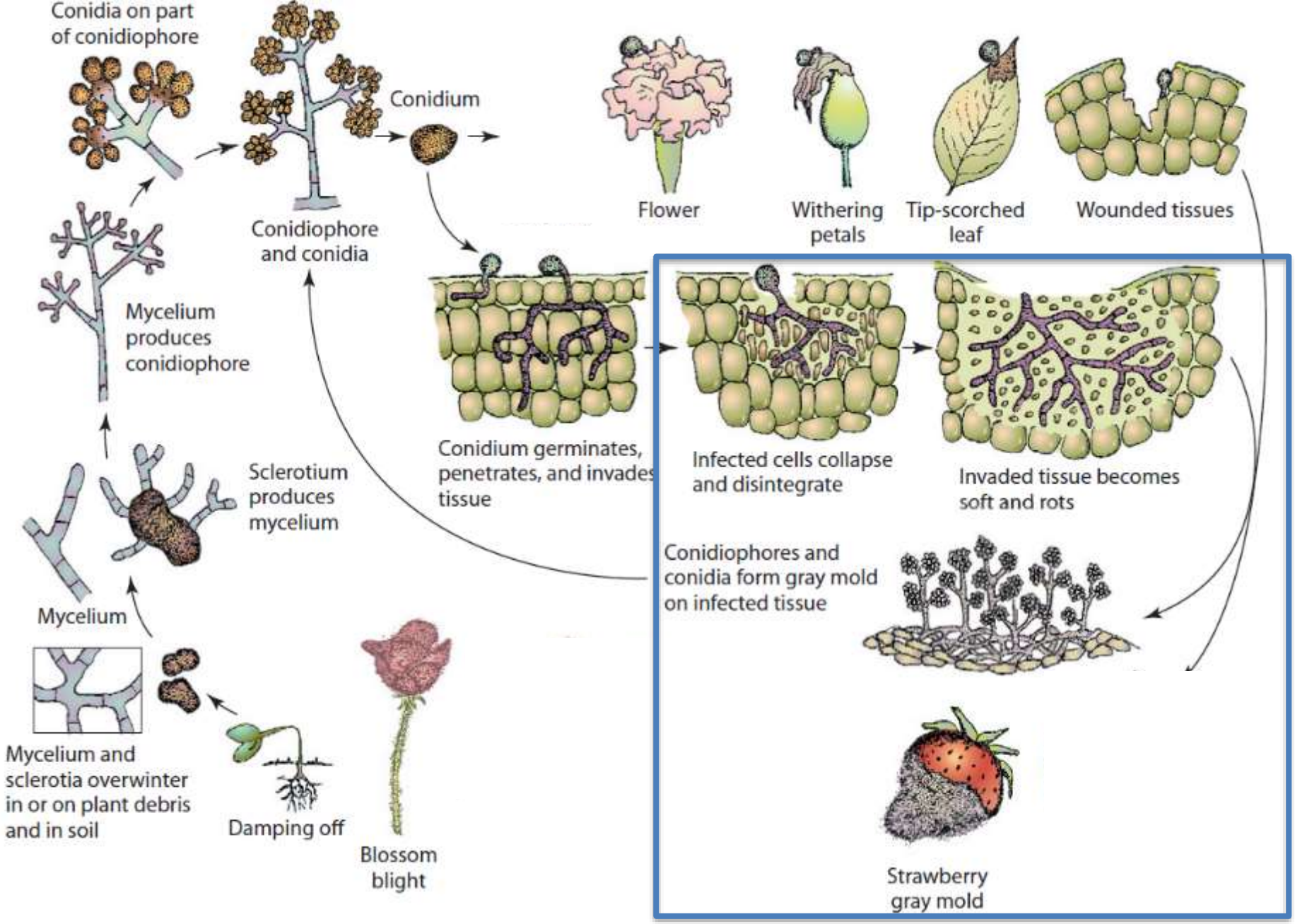

Limiting secondary infections

PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL

Reduce/Limit inoculum load build-up

- **Sanitation**
  - **Clean orchards of pruned material**
  - **Practice good weed control – removing host material**
    - **In pots this will improve air circulation/drying**
  - **Picking more frequently to reduce highly susceptible over mature fruit**
  - **Limit berry wastage on orchard floor**

- **Labour and cost implications?**

- **Depending on orchard site spore density can vary to a large extent**

- **Prevent/limit primary infections through chemical control**

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL

Improve airflow and drying of fruit

Orchard layout

- **Site selection**
  - **Avoid low lying areas with poor airflow prone to long periods of high relative humidity**
  - **Seasonal influence on infection period *vs* susceptibility**

- **Row direction, prevailing wind direction, horticultural considerations**

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL

Improve airflow and drying of fruit

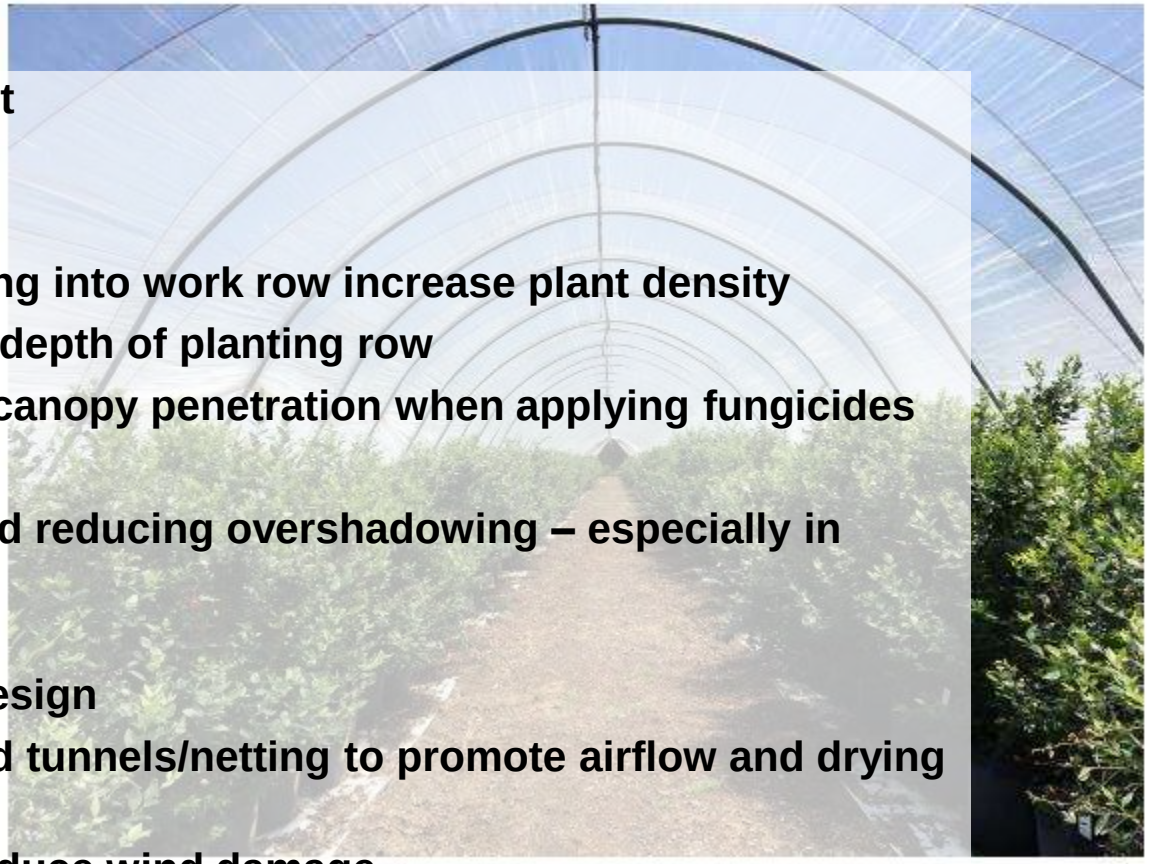
Orchard layout

- **Row spacing**
  - **Space rows for good air circulation, drying and to avoid mechanical damage**
  - **Irregular row spacings**
  - **Narrow spacings problematic (2.25 m<)**
    - **Difficult/expensive to find effective spray application systems**
    - **Restricted movement**
      - **Spray application of fungicides later in season problematic**
      - **Increased mechanical fruit damage**
    - **Increased planting density – reduces air flow and drying**

PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL



Improve airflow and drying of fruit

Orchard layout

- **Avoid high planting densities**
- **Trellising to keep canes hanging into work row increase plant density**
- **Stagger plantings – increases depth of planting row**
    - **Difficult to get good canopy penetration when applying fungicides**

- **Improving light penetration and reducing overshadowing – especially in winter**

- **Tunnel or netting structures design**
    - **Make use of well designed tunnels/netting to promote airflow and drying of fruit**
    - **Structures designed to reduce wind damage**
    - **Cover material to reduce wetness**
        - **Polyethene vs netting**

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL

Improve airflow and drying of fruit

Orchard layout

Cultivar characteristics

- **Size and density**
- **Follow pruning strategies that improve airflow – especially in densely planted orchards**
- **Delayed corolla (fused petals of the flower) drop**
    - **Dead/senescing tissue prone to infection – inoculum build-up, latent infections**

Cultivar combinations

- **Flowering periods not in sync**
    - **Fungicide application timing management difficulties**

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL

Wound management

- **Mechanical damage**
  - **More prone in high density orchards**
  - **Labour (Pickers, weeding)**
  - **Spray application**
- **Birds**
  - **Very difficult to control**
  - **Harassment**
    - **Reflection**
    - **Noise**
  - **Exclusion and controlled access**
  - **Registered repellents?**
    - **methyl anthranilate**
  - **Biological control**
    - **Predation**

Pecking damage on blueberry. Mark Longstroth, MSU Extension

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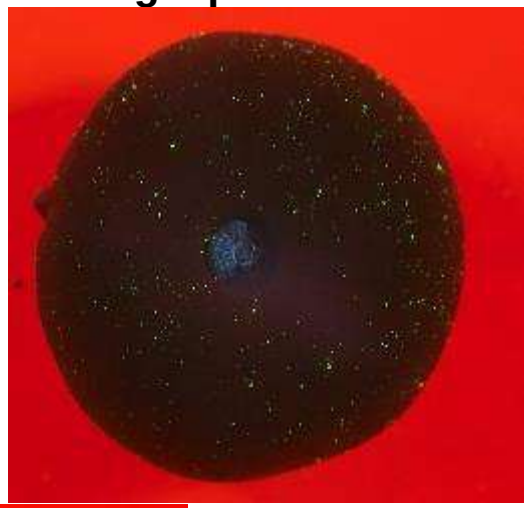
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

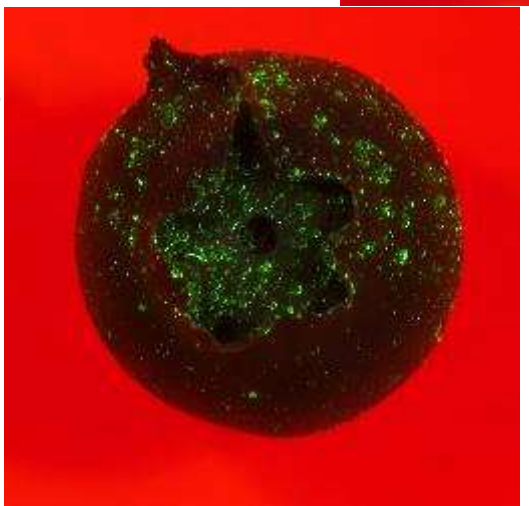
CULTURAL CONTROL

Water management – over irrigation – bloom protection – fruit cracking – poor deposition



Wound management

- **Insect damage**
- **Wind damage**
  - **Trellising of large plants in pots**
  - **Wind breaks**
  - **Too high air volumes – spray machines**
- **Berry splitting**
  - **Late season fertilization/fertigation**
  - **Picking of wet fruit, just after rain**



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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CULTURAL CONTROL

Monitoring

- **Effective and regular monitoring to detect infections**

- **To evaluate success of control strategies used**

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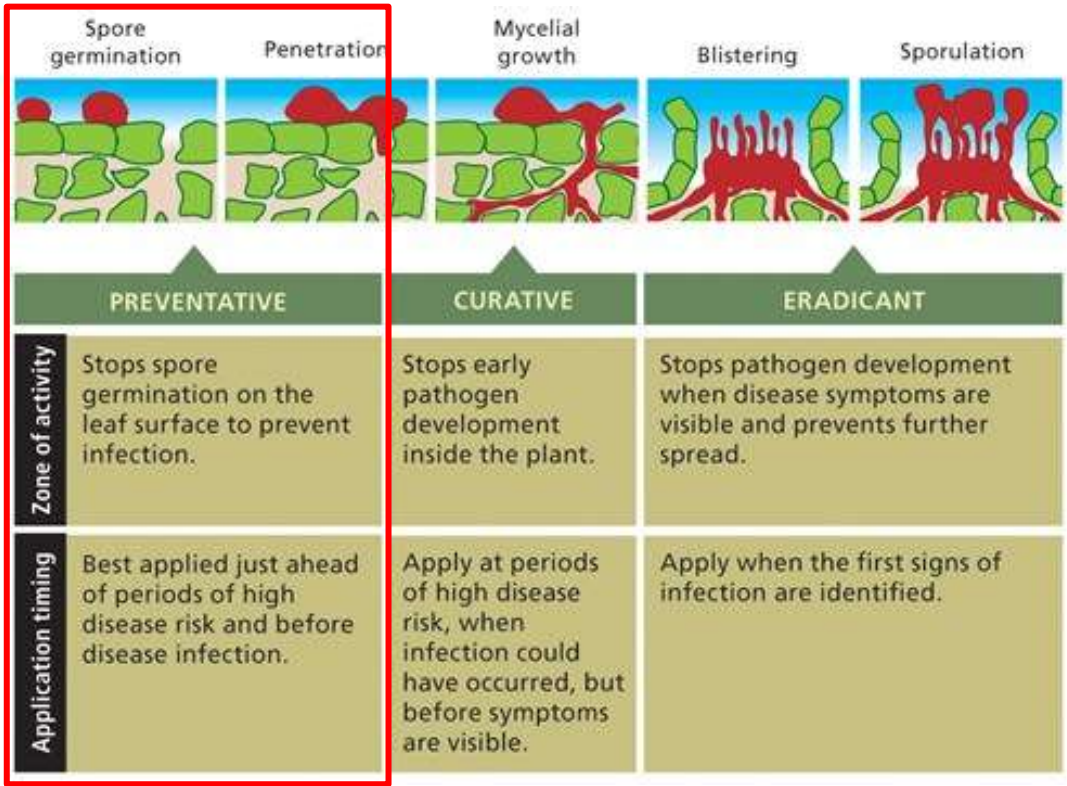
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CHEMICAL CONTROL

Chemical control should focus on preventing infections

- **Not a silver bullet! Fungicides form part of an integrated disease management strategy.**
- **Active ingredient must be on the target surface to prevent germination before the infection period**



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PRE-HARVEST BOTRYTIS MANAGEMENT

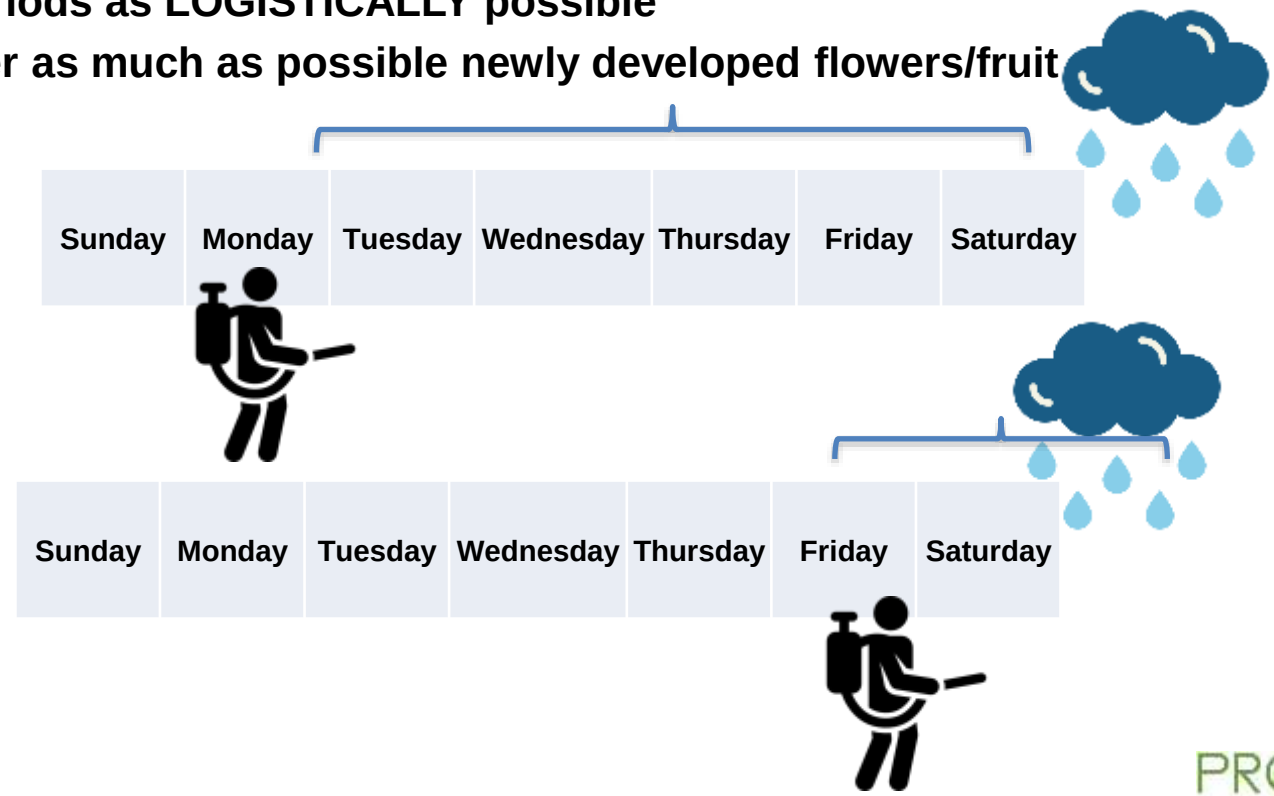
WHAT, WHEN, WHERE AND HOW

CHEMICAL CONTROL

Chemical control should focus on preventing infections

Timing of applications is NB!

- **Fungicide applications should be made as close as possible to start of infection periods as LOGISTICALLY possible**
  - **To cover as much as possible newly developed flowers/fruit**



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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CHEMICAL CONTROL

Chemical control should focus on preventing infections

Timing of applications is NB!

- **Keep an eye on the weather and plan applications**

Severity Rating of Botrytis Infection Periods					
Mean Temperature (°C) during Infection Period					
Wetness (H)	4 °C	8 °C	12°	16°	20°
4	LOW	LOW	LOW	LOW	LOW
6	LOW	LOW	LOW	LOW	LOW
8	LOW	LOW	LOW	LOW	MED
10	LOW	LOW	LOW	LOW	HIGH
13	LOW	LOW	LOW	HIGH	HIGH
24	LOW	MED	HIGH	HIGH	HIGH
36	LOW	HIGH	HIGH	HIGH	HIGH
48	MED	HIGH	HIGH	HIGH	HIGH
Fact Sheet No. 212, UMaine Extension No. 2027					

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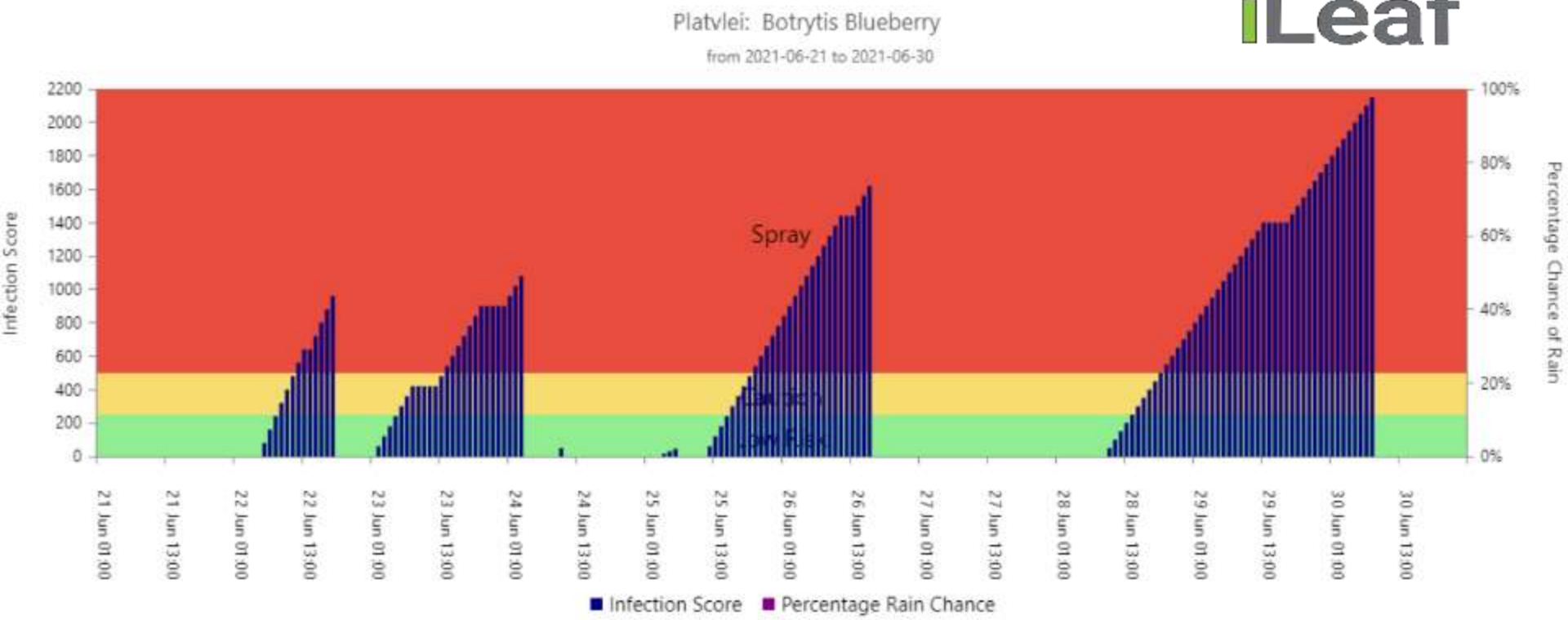
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CHEMICAL CONTROL

Timing of applications is NB!

- **Use prediction models**



SUSCEPTIBLE GROWTH STAGES VS INFECTION PERIODS

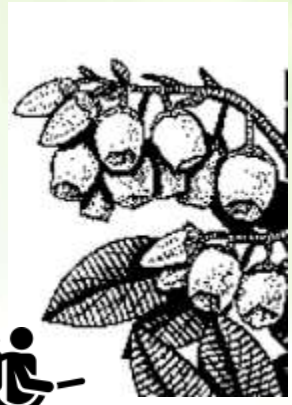

Dormant

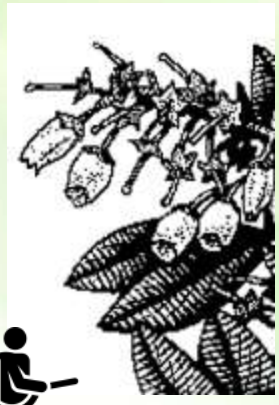

Bud swell


Green tip


Bud cluster


Pink bud


Bloom


Petal fall


Calyx


Green fruit


Fruit ripening

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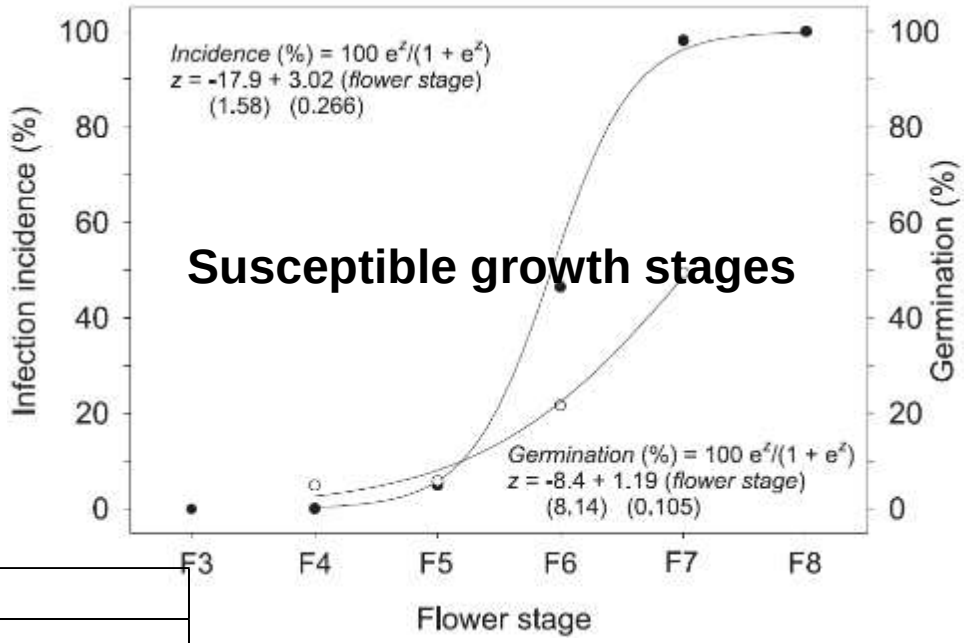
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW CHEMICAL CONTROL

Timing of applications is NB!

- **Do not start to early!**
- **Fungicides positioned according to efficacy and infection risk**



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24	LOW	MED	HIGH	HIGH	HIGH
36	LOW	HIGH	HIGH	HIGH	HIGH
48	MED	HIGH	HIGH	HIGH	HIGH
Fact Sheet No. 212, UMaine Extension No. 2027					

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INFO ON FUNGICIDES FOR BOTRYTIS CONTROL

Active Ingredient	Trade names	Allowed number of applications	Dosage (g or mℓ) per 100 ℓ water or kg/ha	FRAC Code	Local (RSA)		EU		Notes
					MRL	PHI	MRL	PHI	
Fenhexamid	Teldor 500 SC	3	75ml/100L	17	5	3	20	3	Maximum 3 sprays per season. MRL San Lucar = 2.7ppm
	Providor	3	75ml/100L	17	5	3	20	3	Maximum 3 sprays per season. MRL San Lucar = 2.7ppm
Fluopyram	Luna Privilege	2	500ml/ha	7	5	3	7	3	Maximum 2 sprays per season. Fluopyram MRL San Lucar = 0.162ppm
Cyprodinil + Fludioxonil	Switch	4	800-950g/ha	9+12	3/2	3	3/2	3	Do not apply more than 2 sequential applications and not more than 4 sprays per season. Restricted use – Waitrose Amber Monitored substance – Sainsbury's Fludioxonil MRL San Lucar = 0.667ppm Cyprodinil MRL San Lucar = 0.405ppm
Pyrimethanil	Scala	2	120ml/100 L	9	5	3	8	3	Maximum 2 sprays per season. MRL San Lucar = 1.148ppm
Trichoderma asperellum	Real Trichoderma	NA	200ml/ha	BM02		0			

NOTE:

Although not registered for control of botrytis on blueberries Pyraclostrobin/Boscalid (Bellis) and Copper oxychloride will also be effective against botrytis

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NOT REGISTERED - EFFECTIVE

Active Ingredient	Trade names	Allowed number of applications	Dosage (g or mℓ) per 100 ℓ water or kg/ha	FRAC Code	Local (RSA)		EU		Notes
					MRL	PHI	MRL	PHI	
Pyraclostrobin + Boscalid	Bellis	3	60g/100L	11+7	1/1.5	28	4/15	14	Maximum 3 applications per season. Restricted use – Waitrose Amber Monitored substance – Sainsbury's Boscalid MRL San Lucar = 0.540ppm Pyraclostrobin MRL San Lucar = 0.405ppm
Copper oxychloride	Demildex	NA	300g/100L	M1		14	5	14	MRL San Lucar = 1.667ppm
Potassium bicarbonate [syn. potassium hydrogen carbonate]	Agri-Cure SP	850 g/kg	300-500g/100L (2.5-5kg/ha)	NC		0			See label for use recommendations

- **Challenges:**
  - **Detectible residue management**
  - **Insecticides**
  - **Visible residues – poor sprayer mixing and too high spray volumes**
  - **Too low MRL values**

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW
CHEMICAL CONTROL

Timing of applications is NB!

- **Total of 11 to 12 sprays available**
- **On a 14 day interval spray schedule**
  - **24 weeks**

Tutor?

Pyrimethanil/Fludioxonil 9/12
Replace 2 switch sprays?

TRADE NAME	ACTIVE INGREDIENT	FRAC CODE	PHI	USE RESTRICTIONS
Bellis	Pyraclostrobin Boscalid	11/7	28	Maximum 3 applications
Luna Privelege*	Fluopyram	7	1	Maximum 2 applications
Teldor/Providor*	Fenhexamid	17	3	Maximum 3 applications
Scala*	Pyrimethanil	9	3	Maximum 2 applications
Switch	Cyprodinil Fludioxonil	9/12	3	Maximum 4 applications. After 2 consecutive applications alternate with different mode of action
Agri-Cure SP	Potasium bicarbonate	NC		None

*** Only actives with *Botrytis* on the label (official registration).**
All products listed are however effective for the control of *Botrytis*

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PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW
CHEMICAL CONTROL

Timing of applications is NB!

- **Do not start to early!**
- **Position sprays…**
  - **close to peak flower onwards**
  - **OR peak/last pick backwards**
- **Use combinations of CuOCl, sulphur and KHCO3 extend program in early season low risk scenarios (few flowers)**
- **Plan your sprays per cultivar**
- **Fungicides positioned according to efficacy and infection risk**

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PRE-HARVEST BOTRYTIS MANAGEMENT

	Early flower	Captan/Copper/ Sodium bicarb/sulphur
Wk1 (23-24)	30% Flower	Bellis
Wk2		Captan/Copper/Sodium bicarb/sulphur
Wk3		Bellis
Wk4		Captan/Copper/Sodium bicarb/sulphur
Wk5		Bellis
Wk6		Captan/Copper/Sodium bicarb/sulphur
Wk7		Teldor
Wk8		Captan/Copper/Sodium bicarb/sulphur
Wk9		Teldor
Wk10		Captan/Copper/Sodium bicarb/sulphur
Wk11		Switch
Wk12		Captan/Copper/Sodium bicarb/sulphur
Wk13		Switch
Wk14		Captan/Copper/Sodium bicarb/sulphur
Wk15		Teldor
Wk16		Captan/Copper/Sodium bicarb/sulphur
Wk17		Scala
Wk18		Captan/Copper/Sodium bicarb/sulphur
Wk19		Switch
Wk20		Captan/Copper/Sodium bicarb/sulphur
Wk21		Switch
Wk22		Captan/Copper/Sodium bicarb/sulphur
Wk23 (45)	Peak pick	Scala

Early protection

Only if necessary

14 day intervals

Max allowed applications with *ai*

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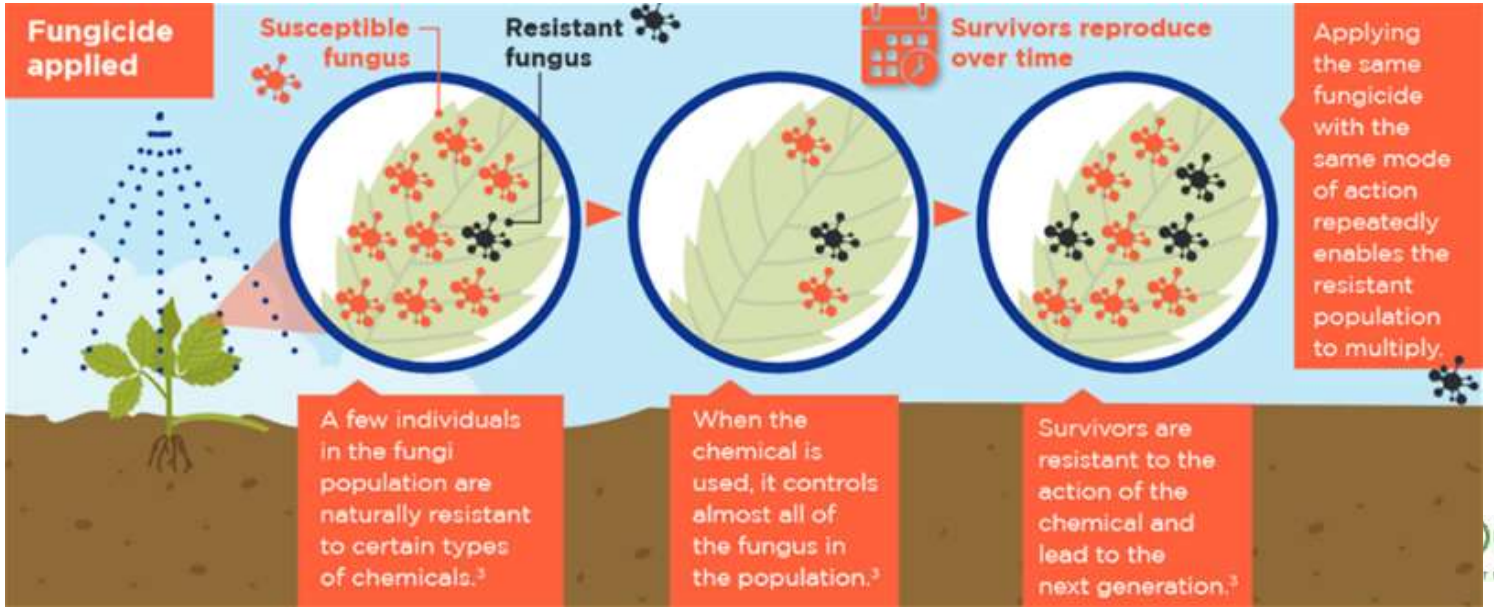
PRE-HARVEST BOTRYTIS MANAGEMENT

Manage resistance development (FRAC guidelines)

- **Fungicides are not silver bullets and should be used in integrated disease management strategies**
- **Plan backwards – last viable or peak pick to plan start of season**
- **Only use registered active ingredients**
- **Do not apply a Mode of Action (MoA) more than the recommended amount of applications (PLANNING NB!)**
- **Always spray preventatively, not reactively!**
- **Fungicides are not effective eradicants…**
- **Avoid consecutive use of similar MoA**



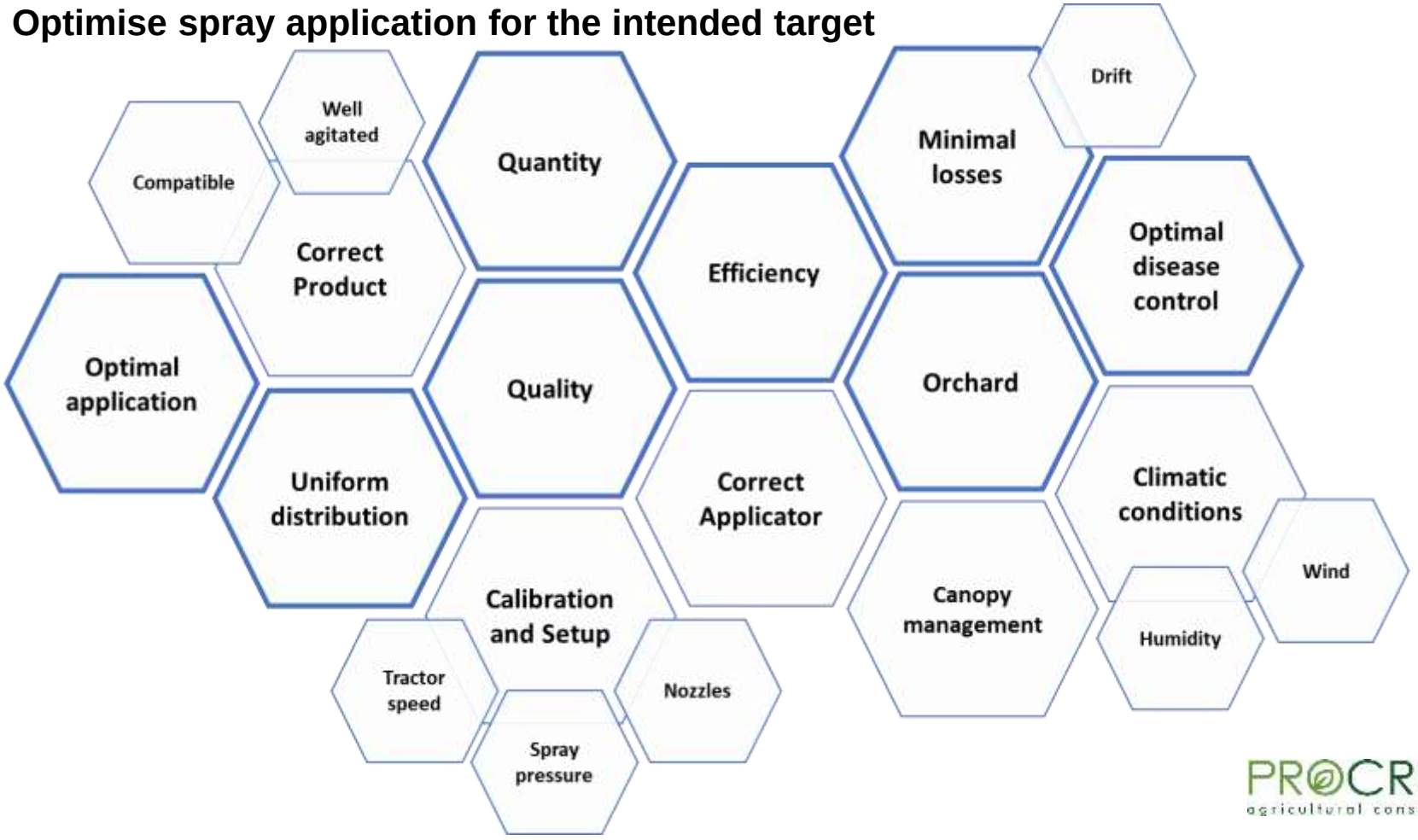
PRE-HARVEST BOTRYTIS MANAGEMENT

WHAT, WHEN, WHERE AND HOW

CHEMICAL CONTROL

Spray effectively

- **Optimise spray application for the intended target**



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PRE-HARVEST BOTRYTIS MANAGEMENT

CONCLUSION – PLAN AHEAD, MANAGE RISK
WHAT, WHEN, WHERE AND HOW

Reduce/Limit inoculum load build-up

Improve airflow and drying of fruit

Manage wounding

Monitor

Prevent infections

Time applications

Manage resistance

Spray effectively

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