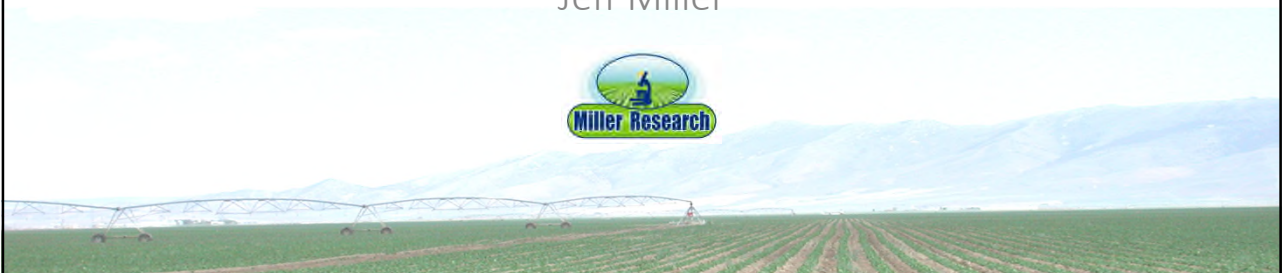


Resisting Resistance

Avoiding the Development of Fungicide Resistance

Jeff Miller



**Cruise
buffet
was AMAZING!**



The Rise of Superweeds—and What to Do About It (2013)

December 2013

NBC NEWS

SECTIONS

NIGHTLY NEWS

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See how herbicide-resistant genetically-modified seeds helping to create a new breed of "superweeds." © Seth Perlman / ASSOCIATED PRESS

SHARE

First came "Frankenfood." Now we've got "superweeds."

superweeds



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Superweeds: A Frightening Reality

The New York Times Magazine <https://www.nytimes.com/2021/08/18/magazine/superweeds-monsanto.html>



Attack of the Superweeds

Herbicides are losing the war — and agriculture might never be the same again.



UNIVERSITY OF
GEORGIA

February 8, 2022

Agricultural fungicides may be driving antimicrobial resistance

Drugs used to treat life-threatening fungal infections are becoming less effective at fighting certain fungi

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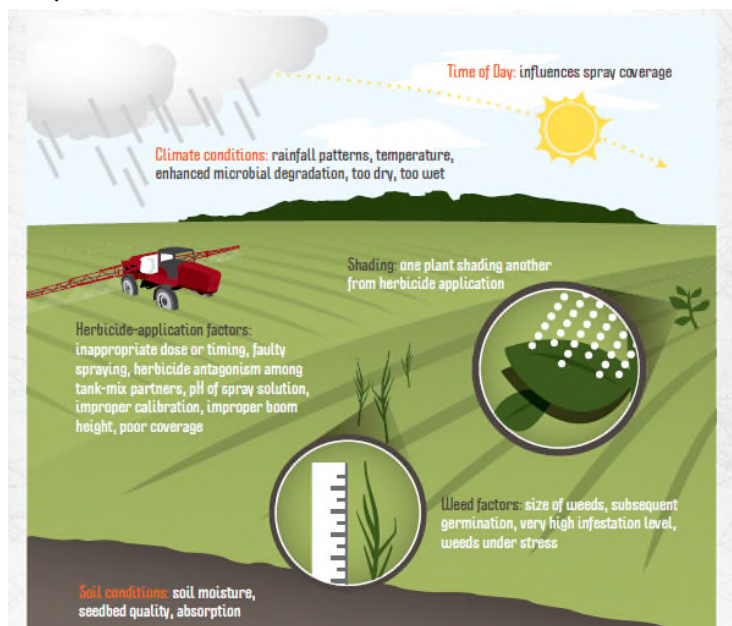
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Fungicide resistance is noticed

Researchers ask cherry growers to temporarily avoid two cherry powdery mildew fungicide groups.

Ross Courtney // March 9, 2021

Not all pesticide “failure” is due to resistance...



What is Pesticide Resistance?

The heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to label recommendation for that pest species. (IRAC, emphasis added)



Pesticide Resistance

- Influenced by:
 - Biology of pathogen/pest
 - Nature of pesticide (protectant vs. systemic)
 - Pesticide use patterns
- Cross resistance = Development of resistance to one chemical also confers resistance to another chemical.

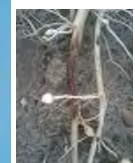


Risk of Resistance – Potato Pathogens

- High risk
 - *Alternaria alternata* (Brown spot)
- Medium risk
 - *Alternaria solani* (Early blight)
 - *Phytophthora infestans* (Late blight)
- Low risk
 - *Fusarium* sp. (Dry rot)
 - *Helminthosporium solani* (Silver scurf)
 - *Rhizoctonia* sp. (Rhizoctonia canker and black scurf)
 - *Sclerotinia sclerotiorum* (White mold)

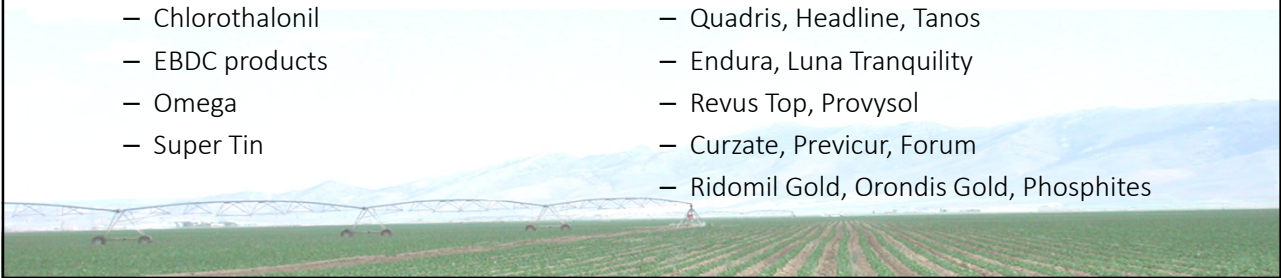


Courtesy P. Wharton



Protectant vs. Systemic Fungicides

- Protectant
 - Attack multiple sites in pest
 - Protect where applied
 - Not as effective as systemics
 - Risk of resistance low (none?)
- Examples
 - Chlorothalonil
 - EBDC products
 - Omega
 - Super Tin
- Systemic
 - Target one or few sites in pest
 - Can move within the plant
 - Highly effective
 - Risk of resistance is moderate to high
- Examples
 - Quadris, Headline, Tanos
 - Endura, Luna Tranquility
 - Revus Top, Provysol
 - Curzate, Previcur, Forum
 - Ridomil Gold, Orondis Gold, Phosphites



Resources for Managing Pesticide Resistance



Weed Science Society of
America



Pesticide Group Numbers

- Members of same group target pests in a similar manner.
 - Mode of action
- Resistance to one group member may confer resistance to other group members.
 - Cross resistance
- Effective tool for helping rotate active ingredients.

ADMIRE® PRO™
SYSTEMIC PROTECTANT

GROUP 4A INSECTICIDE

Prowl® H20

Herbicide

Pendimethalin Group 3 Herbicide

GROUP 3 40 FUNGICIDES

RevusTop®



C. respiration

7

C2
complex II:
succinate-dehydro-
genase

SDHI
(Succinate-
dehydrogenase
inhibitors)

phenyl-benzamides	benodanil flutolanil mepronil	
phenyl-oxo-ethyl thiophene amide	isofetamid	
pyridinyl-ethyl- benzamides	fluopyram	
furan- carboxamides	fenfuram	
oxathiin- carboxamides	carboxin oxycarboxin	
thiazole- carboxamides	thiifuzamide	
pyrazole-4- carboxamides	benzovindiflupyr bixafen fluidapyr fluxapyroxad furametpyr inpyrfluxam isopyrazam penflufen penthiopyrad sedaxane	Resistance known for several fungal species in field populations and lab mutants. Target site mutations in sdh gene, e.g. H1Y (or H1L) at 257, 267, 272 or P225L, dependent on fungal species. Resistance management required.
N-cyclopropyl-N- benzyl-pyrazole- carboxamides	isoflucypram	Medium to high risk
N-methoxy-(phenyl- ethyl)-pyrazole- carboxamides	pydiflumetofen	See FRAC SDHI Guidelines for resistance management.
pyridine- carboxamides	boscalid	
pyrazine- carboxamides	pyraziflumid	

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Miravis Prime®

Endura®

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL OR BIOLOGICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE			
sterol biosynthesis in membranes	3 G1 C14- demethylase in sterol biosynthesis (erg11/cyp51)	DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	piperazines	triforine	There are big differences in the activity spectra of DMI fungicides.	3			
			pyridines	pyrifenox pyrisoxazole					
			pyrimidines	fenarimol nuarimol					
			imidazoles	imazalil oxpoconazole pefurazate prochloraz triflumizole	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.				
			triazoles	azaconazole bitalan bromuconazole cyproconazole difenoconazole diniconazole epoxiconazole etaconazole fenbuconazole fluquinconazole flusilazole flutriafol hexaconazole imibenconazole ipconazole mefentrifluconazole metconazole myclobutanil penconazole propiconazole simeconazole tebuconazole tetraconazole triadimefon triadimenol triticonazole prothioconazole	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.				
			triazolinthiones		Medium risk.				
					See FRAC SBI Guidelines for resistance management.				





Selected Foliar Fungicides for Potato

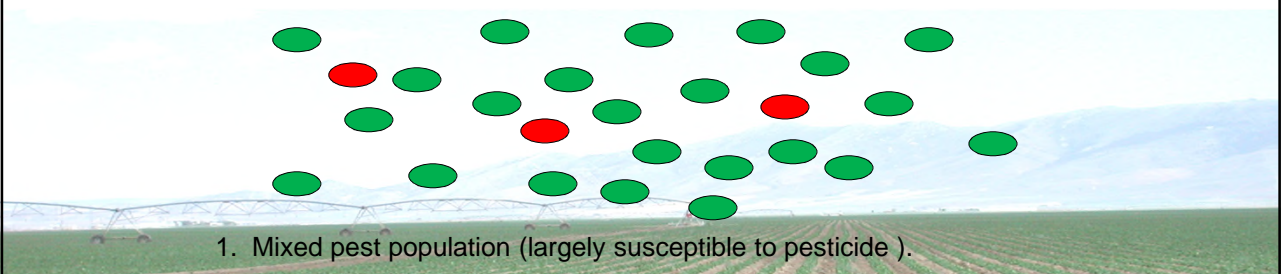
Product	7	3	11	Other	M
Bravo, Equus					Chlorothalonil
Dithane, Manzate					Mancozeb
Rovral				Iprodione (2)	
Super Tin				Tri-phenyl tin (30)	
Quadris Headline			Azoxystrobin Pyraclostrobin		
Endura	Boscalid				
Revus Top		Difenoconazole		Mandipropamid (40)	
Luna Tranquility	Fluopyram			Pyrimethanil (9)	
Priaxor	Fluxapyroxad		Pyraclostrobin		
Amistar Top		Difenoconazole	Azoxystrobin		
Quash		Metconazole			
Miravis Prime	Pydiflumetofen			Fludioxonil (12)	
Provysol		Mefentrifluconazole			

So how does pesticide resistance develop?



Development of Pesticide Resistance

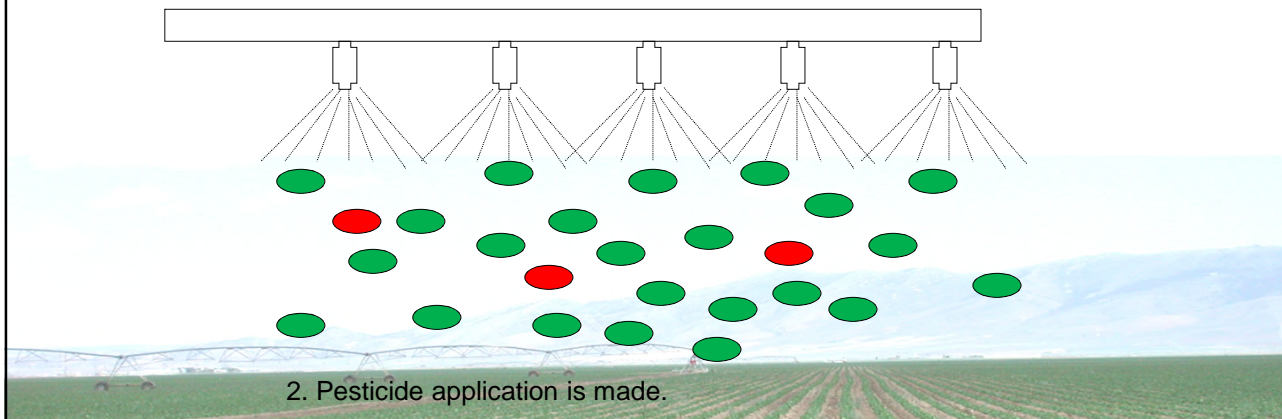
Scenario 1



1. Mixed pest population (largely susceptible to pesticide).

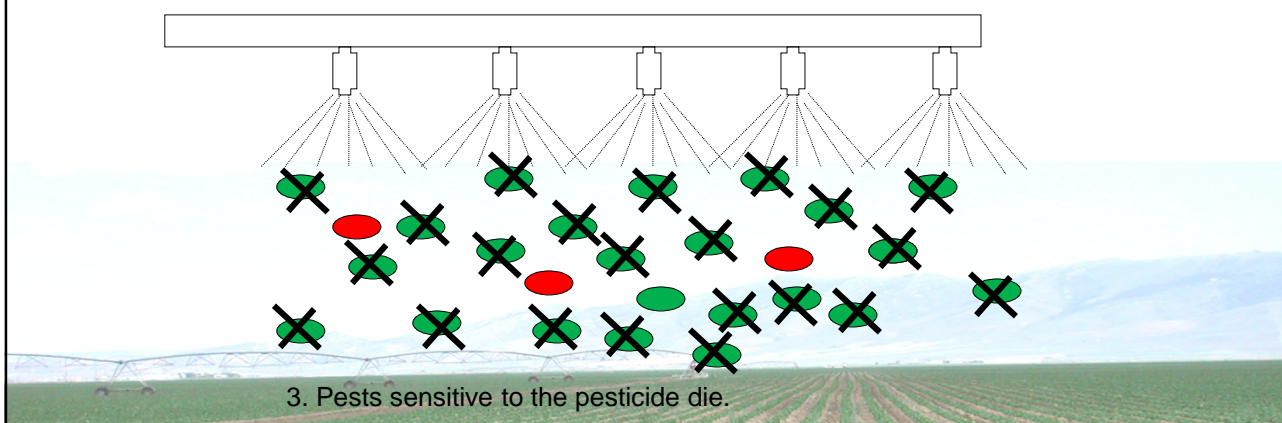
Development of Pesticide Resistance

Scenario 1



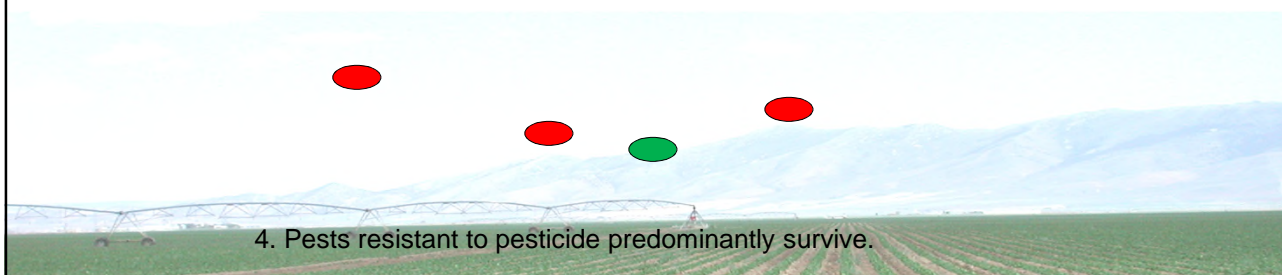
Development of Pesticide Resistance

Scenario 1



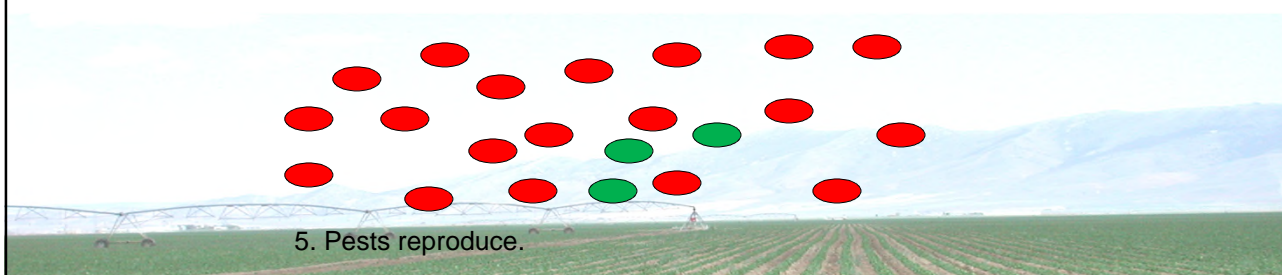
Development of Pesticide Resistance

Scenario 1



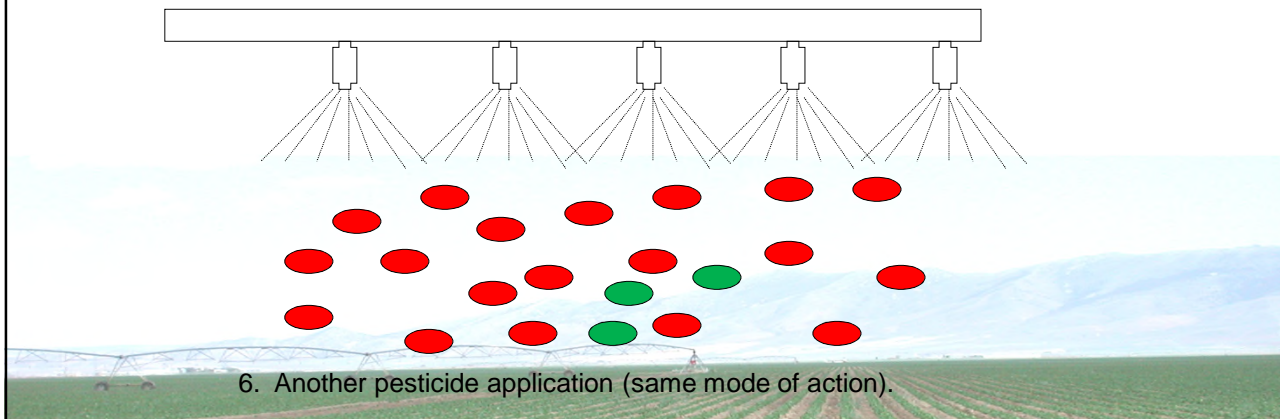
Development of Pesticide Resistance

Scenario 1



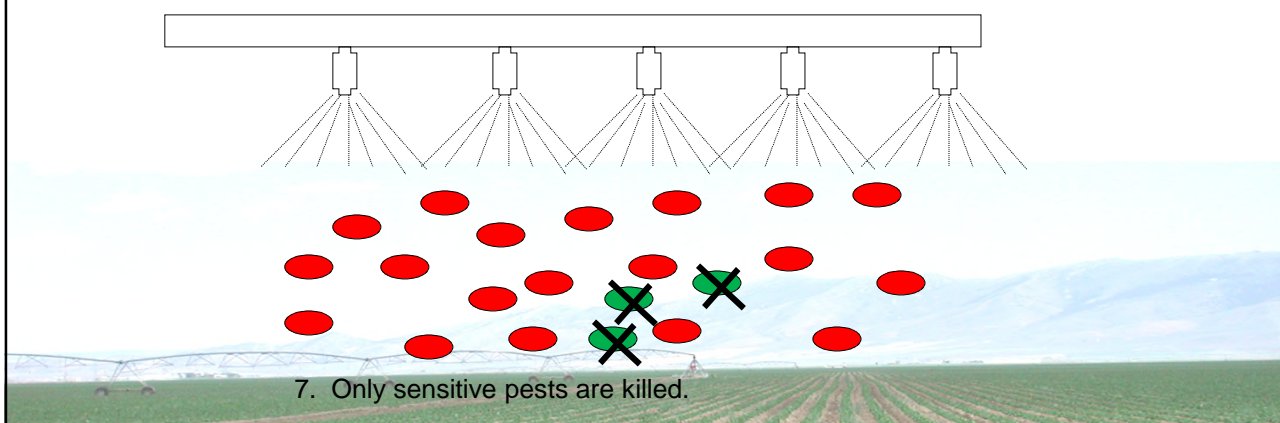
Development of Pesticide Resistance

Scenario 1



Development of Pesticide Resistance

Scenario 1



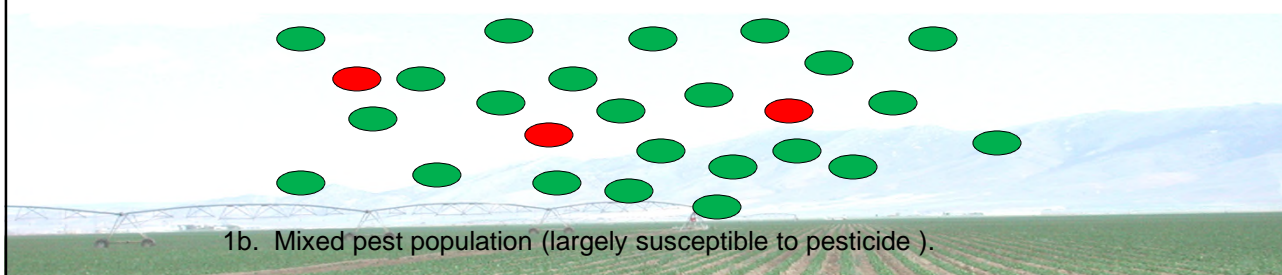
Development of Pesticide Resistance

Scenario 1



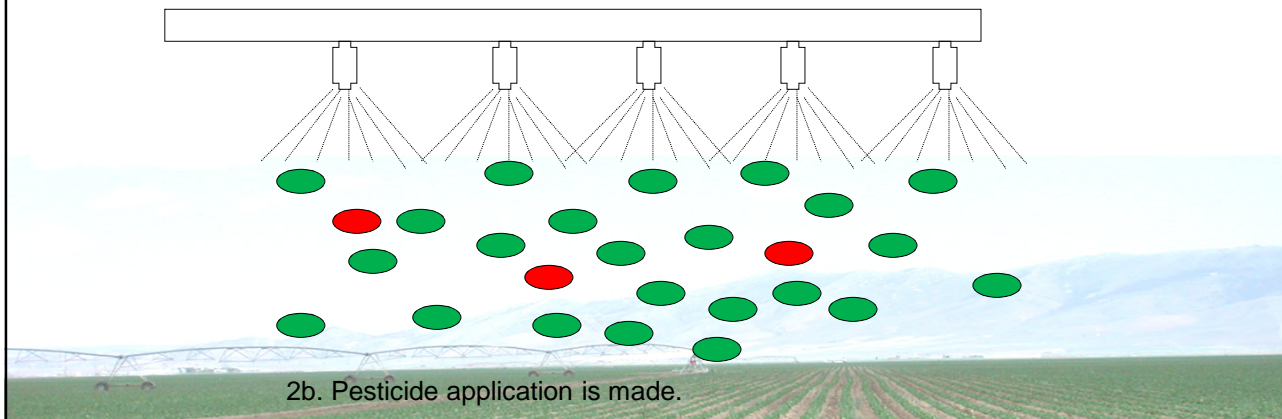
Development of Pesticide Resistance

Scenario 2



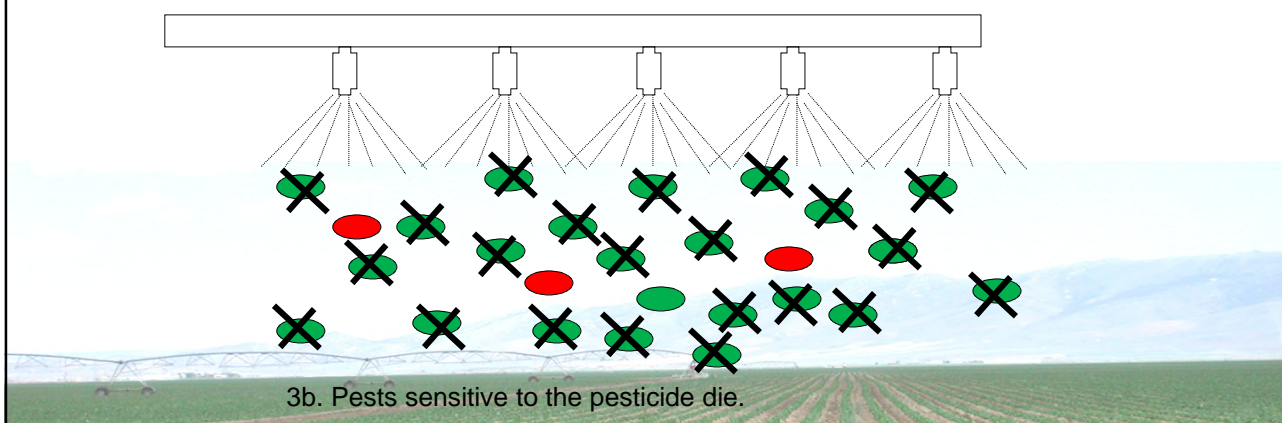
Development of Pesticide Resistance

Scenario 2



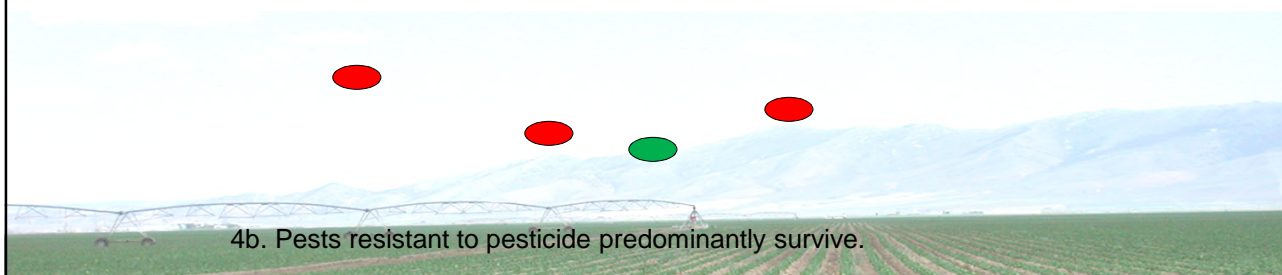
Development of Pesticide Resistance

Scenario 2



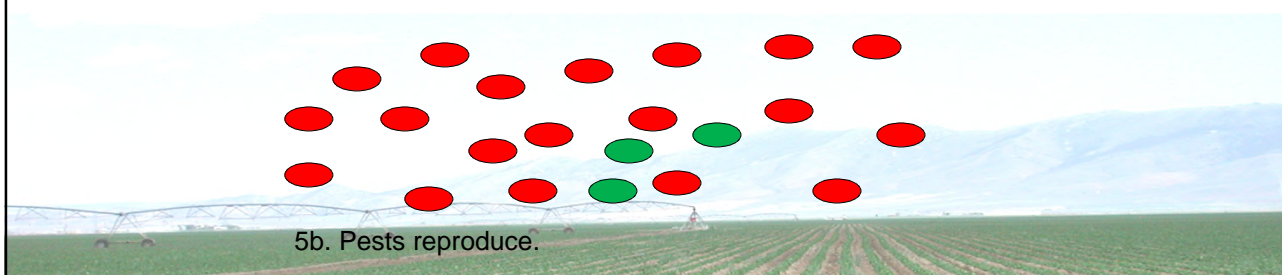
Development of Pesticide Resistance

Scenario 2



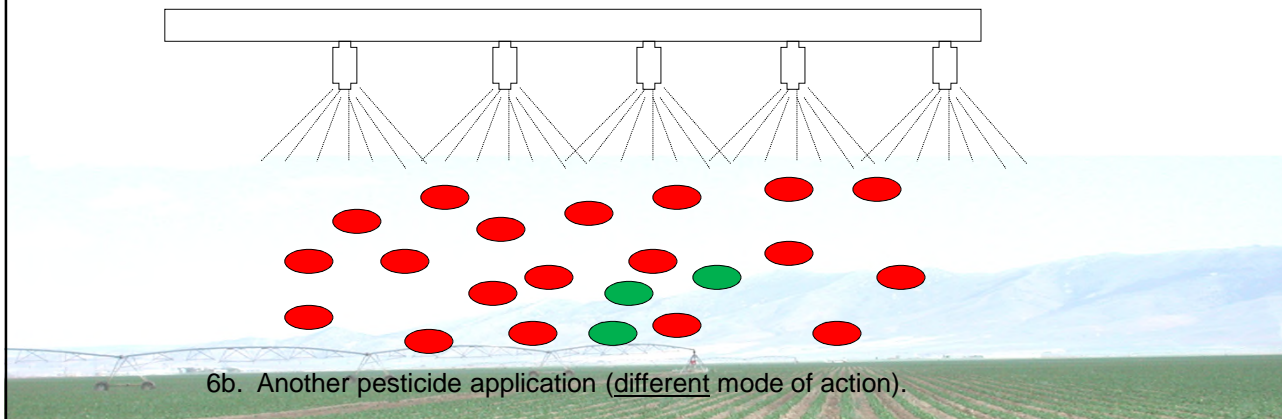
Development of Pesticide Resistance

Scenario 2



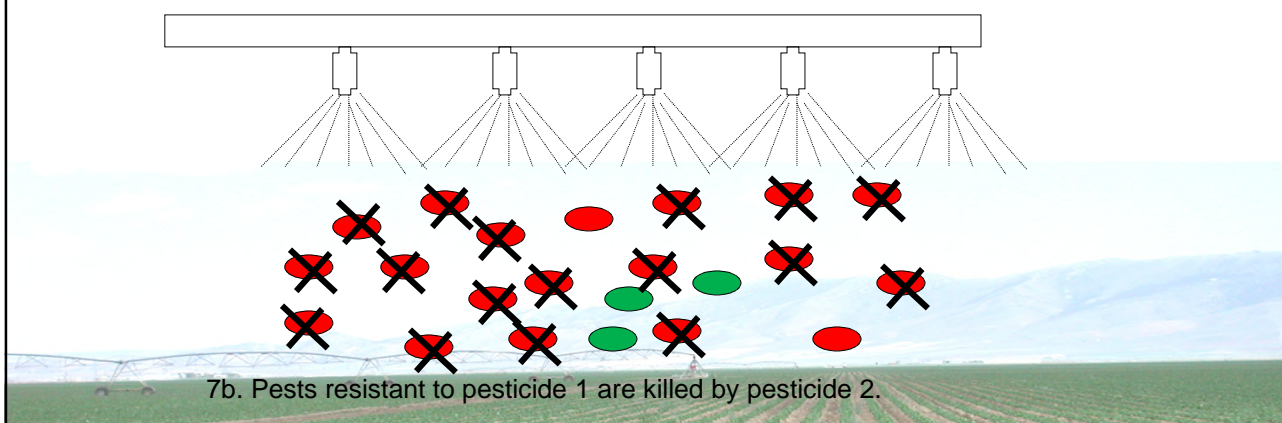
Development of Pesticide Resistance

Scenario 2



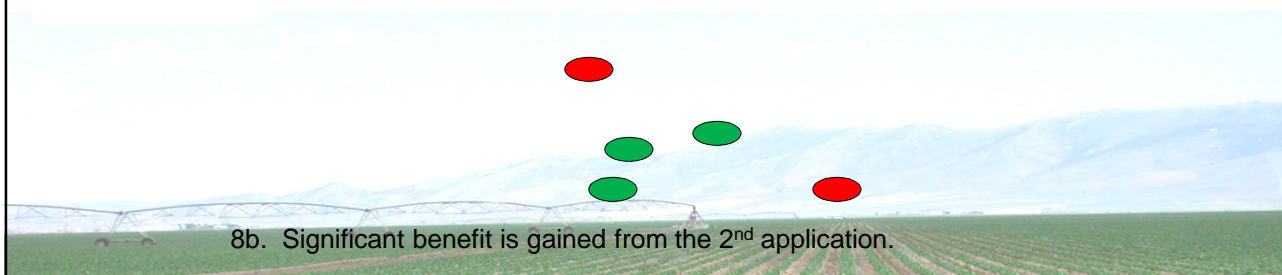
Development of Pesticide Resistance

Scenario 2

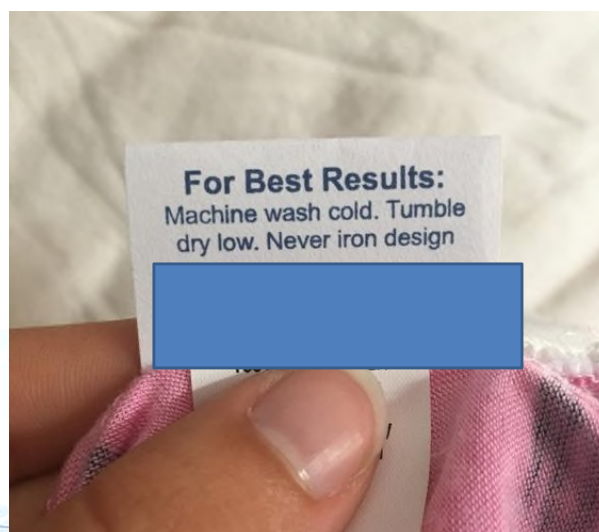


Development of Pesticide Resistance

Scenario 2



Providing good advice...



From ruinmyweek.com

RESISTANCE MANAGEMENT

AZOXYSTROBIN GROUP 11 FUNGICIDE

From the Quadris label:

Quadris contains Azoxystrobin, a Group 11 fungicide. Any fungal population may contain individuals naturally resistant to Azoxystrobin and other Group 11 fungicides. A gradual or total loss of pest control may occur over time if these fungicides are used repeatedly on the same fields. Appropriate resistance-management strategies should be followed. Conform to resistance management strategies established for the crop and use area when using this product. Consult your local or State agricultural authorities for resistance management strategies that are complementary to those in this label.

Syngenta encourages responsible resistance management to ensure effective long-term control of the fungal diseases on this label.

Follow the crop specific resistance management specifications in the directions for use.

To delay fungicide resistance, take one or more of the following steps:

- Rotate the use of Azoxystrobin or other Group 11 fungicides (strobulurins, including pyraclostrobin and trifloxystrobin) within a growing season sequence with different fungicide groups that control the same pathogens.
- Use tank mixtures with fungicides from a different group that are equally effective on the target pest when such use is permitted. Use at least the minimum application rate as labeled by the manufacturer.
- Adopt an integrated disease management program for fungicide use that includes scouting, uses historical information related to pesticide use, and crop rotation, and which considers host plant resistance, impact of environmental conditions on disease development, disease thresholds, as well as cultural, biological and other chemical control practices.
- Where possible, make use of predictive disease models to effectively time fungicide applications. Note that using predictive models alone is not sufficient to manage resistance.
- Monitor treated fungal populations for resistance development.
- Contact your local extension specialist or certified crop advisor for any additional pesticide resistance-management and/or IPM recommendations for specific crops and pathogens.
- For further information or to report suspected resistance contact Syngenta representatives at 1-800-334-9481 or visit the Fungicide Resistance Action Committee (FRAC) on the web at www.frac.info. You can also contact your pesticide distributor or university extension specialist to report resistance.

If there are no resistance management directions on the number of applications in the directions for use, then follow the directions in the table below.

If planned total number of fungicide applications per crop is:	1	2	3	4	5	6	7	8	9	10	11	12
Specified Solo QoI fungicide sprays	1	1	2	2	2	2	2	3	3	3	3	4
Specified QoI fungicide sprays in mixture (tank-mix or formulated)	1	2	2	2	2	3	3	4	4	5	5	6

In situations requiring multiple sprays, develop season long spray programs for Group 11 (QoI) fungicides. In crops where two sequential Group 11 fungicide applications are made, alternate with two or more applications of a fungicide that is not in Group 11. If more than 12 applications are made, observe the following guidelines:

- When using a QoI fungicide as a solo product, the number of applications must be no more than $\frac{1}{3}$ (33%) of the total number of fungicide applications per season.

How do you avoid fungicide resistance?

1. Apply fungicides in a preventative, not curative manner.
 - Avoid “rescue” treatments
2. Apply products at the recommended rate.
3. Rotate products – use different fungicide groups.
 - Reduce the overall use of the fungicide class in question
4. Tank mix two different active ingredients for the target pathogen.

