Weed Control and Resistance Management

Bob Johnson

UCCE Farm Advisor Intern

Tree and vine weed science team

- **Brad Hanson** - Cooperative Extension Weed Specialist
  - Chemical weed control, herbicide resistance, herbicide fate, methyl bromide alts
- **Lynn Sosnoskie**, Ph.D. (Project Scientist)
  - Weed biology, ecology and resistance management
- **Sorkel Kadir**, Ph.D. (Visiting Scientist)
  - Herbicide fate in plants and soil
- **Seth Watkins,** B.Sc. (Research Technician)
  - Orchard and vineyard herbicide efficacy and crop safety evaluations
- **Marcelo Moretti**, M.Sc. (Ph.D. Student)
  - Mechanisms of resistance in glyphosate- and paraquat-resistant Conyza, herbicide field performance, control of herbicide resistant biotypes
- **Andrew (Bob) Johnson**, B.Sc. (M.S. Student)
  - Non-fumigant approaches for orchard re-plant issues, herbicide performance
- **UCCE and industry cooperators**

Orchard Floor Management

- Vital to the health, vigor, success of an Walnut orchard
  - Condition at harvest
  - Reduce competition with trees
  - Allow proper functioning of sprinklers
  - Infiltration and runoff
  - Disease/ Pest management
  - Orchard accessibility

Before planting

- Survey weeds several times before you cultivate
- Surveys in late winter, summer and fall provide full spectrum of species
- Established perennials (bermuda grass, johnson grass) easier to control before planting with multiple cultivations
- Can apply or incorporate pre-emergent herbicide before planting

Vegetated Middles

- Allows access under wet conditions
- Improves infiltration
- Reduces runoff
- Can be planted cover or resident weedy cover
  - Mowing must be timely
  - Mow when weeds reach 6-8 inches

Sprayed Strip

- Maintained relatively weed free typically with herbicides
  - **Easier to move nuts out of tree row at harvest**
  - **Weeds compete for water and nutrients, especially trees on drip or micro-sprinklers**
  - Uncontrolled weeds can harbor vertebrate pests
  - Less weeds means lower humidity around trunks so less chance of crown disease

An Effective Herbicide Program

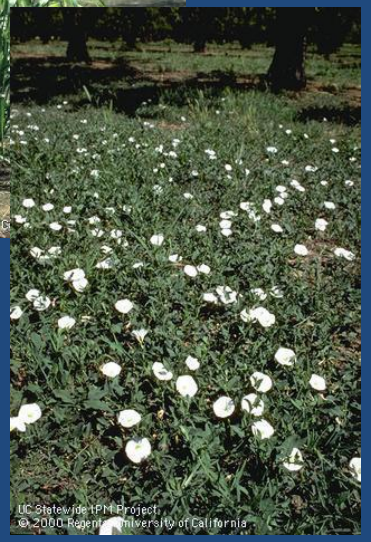
- Correctly identify weed problem(s)
- Select registered herbicide(s) that match the weed spectrum and address YOUR weeds
- Properly apply herbicide(s)
  - Timing and growth stage
  - Rates and adjuvants
  - Calibrated Equipment

Identify your weeds

- Survey Weeds in Fall and Late Spring
- Not all herbicides control all weeds
- Not all weed can be controlled after a certain point in their growth and development
- Some weeds are more of a problem then others

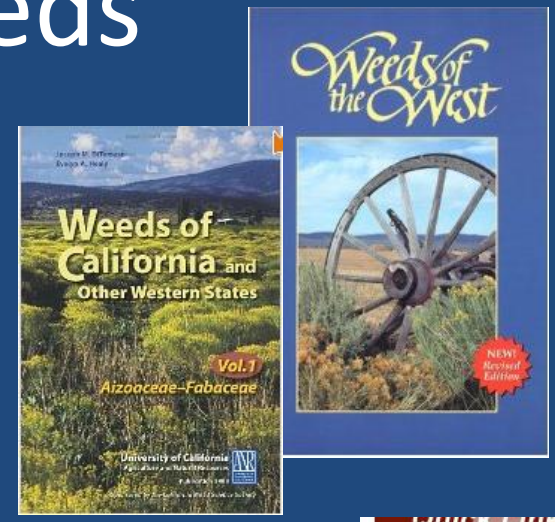
Difficult to control Weeds

Broadleafs	Grasses
Field bindweed	Dallis grass
Curly dock	Johnson grass
Dandelion	Bermuda grass
Horseweed	Junglerice
Hairy Fleabane	Italian ryegrass



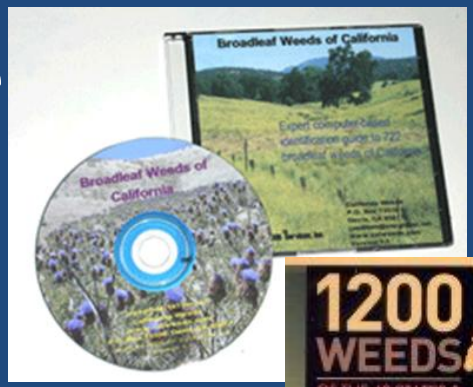
Know your weeds

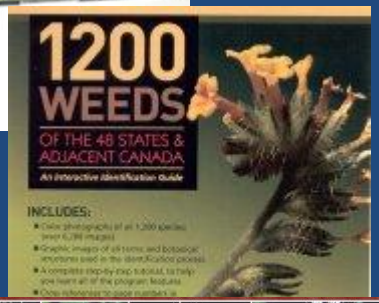
Books and Pamphlets



Weed ID – Software

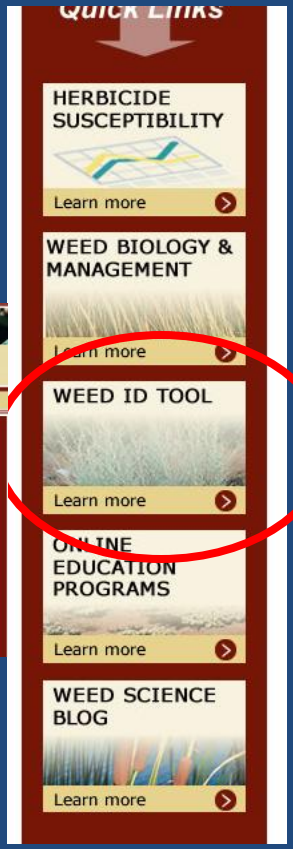
- -UC Davis
- -WSSA
- -WSWS
- - others





Online resources

- Weed ID tool (http://wric.ucdavis.edu)
- Almond weed photo gallery (www.ipm.ucdavis.edu)



Selecting an Herbicide

- Availability (registration)
- Weed spectrum
- PRE vs POST emergence activity
- Incorporation by rainfall or irrigation
- Resistance management
  - Mode of action, tank mix partners, rotation
- Reentry and harvest intervals
- Toxicity and safety
- Cost / benefit

California Herbicide Registration on Horticultural Tree and Vine Crops - (updated January 2012) - UC Cooperative Extension

	Herbicide-Common Name *(example trade name)*	Site of Action Group[1]	Almond	Pecan	Pistachio	Walnut	Apple	Pear	Apricot	Cherry	Nectarine	Peach	Plum / Prune	Avocado	Citrus	Date	Fig	Grape	Kiwi	Olive	Pomegranate
			----- tree nut -----				- pome -		---------stone fruit ---------												
Preemergence	dichlobenil *(Casoron)*	L / 20	N	N	N	N	R	R	N	R	N	R	N	N	N	N	N	R	N	N	N
	diuron *(Karmex,Diurex)*	C2 / 7	N	R	N	R	R	R	N	N	N	R	N	N	R	N	N	R	N	R	N
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
	flumioxazin (Chateau)	E / 14	R	NB	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	NB	NB
	indaziflam (Alion)	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	N	N	N	N
	isoxaben *(Trellis)*	L / 21	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB	NB
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	N
	norflurazon *(Solicam)*	F1 / 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	N	N	N
	oryzalin *(Surflan, Farm Saver)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	oxyfluorfen *(Goal, GoalTender)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	R	R	R	R	R	R
	pendimethalin *(Prowl H_2O)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	R
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	pronamide *(Kerb)*	K1 / 3	N	N	N	N	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	rimsulfuron *(Matrix, Mana)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	simazine *(Princep,Caliber 90)*	C1 / 5	R	R	N	R	R	R	N	R^2	R	R	N	R	R	N	N	R	N	R	N
	thiazopyr *(Visor)*	K1 / 3	NB	N	NB	NB	N	N	NB	NB	NB	NB	NB	N	R^2	N	N	NB	N	N	N
Postemergence	carfentrazone (Shark, Rage)	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	clethodim *(Prism)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB	N
	clove oil *(Matratec)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2,4-D *(Clean-crop, Orchard Master)*	O / 4	R	R	R	R	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	diquat *(Diquat)*	D / 22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
	d-limonene *(GreenMatch)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	N	R	N	R	R	R	N	N
	fluazifop-p-butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	NB	NB	NB	NB	N	NB	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	R	R	R	R	R	N	N	N	N	N	N	N	N	N	N	R	N	N	N
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	paraquat *(Gramoxone Inteon)*	D / 22	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	N
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N
	pyraflufen *(Venue)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	R	R	R	R
	saflufenacil *(Treevix)*	E / 14	R	N	R	R	R	R	N	N	N	N	N	N	R	N	N	N	N	N	N
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB	NB

Notes: N = Not registered, NB = ..., R = Registered. This chart is intended ... herbicide only.

Susceptibility of Winter Weeds to Herbicide Control

Customize list of weeds

ANNUAL WEEDS	PREEMERGENCE								POSTEMERGENCE						COMBINATIONS					ANNUAL WEEDS
	DIU	NAP	NOR	ORY	OXY	PEN	SIM	TRI	24D*	FLU	GLY	OXY	PAR*	SET	ORY OXY	GLY[1] OXY	GLY[1] ORY	GLY[1] 24D*	GLY[1] SIM ORY	
Barley, Hare	C	C	C	C	P	C	C	C	N	C	C	P	C	C	P	C	C	C	C	Barley, Hare
Bluegrass, Annual	C	C	C	C	P	C	C	C	N	N	C	P	C	N	C	C	C	C	C	Bluegrass, Annual
Bromegrasses	C	C	C	C	P	C	C	C	N	C	C	N	C	C	P	C	C	C	C	Bromegrasses
Canarygrass	C	C	C	C	P	C	C	C	N	C	C	N	C	C	N	C	C	C	C	Canarygrass
Clovers	P	P	N	N	C	P	C	N	P	N	C	P	P	N	P	P	P	P	P	Clovers
Cudweeds	C	C	C	N	N	N	C	N	P	N	C	P	N	N	P	C	C	C	C	Cudweeds
Fiddlenecks	C	C	C	C	C	C	C	P	P	N	C	C	C	N	C	C	C	C	C	Fiddlenecks
Filarees	C	C	C	N	C	C	C	P	C	N	P	P	P	N	P	C	P	C	C	Filarees
Groundsel, Common	P	C	P	N	C	P	C	N	C	N	C	C	C	N	C	C	C	C	C	Groundsel, Common
Henbit	C	P	P	P	C	C	C	C	C	N	C	C	C	N	C	C	C	C	C	Henbit
Lettuce, Miner's	C	C	C	C	C	C	C	C	C	N	C	C	C	N	C	C	C	C	C	Lettuce, Miner's
Mustards	C	P	C	N	C	N	C	N	C	N	C	P	C	N	P	C	C	C	C	Mustards
Nettles	C	N	C	P	C	N	C	N	C	N	C	P	C	N	P	C	C	C	C	Nettles
Oat, Wild	P	C	P	C	P	P	C	P	N	C	C	N	C	C	P	C	C	C	C	Oat, Wild
Polypogon, Rabbitfoot	C	C	C	C	P	C	C	C	N	C	C	N	C	C	N	C	C	C	C	Polypogon, Rabbitfoot
Radish, Wild	C	P	P	N	C	N	C	N	P	N	C	P	P	N	P	C	C	C	C	Radish, Wild
Redmaids (Desert Rockpurslane)	C	N	C	C	C	C	C	C	C	N	C	C	C	N	C	C	C	C	C	Redmaids (Desert Rockpurslane)
Rocket, London	C	P	C	N	C	C	C	N	C	N	C	C	C	N	P	C	C	C	C	Rocket, London
Ryegrasses	C	C	C	C	P	C	C	C	N	C	C	N	C	C	N	C	C	C	C	Ryegrasses
Shepherd's-purse	C	N	C	N	C	N	C	N	C	N	C	P	C	N	P	C	C	C	C	Shepherd's-purse
Sowthistles	C	C	P	N	C	N	C	N	C	N	C	P	C	N	P	C	C	C	C	Sowthistles

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Herbicides

Pre-emergent

- Kills weeds before emergence from soil surface
- Applied to soil surface or incorporated into soil
- Provides residual activity
  - 6 months or more

Post-emergent

- Kills weeds after emergence from the soil
- Applied to plant
- Provides no residual activity
- Two types
  - Contact (burndown) herbicides
  - Systemic herbicides

Costs

2012 cost study – Elkins et al.

$35 - Mow/Disc middles 5x

$28 – Dormant Strip (Goal 2XL, Roundup)

$9 – in season spray (Roundup)

$72 – annual total

- Consider the full cost of repeated post-emergent applications
  - active + adjuvants + machine costs + time
  - More mowing or tillage?
  - Timely weed control (wet winter/spring)
  - Weed shifts - herbicide resistant weeds
  - **Consider weed control costs over several years not a single application**

CA walnut herbicide use

	Top 10 active ingredients	2009 treated acreage
1	glyphosate	212,270
2	oxyfluorfen (Goal, Goaltender)	113,113
3	glufosinate (Rely)	46,773
4	paraquat (Gramoxone Inteon)	30,495
5	pendimethalin (Prowl)	24,329
6	2,4-D	23,351
7	simazine (Princep, etc)	23,243
8	carfentrazone (Shark)	17,708
9	diuron (Karmex, etc)	16,887
10	oryzalin (Surflan, etc)	16,862

223,000 A bearing walnut

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CA almond herbicide use

	Top 10 active ingredients	2009 treated acreage
1	glyphosate	1,300,394
2	oxyfluorfen (Goal, Goaltender)	723,524
3	glufosinate (Rely)	271,135
4	paraquat (Gramoxone Inteon)	250,156
5	pendimethalin (Prowl)	167,689
6	2,4-D	152,455
7	oryzalin (Surflan, etc)	99,220
8	simazine (Princep, etc)	92,220
9	flumioxazin (Chateau)	90,718
10	carfentrazone (Shark)	68,360
11	rimsulfuron (Matrix)	52,577

* strip treatments!

740,000 A bearing almond (2010)

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Resistance Management

- Continued use of the same herbicides year after year has led to resistant weeds
- All California tree crops lean heavily on just a few mechanism of action
- More materials registered in Walnuts than some other crops

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	diuron *(Karmex,Diurex)*	C2 / 7	N	R	N	R	R	R	N	N	N	R	N	N	R	N	N	R	N	R	N
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
	flumioxazin (Chateau)	E / 14	R	NB	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	NB	NB
	indaziflam (Alion)	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	N	N	N	N
	isoxaben *(Trellis)*	L / 21	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB	NB
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	N
	norflurazon *(Solicam)*	F1 / 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	N	N	N
	oryzalin *(Surflan, Farm Saver)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	oxyfluorfen *(Goal, GoalTender)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	R	R	R	R	R	R
	pendimethalin *(Prowl H_2O)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	R
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	pronamide *(Kerb)*	K1 / 3	N	N	N	N	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	rimsulfuron *(Matrix, Mana)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	simazine *(Princep,Caliber 90)*	C1 / 5	R	R	N	R	R	R	N	R^2	R	R	N	R	R	N	N	R	N	R	N
	thiazopyr *(Visor)*	K1 / 3	NB	N	NB	NB	N	N	NB	NB	NB	NB	NB	N	R^2	N	N	NB	N	N	N
Postemergence	carfentrazone (Shark, Rage)	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	clethodim *(Prism)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB	N
	clove oil *(Matratec)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2,4-D *(Clean-crop, Orchard Master)*	O / 4	R	R	R	R	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	diquat *(Diquat)*	D / 22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
	d-limonene *(GreenMatch)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	N	R	N	R	R	R	N	N
	fluazifop-p-butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	NB	NB	NB	NB	N	NB	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	R	R	R	R	R	N	N	N	N	N	N	N	N	N	N	R	N	N	N
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	paraquat *(Gramoxone Inteon)*	D / 22	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	N
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N
	pyraflufen *(Venue)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	R	R	R	R
	saflufenacil *(Treevix)*	E / 14	R	N	R	R	R	R	N	N	N	N	N	N	R	N	N	N	N	N	N
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB	NB

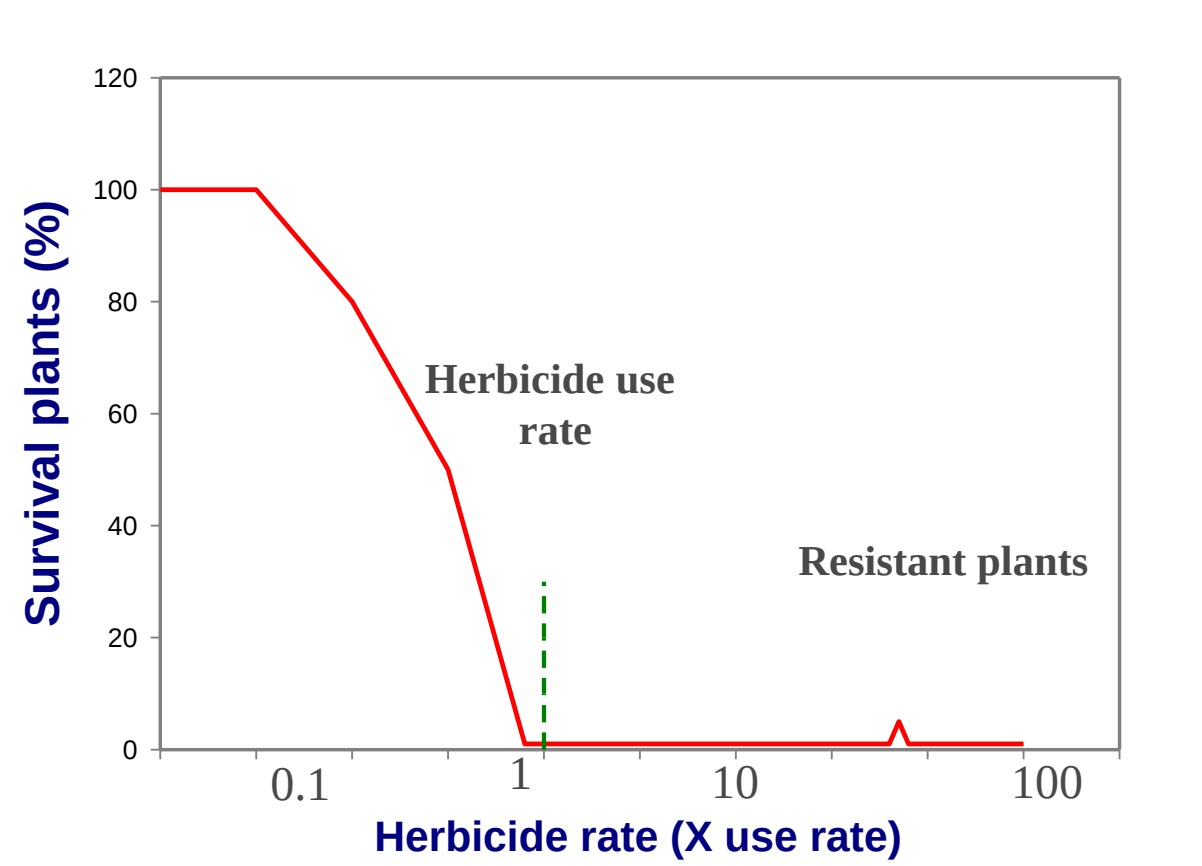
Notes: N = Not registered, NB = ..., R = Registered. This chart is intended ... herbicide only.

Types of herbicide resistance

- Qualitative (Monogenic)
  - Rapid appearance of resistance
  - High level of resistance; environment independent
  - Single gene
    - Examples: ALS and triazine resistance
- Quantitative (Polygenic)
  - Creeping increase in herbicide resistance
  - Low level of resistance; environment and stage of growth dependent
  - Accumulation of multiple alleles
  - Resistance levels is greater in developed plants
    - Example: diclofop resistance in rigid ryegrass, glyphosate resistance

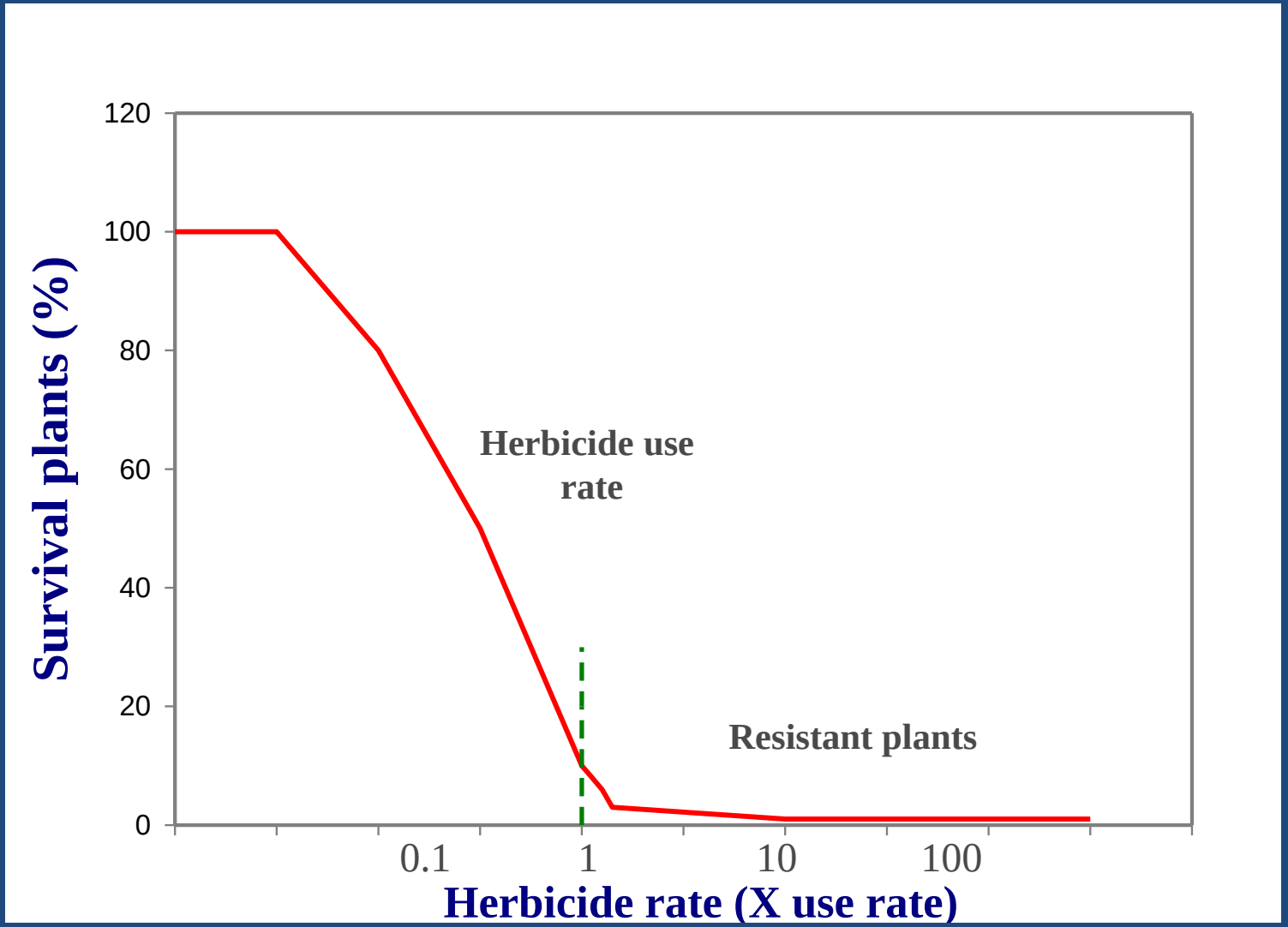
Slide: Hanson

Monogenic herbicide resistance



Slide: Hanson

Polygenic herbicide resistance



Slide: Hanson

Confirmed glyphosate resistance

(grouped by genus)	USA	CA	WA	OR
Palmer amaranth and com. waterhemp	☑ ☑			
Giant and common ragweed	☑ ☑			
Australian fingergrass				
Hairy fleabane and horseweed	☑ ☑	☑ ☑		
Sourgrass				
Junglerice	☑	☑		
Goosegrass				
Wild poinsettia				
Italian and rigid ryegrass	☑ ☑	☑ ☑		☑
Ragweed parthenium				
Buckhorn plantain				
Johnsongrass	☑			
Liverseedgrass				

Slide: Hanson

How can I keep HR weeds out of my orchard?

What if I already have HR weeds?

How can I keep HR weeds out of my orchard?

Rotate MOA

Survey for escapes, clean them up

2011-12 GR weed training sessions

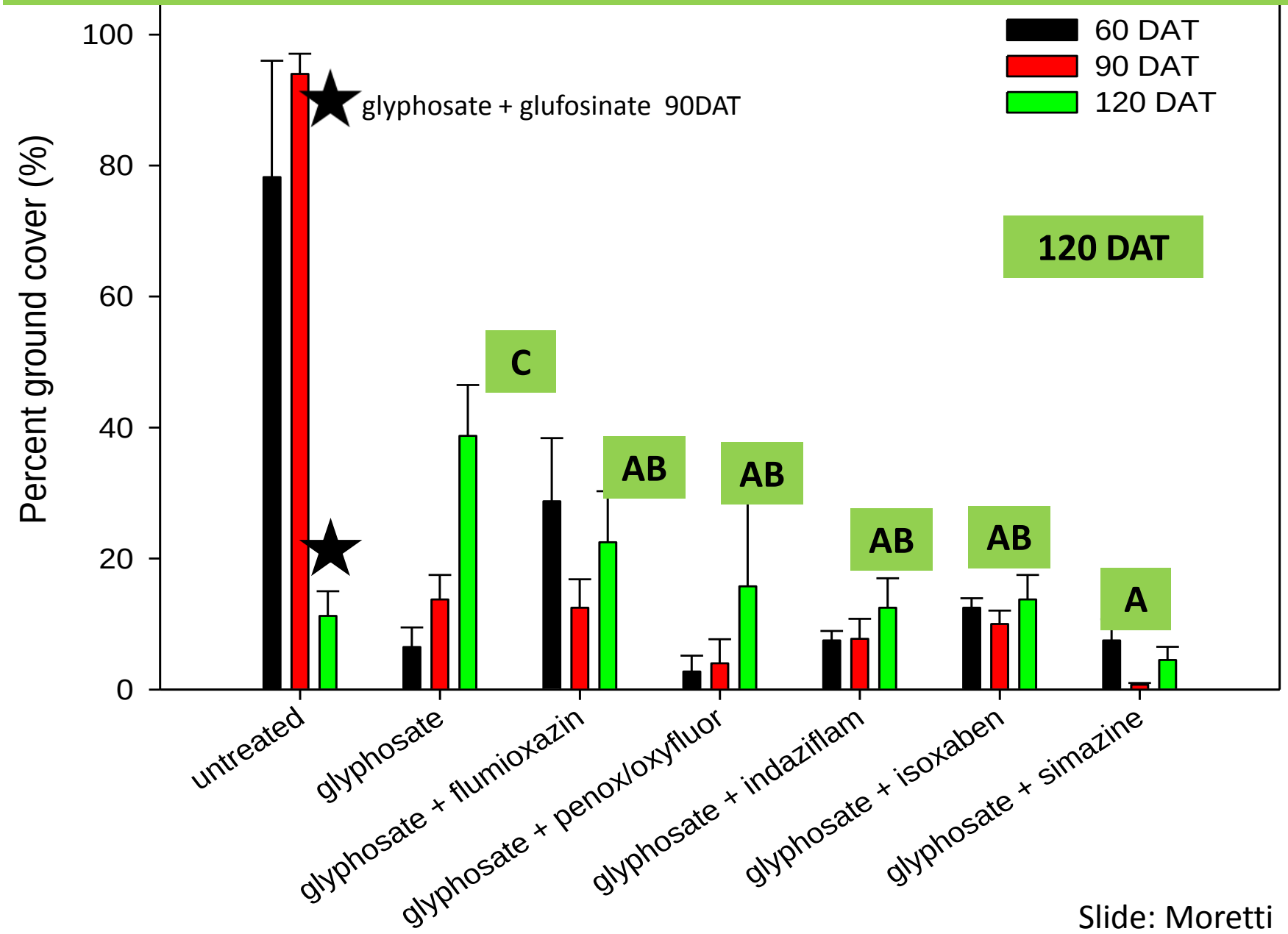
- 7 workshops in CA, OR, and WA
  - University, Extension, and USDA-ARS presenters
- Resulted in a series of UC IPM publications
  - ***Selection Pressure, Shifting Populations, and Herbicide Resistance and Tolerance***
  - ***Glyphosate Stewardship: Keeping an Effective Herbicide Effective***
  - ***Preventing and Managing Glyphosate-Resistant Weeds in Orchards and Vineyards***
  - ***Managing Glyphosate-Resistant Weeds in Glyphosate-Resistant Crops***
- http://www.ipm.ucdavis.edu/IPMPROJECT/glyphosateresistance.html

What do I do if I already have HR weeds?

- Select the proper materials
- Rotate MOA
- Clean up escapes

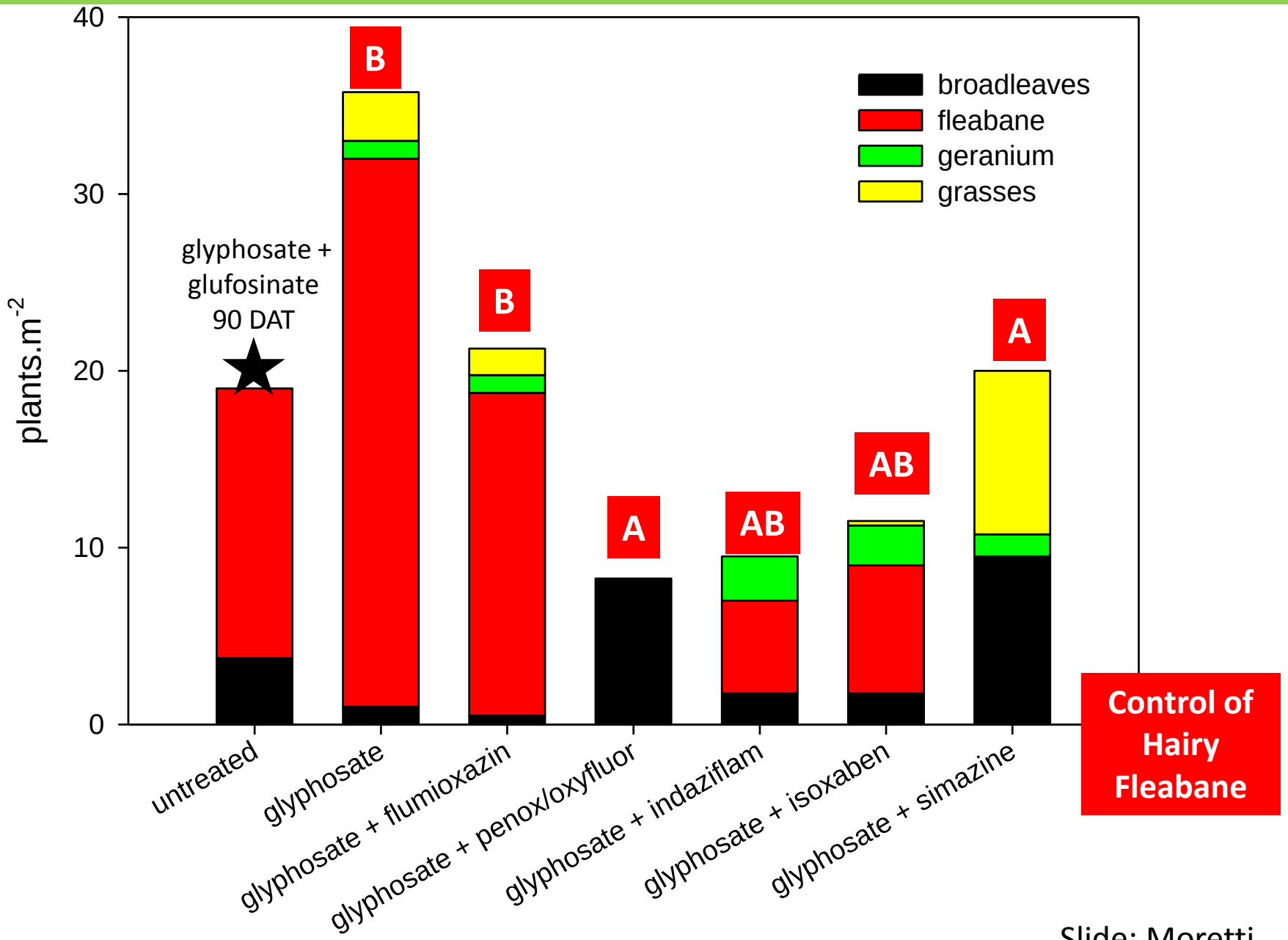
Recent Research from Dr. Hanson and UC Davis tree and vine weed science team

Percent ground cover



Slide: Moretti

Weed density at 120 DAT



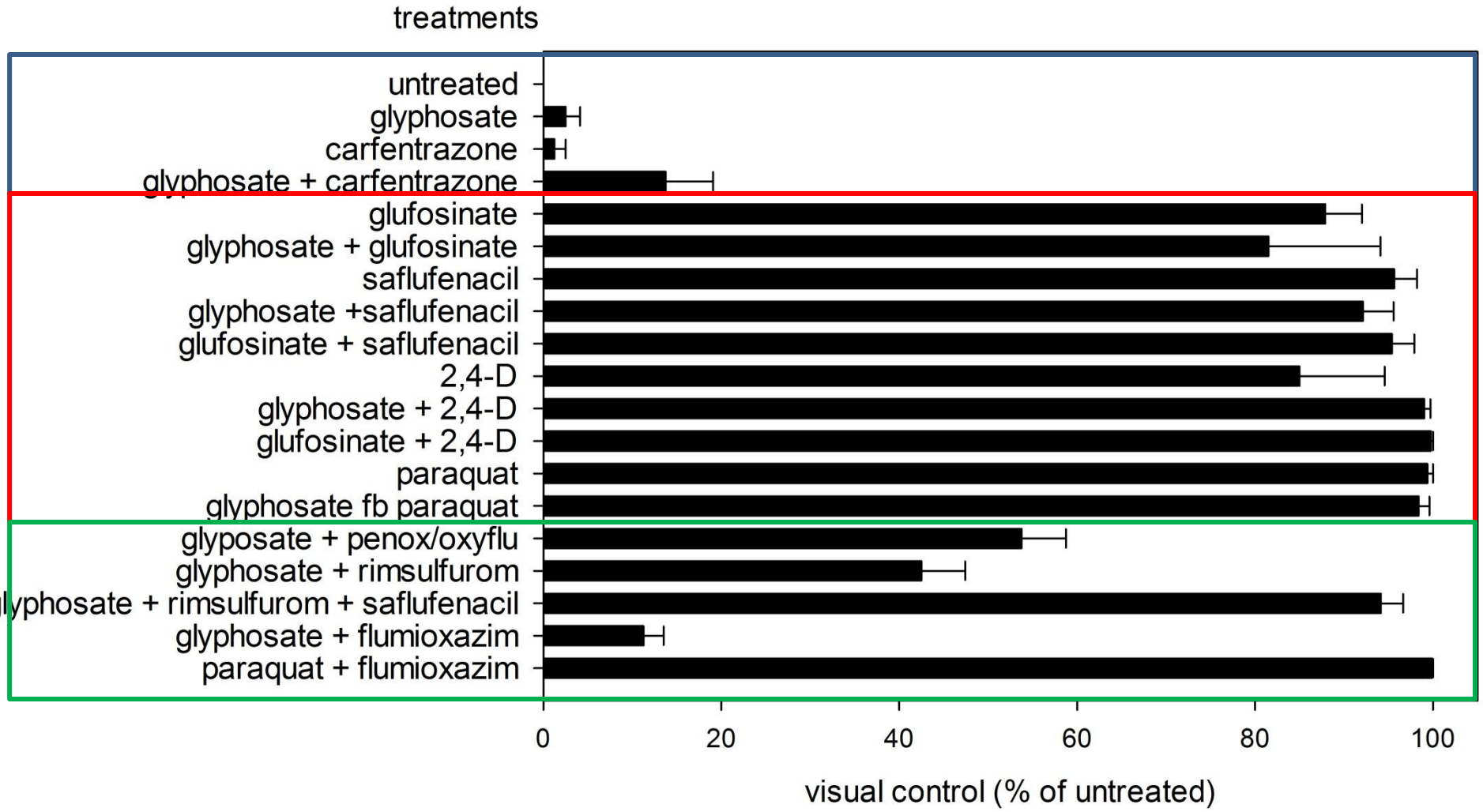
Slide: Moretti

Glyphosate + penoxsulam/oxyfluorfen

Glyphosate + indaziflam

8%
coverage

Hairy fleabane control



Moretti et al. 2013 CWSS presentation

Untreated control

Moretti et al. 2013 CWSS presentation

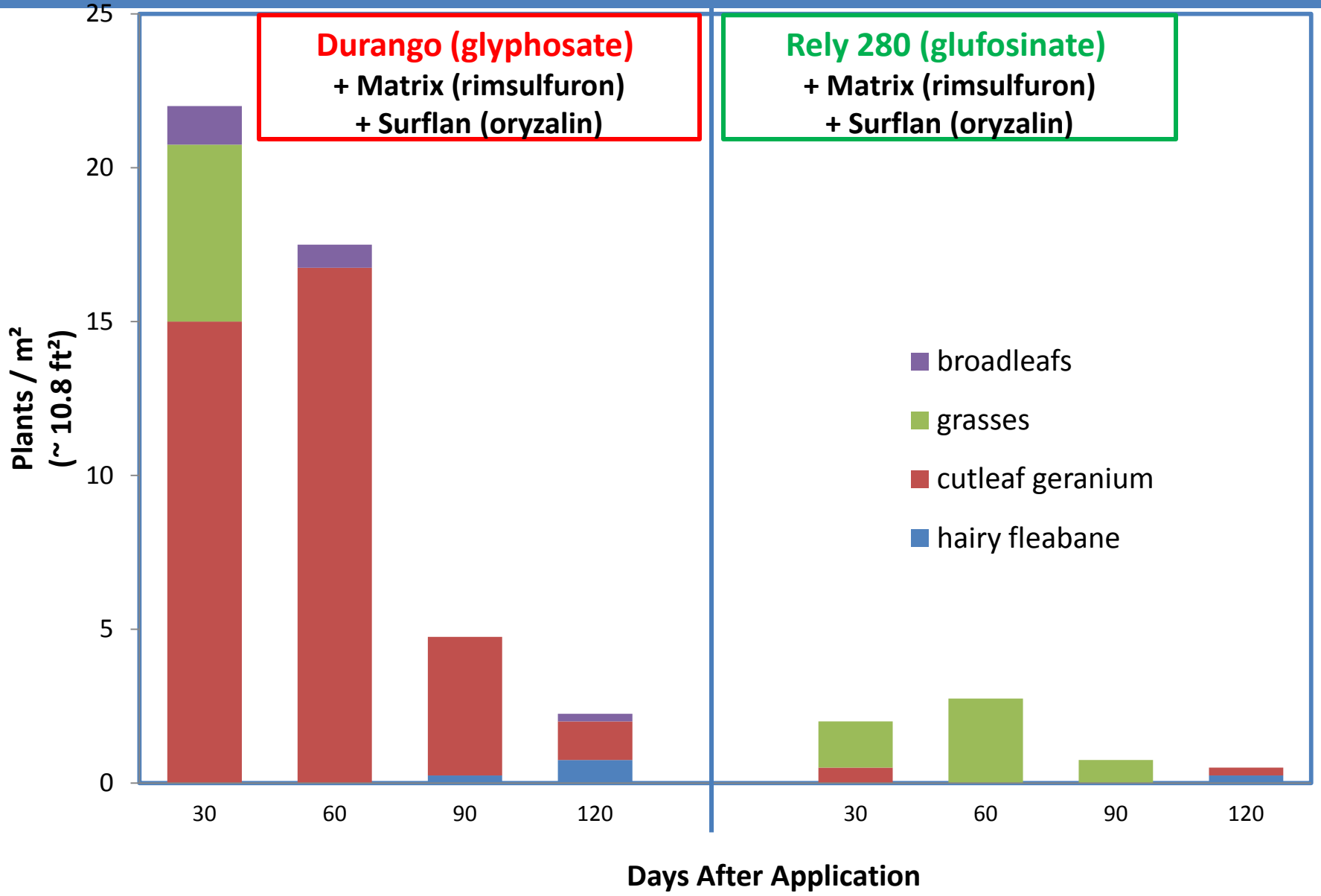
Glyphosate – (Roundup PowerMax 28 fl oz/A)

Moretti et al. 2013 CWSS presentation

Glyphosate followed by paraquat

Moretti et al. 2013 CWSS presentation

Glyphosate vs. glufosinate with residual partner

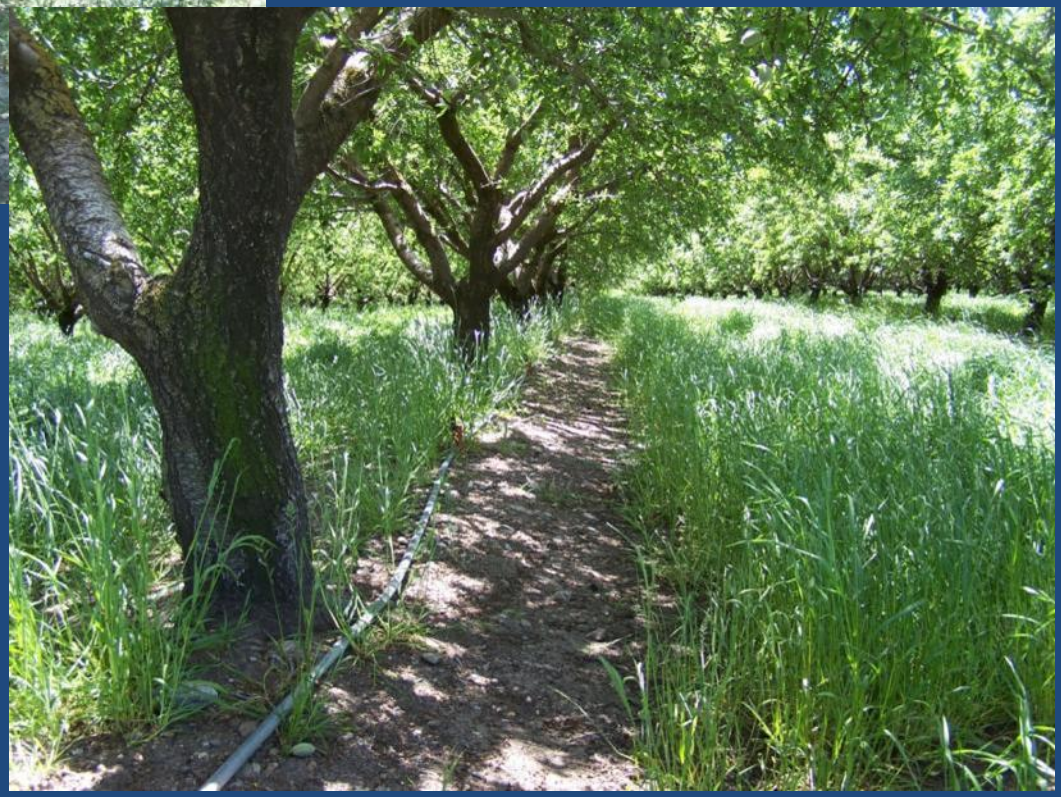


Nozzle Choice and Sprayer Calibration

- Directly affects droplet size
  - Application uniformity
  - Spray coverage
  - Drift potential
- Directly impacts
  - Weed control efficacy
  - Economics
  - Environmental quality

Middles and edges can allow weed problems to continue and grow!

Ensure sprayed strip and mowed area meet



Nozzles and their direction matter!

Herbicide application tips

- Pre-emergent
  - Blow berms clean before application
  - Apply before rain or irrigation
- Post-emergent
  - Large weeds are difficult to control
  - Stressed weeds are difficult to control
  - Use appropriate surfactants

An Effective Herbicide Program

- Correctly identify weed problem(s)
- Select registered herbicide(s) that match the weed spectrum and address YOUR weeds
- Properly apply herbicide(s)
  - Timing and growth stage
  - Rates and adjuvants
  - Calibrated Equipment

DON’T LET PROBLEM WEEDS GO TO SEED!

Acknowledgements

Littlejohn Farm

Questions?

Online Resources

UC Weed Research and Information Center (wric.ucdavis.edu)

UC Integrated Pest Management (ipm.ucdavis.edu)

UC Weed Science Blog (http://ucanr.org/blogs/UCDWeedScience/)