Fungicide Resistance

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According to Darwin

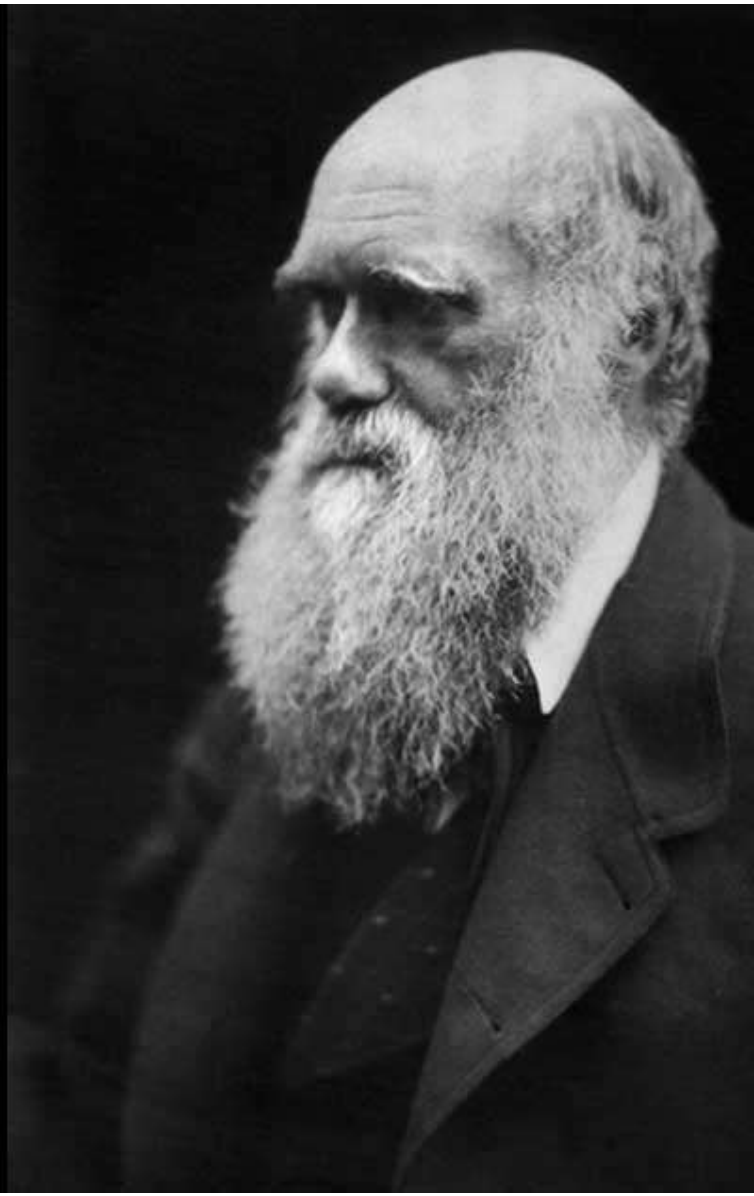
"**Survival of the fittest**"

means, "**better designed**

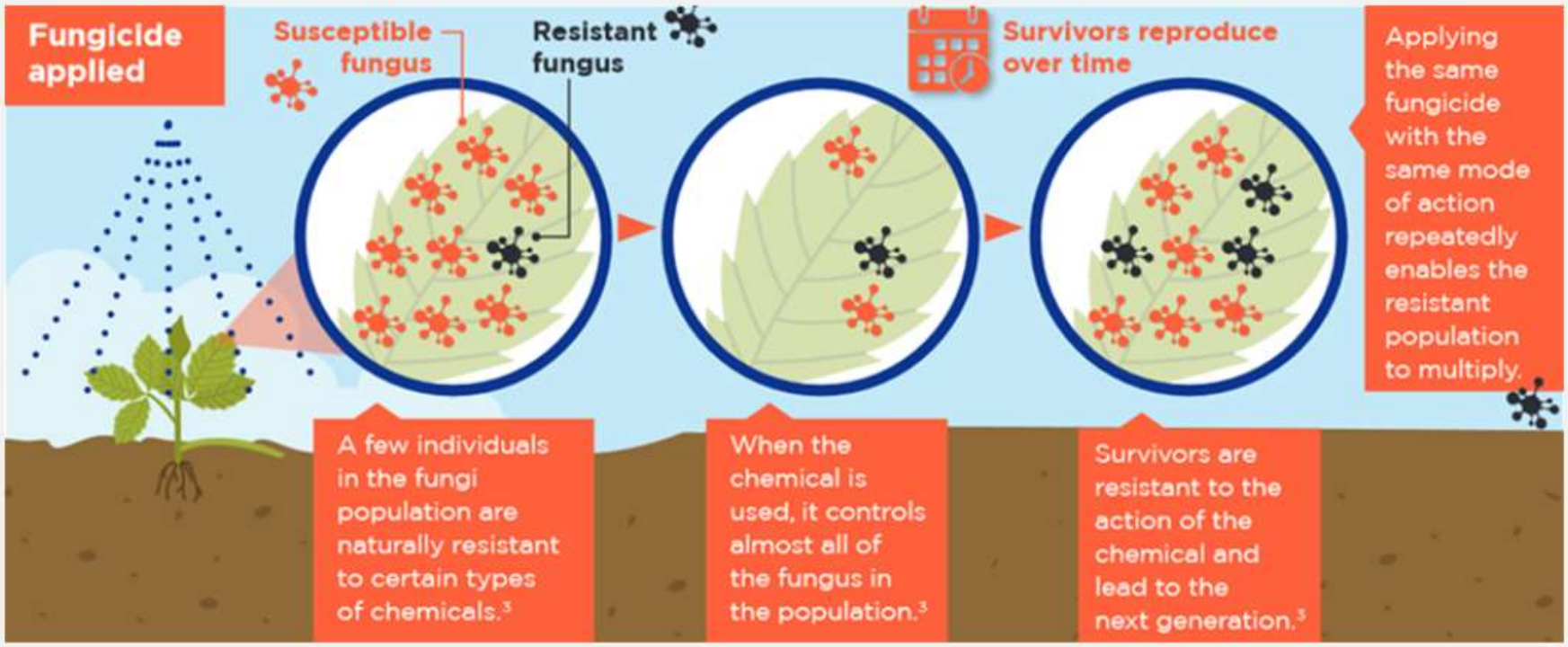
for an immediate, local

environment",

NOT "the strongest".



How Does Fungicide Resistance Evolve?



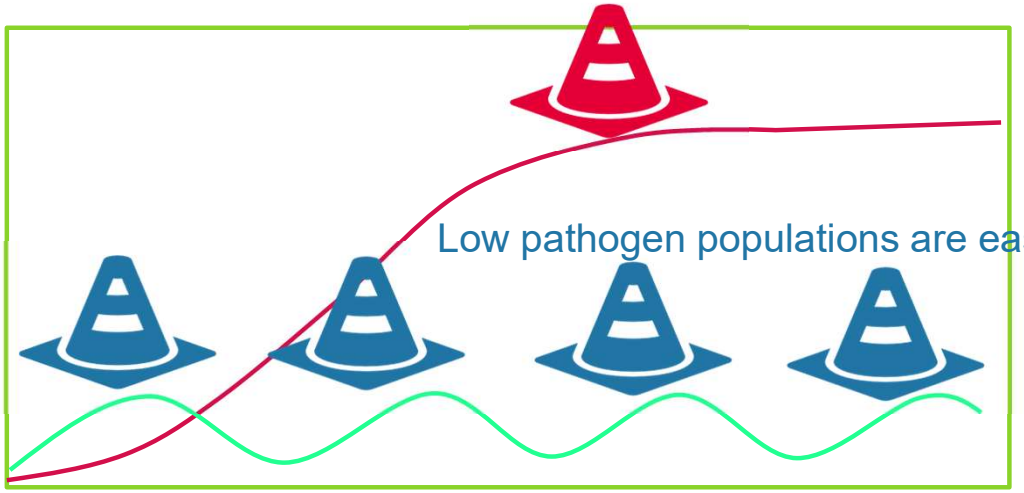
Source: CropLife International

Resistance Triggers (Brent, Hollomon, & D.J, 2007)

- Repeated applications of the same fungicidal mode of action.
- Exclusive treatments with the same mode of action fungicide.
- The rate of the fungicide.
- The population of pathogen exposed to the fungicide.
- When a large area is treated uniformly with a specific fungicide it will pose a greater the risk of resistance.
- The use of integrated disease practices will lower the disease pressure and thus fungicide selection pressure.
- Isolation of pathogen populations (e.g. in greenhouses or tunnels, isolated agronomic regions), preventing re-entry of sensitive forms, can favor development of resistant populations.

Application Timing

High pathogen populations are difficult to reduce

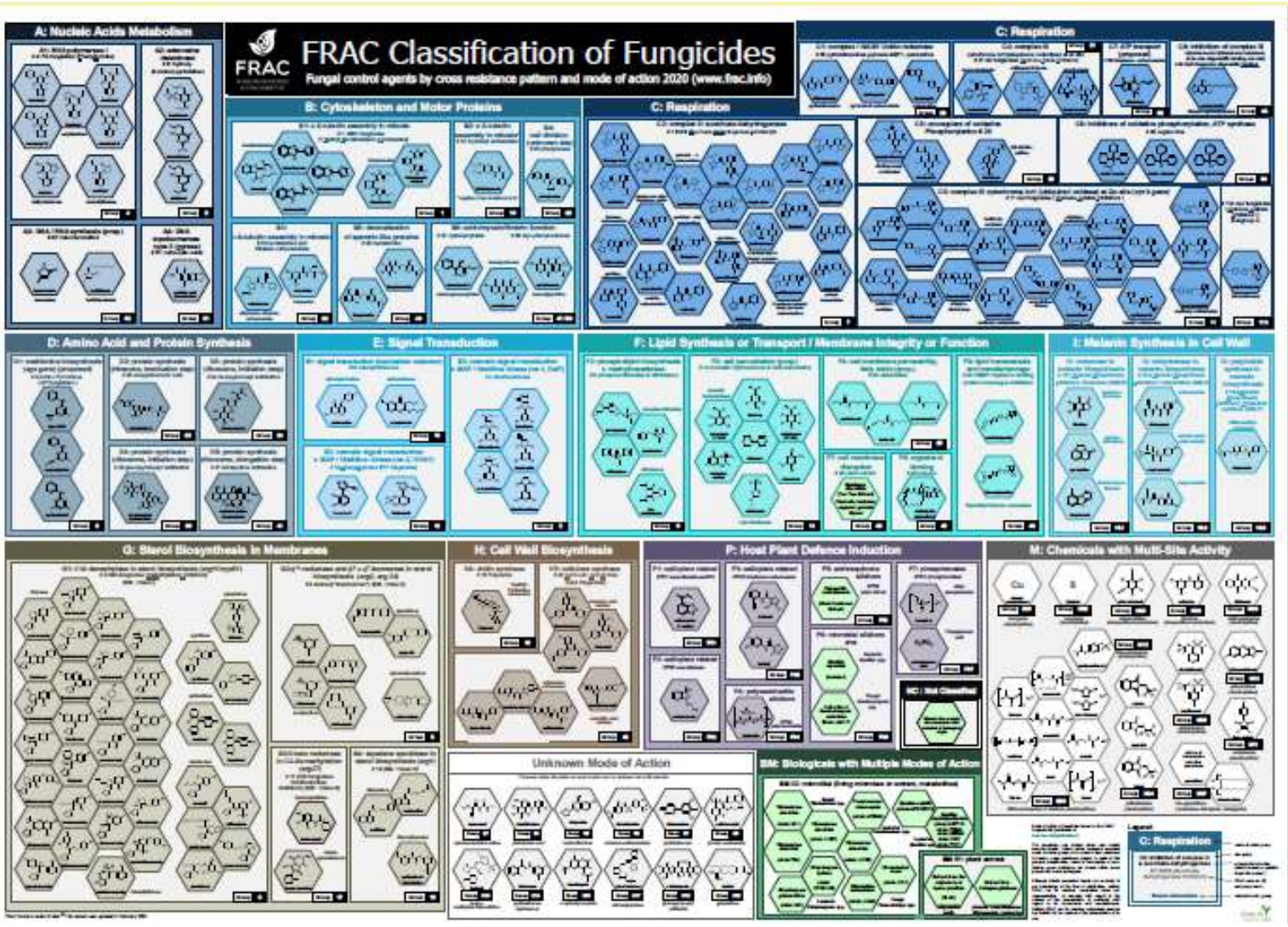


Fungicide Resistance Groups

https://www.frac.info/knowledge-database/videos

Key FRAC Groups

Labelling	Links to Recommendations for FRAC Mode of Action Groups	Synonyms, examples
GROUP 1	MBC fungicides	B1, Methyl Benzimidazole Carbamates, Benzimidazoles, BA, BCM
GROUP 2	Dicarboximide fungicides	E3, DI
GROUP 3	SBI Class I: DMI-fungicides	G1, DeMethylation Inhibitors, Azoles, Triazoles, erg11, cyp51
GROUP 4	PA fungicides	A1, PhenylAmides, Acylalanines,
GROUP 5	SBI Class II: Amines	G2, Morpholines, erg2-, erg24-gene
GROUP 7	SDHI fungicides	C2, Succinate dehydrogenase inhibitors, Carboxamides, sdh-gene
GROUP 9	AP fungicides	D1, Anilino-Pyrimidine
GROUP 10	NPC fungicides	B2, N-Phenyl Carbamates
GROUP 11	Qol-fungicides	C3, Quinone outside Inhibitors, Strobilurines, cyt-b-gene
GROUP 13	AZN fungicides	E1, Azanaphthalenes
GROUP 17	SBI Class III: KRI fungicide	G3, KetoReductase Inhibitors, erg27-gene
GROUP 18	SBI Class IV	G4, Squalene-epoxidase in sterol biosynthesis
GROUP 40	CAA fungicides	H5, Carboxylic Acid Amides
GROUP 49	OSBPI fungicides	F9, OxySterol Binding Protein Inhibitors


FRAC Classification of Fungicides
Fungal control agents by cross resistance pattern and mode of action 2020 (www.frac.info)
A: Nucleic Acids Metabolism
B: Cytoskeleton and Motor Proteins
C: Respiration
D: Amino Acid and Protein Synthesis
E: Signal Transduction
F: Lipid Synthesis or Transport / Membrane Integrity or Function
I: Melanin Synthesis in Cell Wall
G: Sterol Biosynthesis in Membranes
H: Cell Wall Biosynthesis
P: Host Plant Defence Induction
M: Chemicals with Multi-Site Activity
Unknown Mode of Action
BM: Biologicals with Multiple Modes of Action
Legend
C: Respiration

Probability of Resistance

Interaction between the pathogen risk and the fungicide risk

		Risk Factor		
Fungicide Classes	Fungicide Risk Score	Low 1	Medium 2	High 3
Benzimidazole Dicarboxamides Phenylamide SDHI Fungicides QOI	High 3	3	6	9
Azoles, Carboxanilides, Cymoxanil, Fenhexamid	Medium 2	2	4	6
Multi site Fungicides eg Ditiocarbamates (Mancozeb and Propineb)	Low 0.5	0.5	1	1.5
	Pathogen Risk Score	1	***2***	*3*
	Examples	*Ustilago* spp. *Pyrenophora* *Rizoctonia* sp. *Fusarium* sp. *Sclerotinia sclerotorium*	***Alternaria solani*** ***Bipolaris maydis*** ***Leveillula taurica*** ***Monilinia spp.*** ***Penicillium digitatum*** ***Penicillium expansum*** *Phytophthora infestans*** *Setosphaeria turcica*	*Alternaria alternata* *Botrytis cinerea* *Blumeria graminis* ***Erysiphe necator**** *Plasmopara viticola* *Ramularia collo-cygni* *Venturia inaequalis*

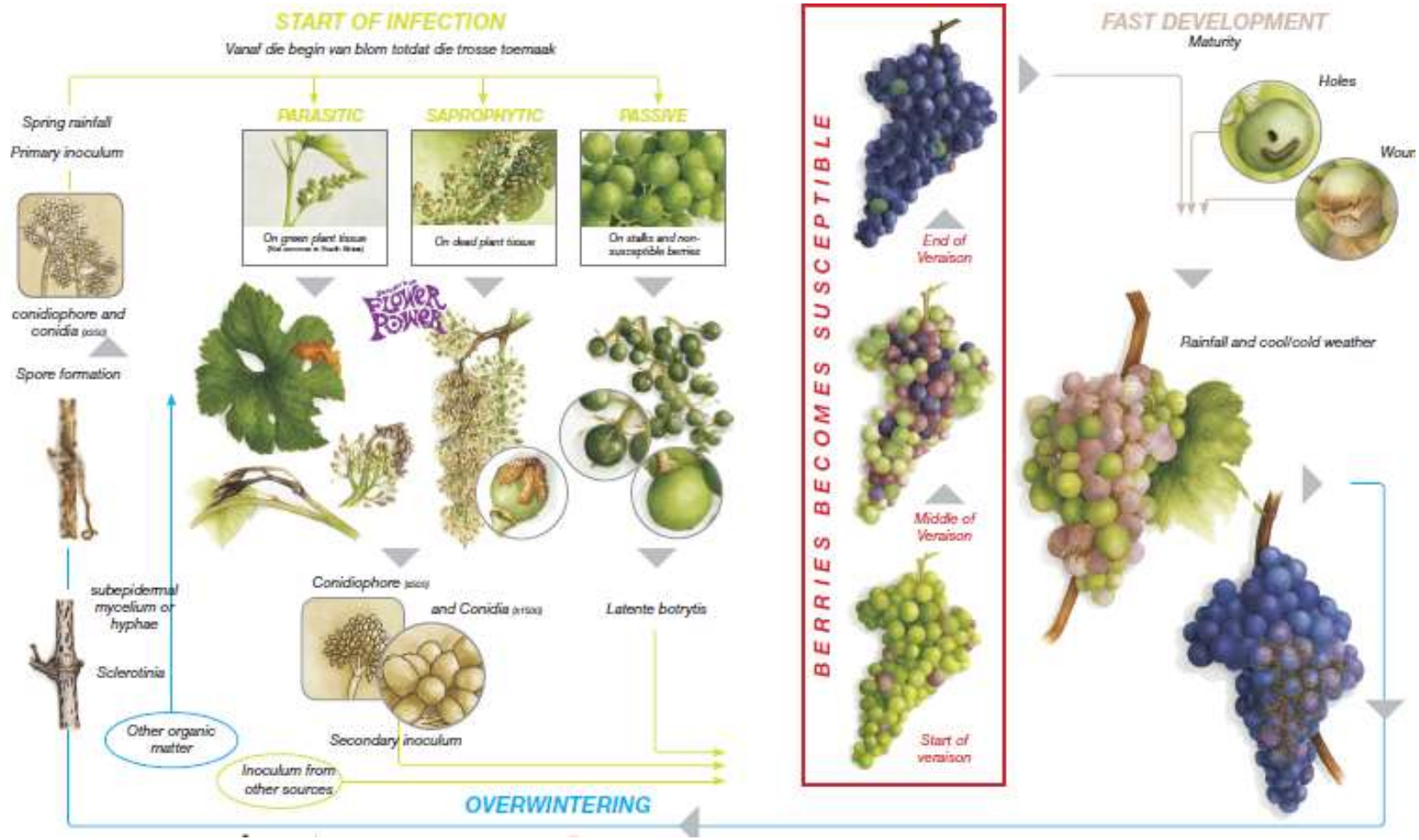
*A Low score reflect a low risk of resistance scenario

The Most Important Pathogen Risk Factors

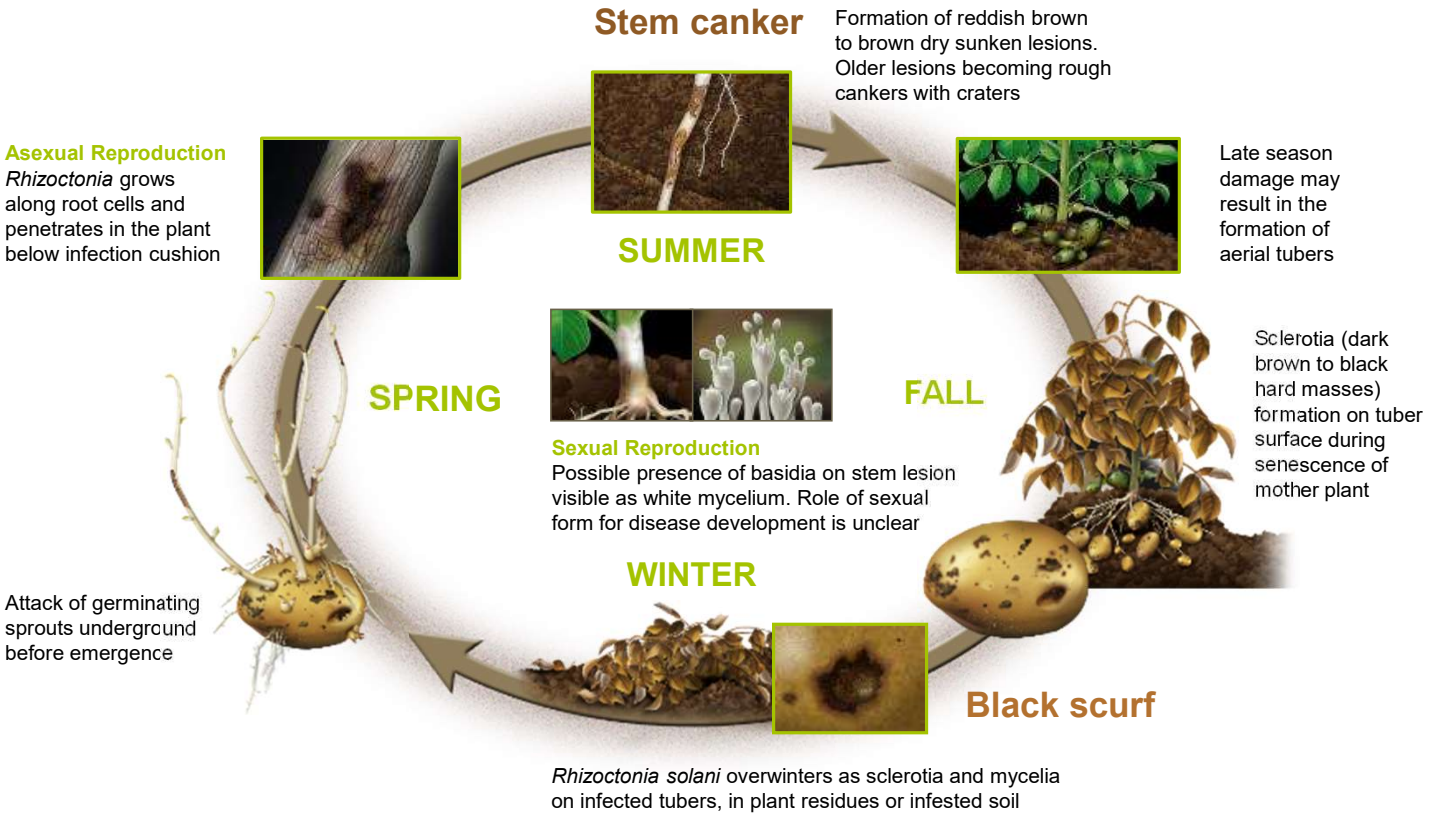
(Brent, Hollomon, & D.J, 2007):

- **Life cycle of the pathogen**; the shorter the life cycle, the more frequent the need for exposure to the fungicide and the faster the build-up of resistance.
- **Abundance of sporulation**; the more spores that are released in the crop the greater the availability of individual genomes for mutation and selection, and the faster the spread of resistant mutants.
- **Ability of spores to spread** between plants, crops, and regions.
- **Ability to infect at all crop stages**, requiring repeated fungicide treatment.
- **Occurrence of a sexual stage in the life cycle**; this could either favor or hinder resistance development.
- **Ability to mutate or to express mutant genes**: certain pathogens produce fit mutants more easily.

Life Cycle Of Botrytis – High Risk Pathogen



Life Cycle Of *Rhizoctonia* – *Low Risk*



Resistance Avoidance Strategies

- Avoid sole use of a single mode of action fungicide.
- Alternate fungicidal modes of action.
- Stick to the approved rate, sub-lethal rates will aggravate resistance.
- Introduce cropping methods to reduce disease incidence which includes:
  - Disease tolerant varieties.
  - Manipulating the crop environment (through pruning and improved air flow).
  - Optimising the crop health.

Thank you