Fungicide Resistance in Sugarbeets

Amalgamated Sugar
Pure. Sweet. Grower-Owned.

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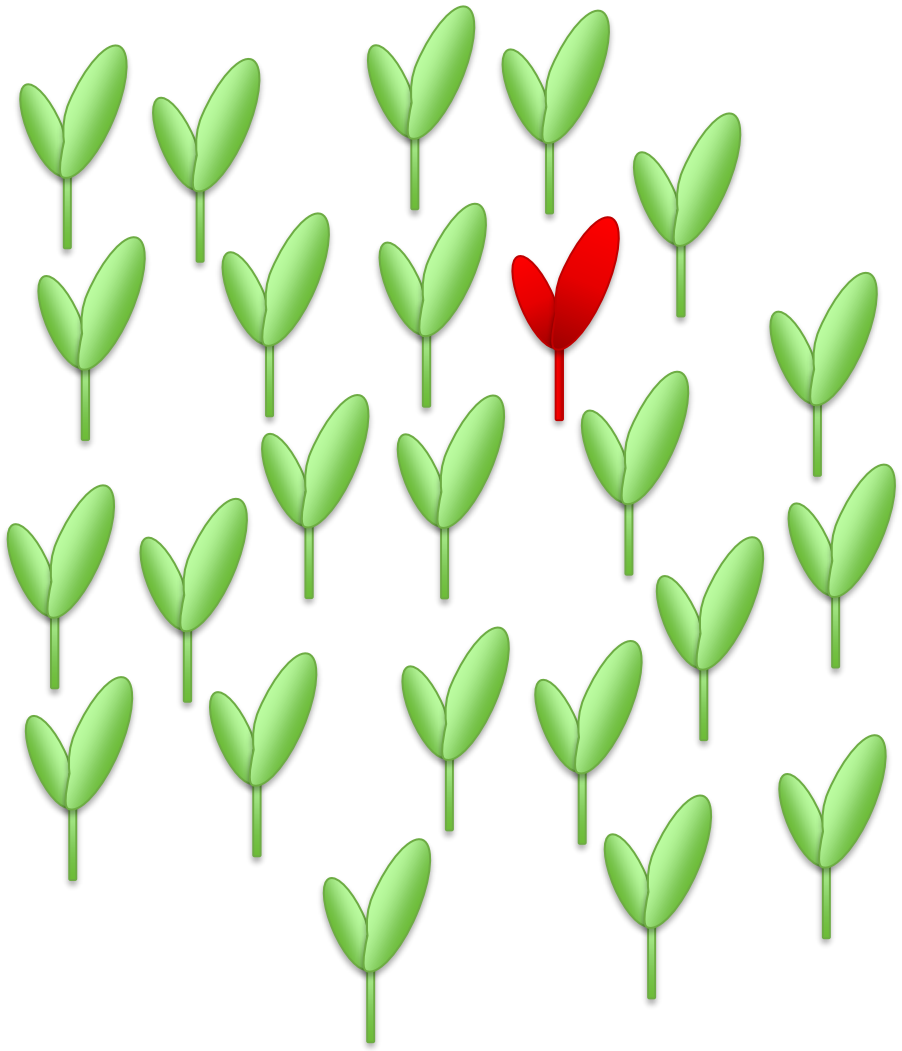
What is Resistance?



- Development is most likely linked to genetic mutation
- Mutation can be single or multi gene
- Single gene mutations to site specific pesticides are more likely to occur

Differences in Resistance?

- Resistance
  - ✓Reduction or complete loss in sensitivity of a pathogen/pest to a specific pesticide
- Reduced sensitivity
  - ✓Small reduction in sensitivity without impact on control
  - ✓Might be a precursor for resistance

Fungicide Resistance

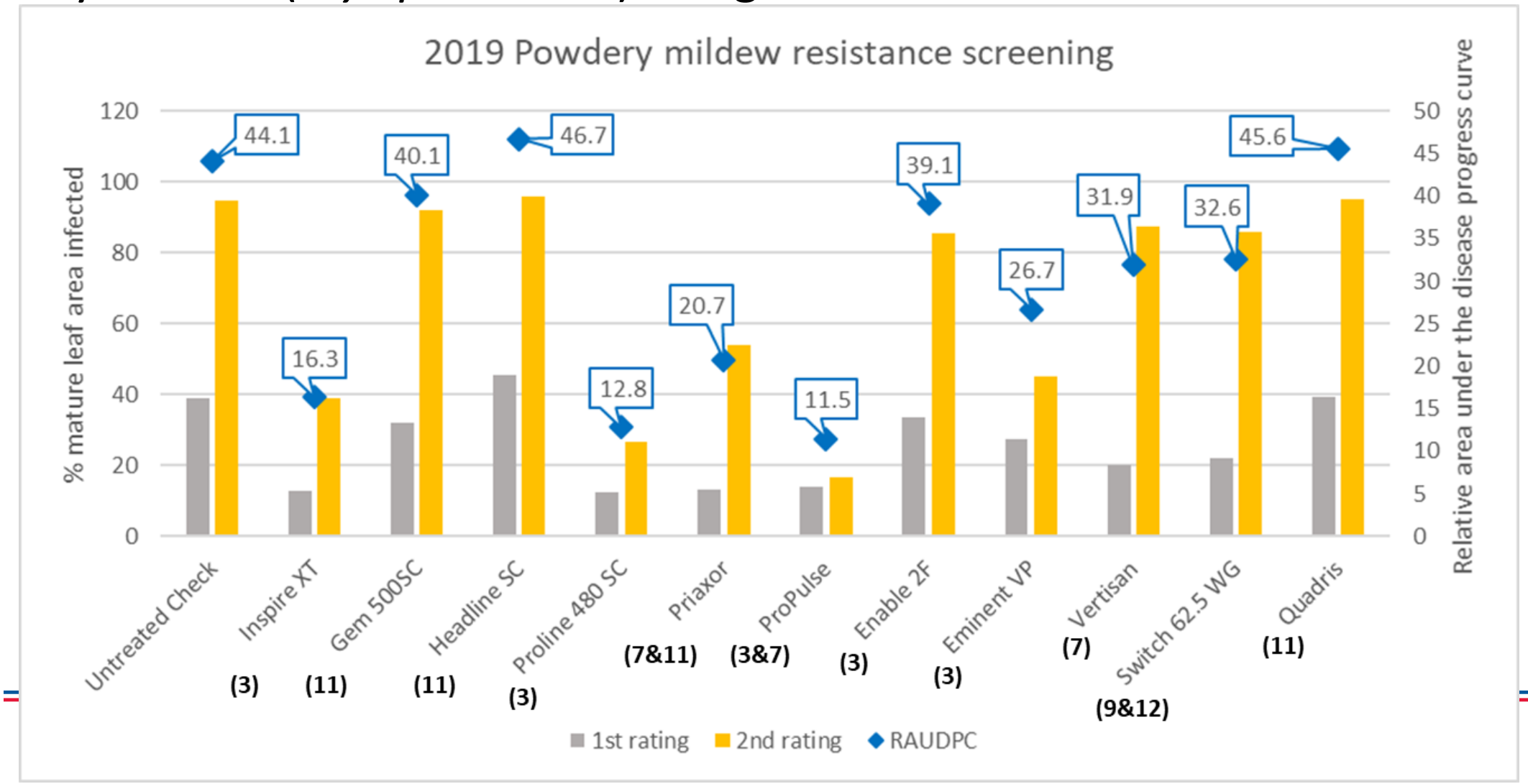
- Early blight (*Alternaria solani*) – potatoes
  - ✓Azoxystrobin, boscalid, penthiopyrad
- Pythium root rot (*Pythium ultimum*) – barley
  - ✓Seed treatment mefenoxam
- Bulb rot (*Fusarium proliferatum*) – onions
- Downy mildew (*Pseudoperonospora humuli*) – hops
  - ✓Fosetyl-Al

Fungicide Resistance

- Powdery mildew (*Erysiphe betae*) – sugarbeets
  - ✓Strobilurins (trifloxystrobin & pyraclostrobin) Group 11

Fungicide Resistance

- Powdery mildew (*Erysiphe betae*) – sugarbeets

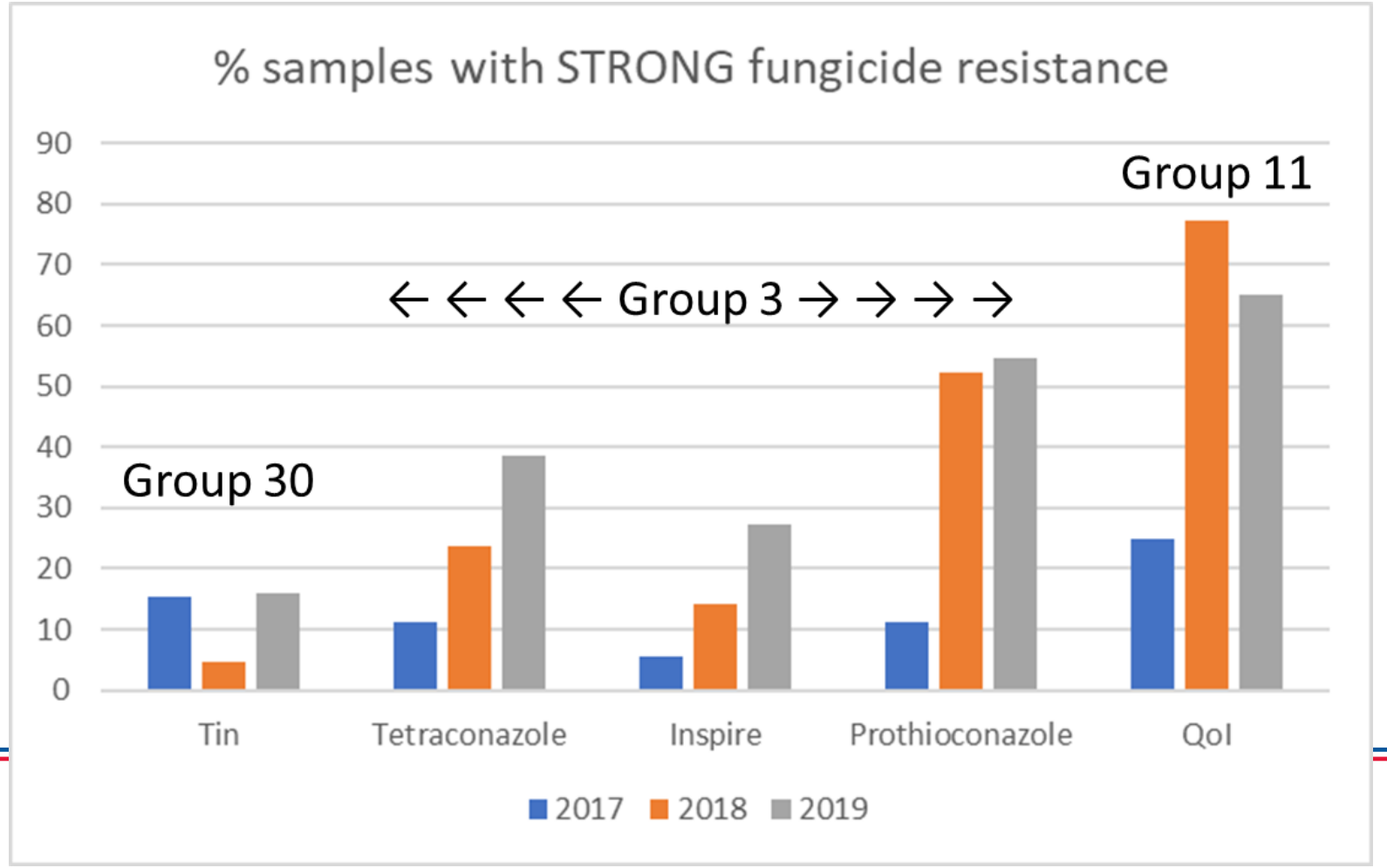


Fungicide Resistance

- Cercospora leaf spot (*Cercospora beticola*) – sugarbeets
  - ✓The better question is “What does still work?”
  - ✓Known resistance in other production areas:
    - Methyl benzimidazole carbamates (Group 1)
    - QoI fungicides (Group 11)
    - Organo tin compounds (Group 30)
    - DMI fungicides (Group 3)

Fungicide Resistance

- Cercospora leaf spot (*Cercospora beticola*) – sugarbeets
  - ✓Idaho and Oregon production area



Effects of Fungicide Resistance

- Environment
  - ✓Increase of inoculum → potentially higher disease pressure in the future
  - ✓The use of more aggressive, less selective pesticides

- Loss of confidence
  - ✓Grower → consultant
  - ✓Grower → product and/or chemical company

Effects of Fungicide Resistance

- $$$
  - ✓Reduced yield and quality → fungicides can control >90% of target diseases
  - ✓Increased control costs → less effective chemicals require more applications, more passes through the field, etc.

  - ✓Reduced pesticide sales
  - ✓Higher investments (time and money) in new products

Discovery and Development Costs of a New Crop Protection Product

Category		1995 Cost ($m.)	2010-14 Cost ($m.)
Research	Chemistry, Biology, Toxicology	72	107
Development	Formulation, Field trials, Toxicology, Environmental Chemistry	67	146
Registration		13	33
Total		**152**	**286**

P. McDougall, The Cost of New Agrochemical Product Discovery, Development and Registration in 1995, 2000, 2005-8 and 2010 to 2014. R&D expenditure in 2014 and expectations for 2019.
A Consultancy Study for CropLife International, CropLife America and the European Crop Protection Association March 2016

Crop Protection Product Discovery and Development Lead Time

	1995	2010-14
Number of years between the first synthesis and the first sale of the product	8.3	11.3

Rate of developing resistance is potentially higher than the development of new products

P. McDougall, The Cost of New Agrochemical Product Discovery, Development and Registration in 1995, 2000, 2005-8 and 2010 to 2014. R&D expenditure in 2014 and expectations for 2019.
A Consultancy Study for CropLife International, CropLife America and the European Crop Protection Association March 2016

Principles of Resistance Management and Pesticide Conservation

Resistance Management Practices

- ***Detection and monitoring***
  - ✓Scouting
    - Determine pest or pathogens → required tools for control
    - Determine onset, severity and action threshold
  - ✓Monitor loss of efficacy
    - Weed patches occur year after year and are spreading
    - Different weed species are managed but one survives
    - Pests survive applications

Resistance Management Practices cont.

- ***Detection and monitoring***
  - ✓ Assessing loss of efficacy between applications
    - Collect resistant weed plants and/or seeds
    - Collect diseased plant parts with pathogen
  - ✓Contact your local extension specialist or consultant
  - → Bio-assays for herbicides
  - → Plate assay for fungicides

Resistance Management Practices cont.

- ***Chemical diversity***
  - ✓Mode of action and FRAC code
  - ✓Also available for other pesticides

IRAC

HERBICIDE RESISTANCE ACTION COMMITTEE

FRAC
FUNGICIDE RESISTANCE ACTION COMMITTEE

FRAC LIST OF FUNGICIDE COMMON NAMES - 2012

The Common Names, MOA Code, FRAC Code and Chemical Group names included in this list are those used in the FRAC Code List and the associated List of Plant Pathogenic Organisms Resistant to Disease Control Agents.

Common Name	MOA Code	FRAC Code	Chemical Group
Acibenzolar-S-methyl	P1: benzo-thiadiazole BTH	P	benzo-thiadiazole BTH
Aldimorph	G2: Amines (morpholines) SBI Class II	5	morpholine
Ametoctradin	C8: QxI	45	triazolo-pyrimidylamine
Amisulbrom	C4: QiI	21	sulfamoyl-triazole
Anilazine	Multi-site: triazine	M8	triazine
Azaconazole	G1: DMI (SBI class 1)	3	triazole
Azoxystrobin	C3: QoI	11	methoxy-acrylates

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Source: BayerCropSciences

Resistance Management Practices cont.

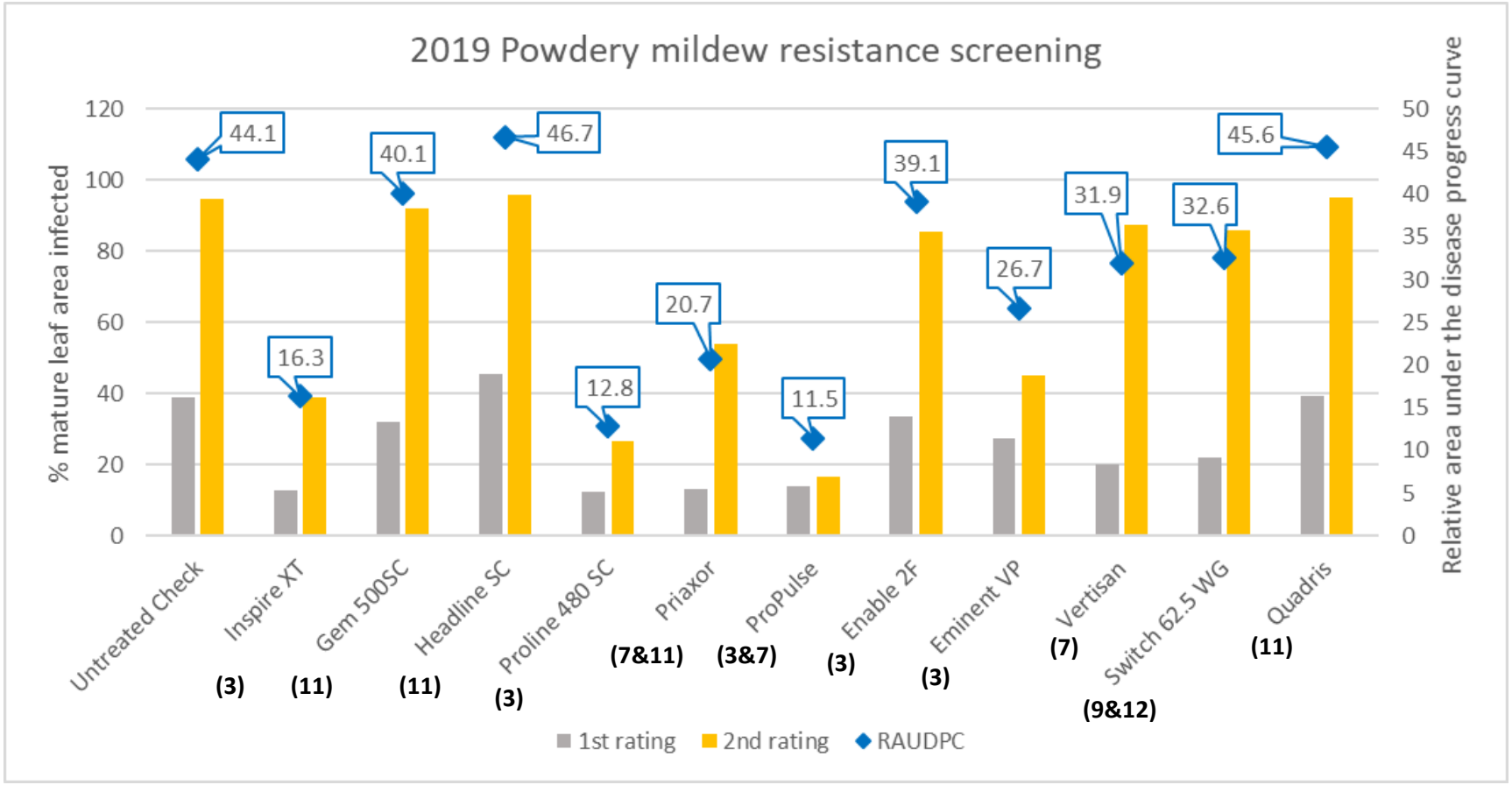
- ***Chemical diversity***
  - ✓Mode of action vs. trade names
    - Trade names and chemistries might be different but target site (mode of action) can be the same

Common name	Trade name	Chemical class	Mode of action
Trifloxistrobin	Gem 500	Oximino-acetates	QoI-fungicide (**Q**uinone **o**utside **i**nhibitor)
Pyraclostrobin	Headline SC	Methoxy-carbamates	

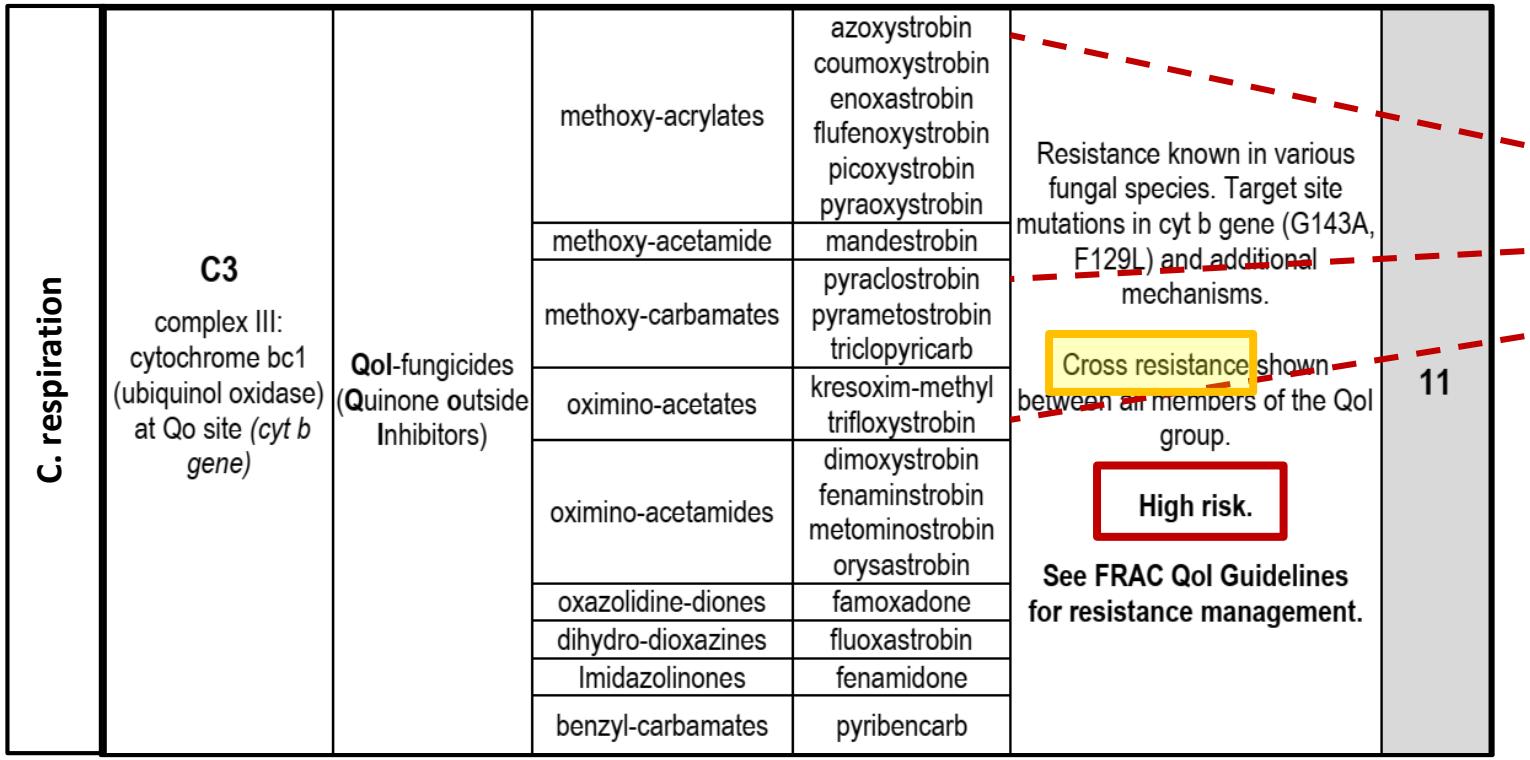
Source: BayerCropSciences

Resistance Management Practices cont.

- Powdery mildew



Resistance Management Practices cont.



C. respiration	C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site *(cyt b gene)*	**QoI**-fungicides (**Q**uinone **o**utside **I**nhibitors)	methoxy-acrylates	azoxystrobin coumoxystrobin enoxastrobin flufenoxystrobin picoxystrobin pyraoxystrobin	Resistance known in various fungal species. Target site mutations in cyt b gene (G143A, F129L) and additional mechanisms. Cross resistance shown between all members of the QoI group. **High risk.** **See FRAC QoI Guidelines for resistance management.**	11
			methoxy-acetamide	mandestrobin		
			methoxy-carbamates	pyraclostrobin pyrametostrobin triclopyricarb		
			oximino-acetates	kresoxim-methyl trifloxystrobin		
			oximino-acetamides	dimoxystrobin fenaminstrobin metominostrobin orysastrobin		
			oxazolidine-diones	famoxadone		
			dihydro-dioxazines	fluoxastrobin		
			Imidazolinones	fenamidone		
			benzyl-carbamates	pyribencarb		

Product	RAUDPC
Quadris	45.6
Headline	46.7
Gem 500 SC	40.1

Resistance Management Practices cont.

C. respiration	C2 complex II: succinate-dehydro-genase	SDHI (Succinate-dehydrogenase inhibitors)	phenyl-benzamides	benodanil flutolanil mepronil	Resistance known for several fungal species in field populations and lab mutants. Target site mutations in sdh gene, e.g. H/Y (or H/L) at 257, 267, 272 or P225L, dependent on fungal species. Resistance management required. **Medium to high risk.** **See FRAC SDHI Guidelines for resistance management.**	7
			phenyl-oxo-ethyl thiophene amide	isofetamid		
			pyridinyl-ethyl-benzamides	fluopyram		
			furan- carboxamides	fenfuram		
			oxathiin-carboxamides	carboxin oxycarboxin		
			thiazole-carboxamides	thifluzamide		
			pyrazole-4-carboxamides	benzovindiflupyr bixafen fluindapyr fluxapyroxad furametpyr inpyrfluxam isopyrazam penflufen penthiopyrad sedaxane		
			N-cyclopropyl-N-benzyl-pyrazole-carboxamides	isoflucypram		
			N-methoxy-(phenyl-ethyl)-pyrazole-carboxamides	pydiflumetofen		
			pyridine-carboxamides	boscalid		
			pyrazine-carboxamides	pyraziflumid		

Product	RAUDPC
ProPulse (17.4%)	11.5
Priaxor (14.33%)	20.7
Vertisan	31.9

Resistance Management Practices cont.

G. Sterol biosynthesis in membranes	G1 C14- demethylase in sterol biosynthesis *(erg11/cyp51)*	**DMI**-fungicides (**De**Methylation **I**nhibitors) (SBI: Class I)	piperazines	triforine	There are big differences in the activity spectra of DMI fungicides. Resistance is known in various fungal species. Several resistance mechanisms are known incl. target site mutations in cyp51 (erg 11) gene, e.g. V136A, Y137F, A379G, I381V; cyp51 promotor; ABC transporters and others. Generally wise to accept that cross resistance is present between DMI fungicides active against the same fungus. DMI fungicides are Sterol Biosynthesis Inhibitors (SBIs), but show no cross resistance to other SBI classes. **Medium risk.** **See FRAC SBI Guidelines for resistance management.**	3
			pyridines	pyrifenox pyrisoxazole		
			pyrimidines	fenarimol nuarimol		
			imidazoles	imazalil oxpoconazole pefurazoate prochloraz triflumizole		
			triazoles	azaconazole bitertanol bromuconazole cyproconazole difenoconazole diniconazole epoxiconazole etaconazole fenbuconazole fluquinconazole flusilazole flutriafol hexaconazole imibenconazole ipconazole metconazole myclobutanil penconazole propiconazole simeconazole tebuconazole tetraconazole triadimefon triadimenol triticonazole		
			triazolinthiones	prothioconazole		

Product	RAUDPC
Enable 2F	39.1
Inspire XT (22.8% each)	12.8
Eminent VP	26.7
Proline 480 SC	12.8
ProPulse (17.4%)	11.5

Resistance Management Practices cont.

- ***Chemical diversity***
  - ✓Consider crop rotation
    - Many crops have chemicals that act on the same MoA (→ Headline)
    - Herbicide resistant crops increase the use of a single MoA

    →Use of single MoA increases chance of resistant weeds

Resistance Management Practices cont.

- ***Companion/partner compounds***
  - ✓Companion compounds will reduce selection pressure and potentially control resistant organisms → Enhanced "Life" of single moa products

  - ✓Older, multi-site compounds with low risk for resistance
  - ✓Unrelated single-site compounds

M. Chemicals with multi-site activity				
inorganic (electrophiles)	inorganic	copper (different salts)	Low risk	M01
inorganic (electrophiles)	inorganic	sulphur		M02

Product
Badge (Cercospora)
Micronized Sulfur (Powdery Mildew)

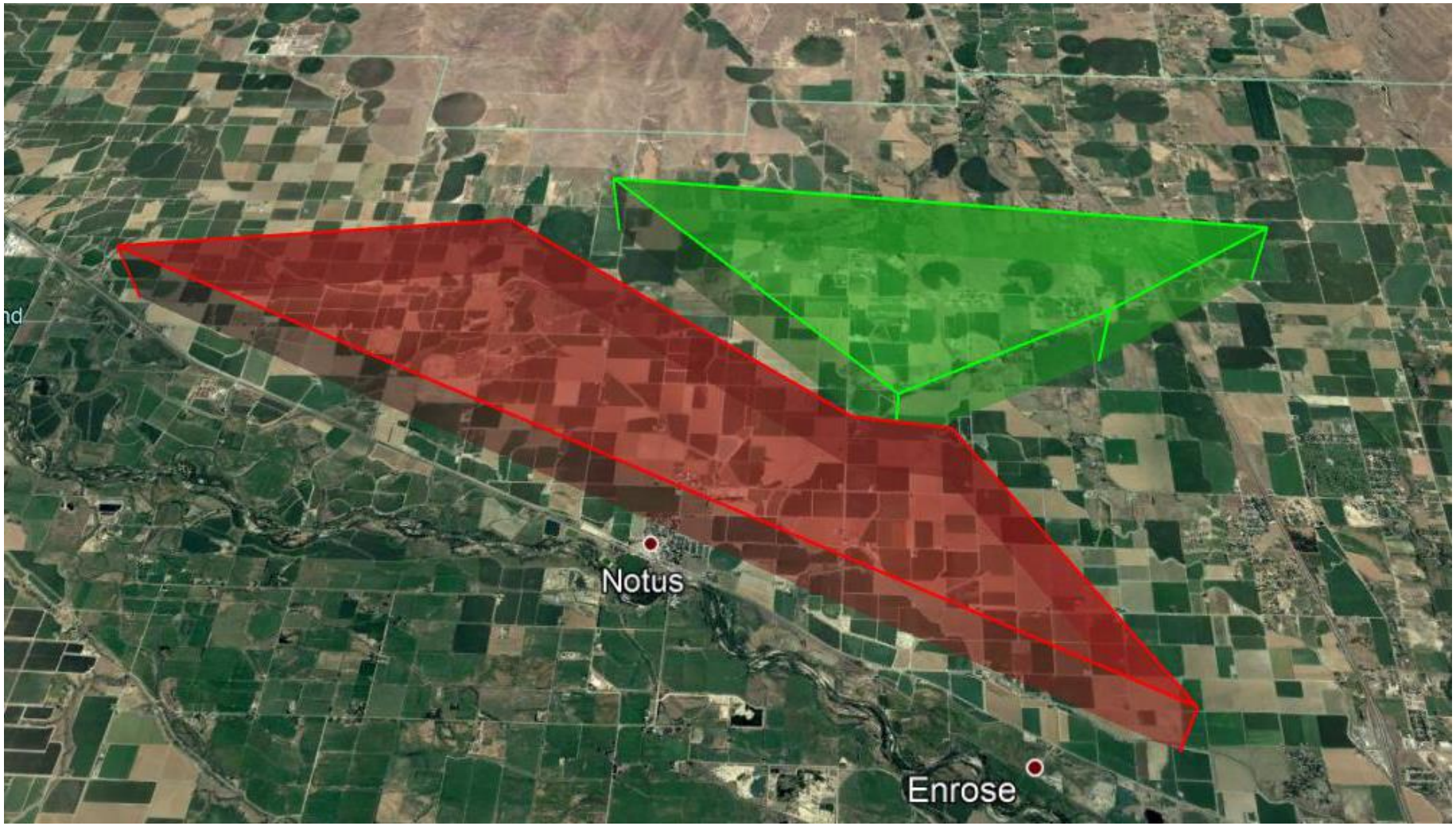
Resistance Management Practices cont.

- ***Good stewardship***
  - ✓Apply only when strictly necessary
    - → No “cosmetic” applications
    - → Spray when all other tools are exhausted, e.g. tolerant varieties
    - →Never spray as “stand alone” treatment
  - ✓Restrict number of “at risk” treatments per season
    - →Survey data can help to identify “at risk” or ineffective products
    - →“Heat” maps

Resistance Management Practices cont.

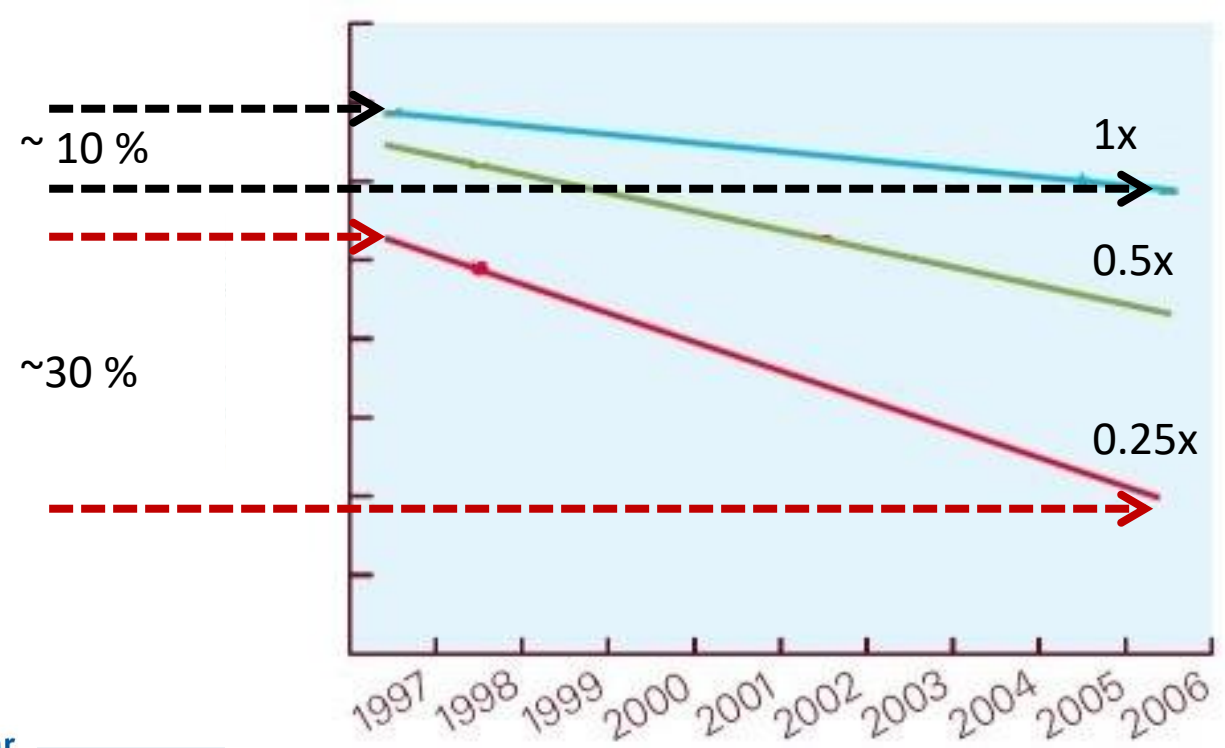
Cercospora Resistance Level

- QoI High
- QoI Low



Resistance Management Practices cont.

- ***Good stewardship***
  - ✓Maintain recommended dose
    - → Reduced doses can enhance the development of resistance



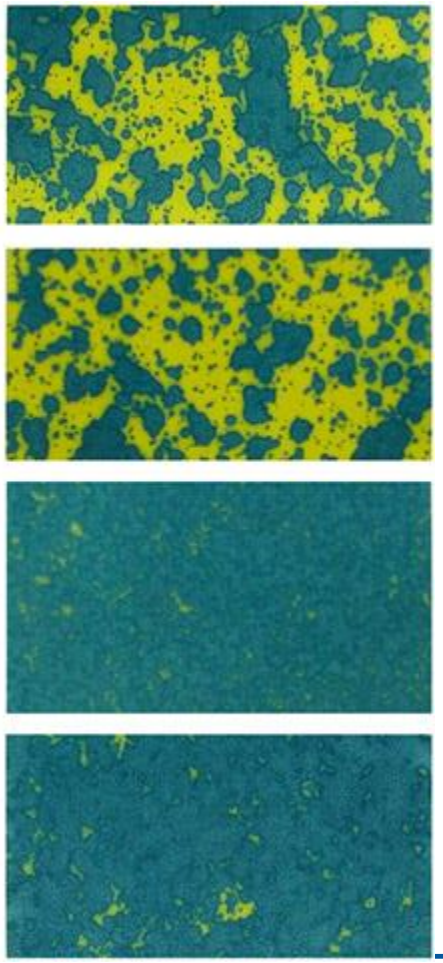
- FRAC 3 (Triazole)
- Leaf blotch of wheat
- 1x, 0.5x, 0.25x of Triazole

Resistance Management Practices cont.

- ***Good stewardship***
  - ✓Application timing
    - Apply pesticides at the right developmental stage of the pest
    - Avoid eradicative use

Resistance Management Practices cont.

- ***Good stewardship***
  - ✓Coverage & spray volume
    - Use sufficient carrier to guarantee good coverage
    - Excellent coverage for contact or protective pesticides is a **MUST**
    - Systemic products are more “forgiving”
    - Calibrate equipment



Additional Information

University of Idaho
College of Agricultural and Life Sciences

CIS 1130

Managing Fungicide Resistance

by John J. Gallian, Jeffrey S. Miller, and Phillip Nolte

INTRODUCTION—
All Idaho crops are at risk

Resistance to fungicides in plant pathogen populations is one of the most significant problems in chemical disease management. Fungicide resistance may be defined as the stable, inheritable adjustment by a pathogen to a fungicide, resulting in reduced sensitivity of the pathogen to the fungicide.

The use of fungicides will continue to play a major role in disease management for the foreseeable future, so development of strategies to manage fungicide resistance is necessary to maintain a useful arsenal of the most effective fungicides. Such strategies are required if we are to prolong the useful life of these disease control agents.

Resistance to formerly effective fungicides has been reported from almost all crops where fungicides are used. All major crops in Idaho are at risk. Although this publication will focus on fungicide resistance management in sugarbeet and potato production, the principles are applicable to all crops.

The rate of resistance evolution in the fungi can be attributed to several factors that can act separately or together. The

Late blight of potato caused by *Phytophthora infestans* shows severely diseased plants with no fungicide treatment compared with an effective fungicide treatment. It's not hard to guess which is which.


Thank you…..
Questions ???