Weed Control and Resistance Management

Bob Johnson

UCCE Farm Advisor Intern

UC Davis Weed Science

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
- **Don Stewart -** Staff Research Associate
  - IR-4 minor crop pesticide residue testing program
- **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
- **Rolando Mejorado and Casey Erickson** – undergrad lab assistants
- **UCCE and industry cooperators**

Why Control Weeds

- Young orchard
  - Competition for nutrients and water
- Mature orchard
  - Competition for nutrients and water
  - Harbor diseases and pest
  - Interfere with irrigation functioning
  - Interfere with harvest

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
  - Weeds compete for water and nutrients, especially trees on drip or micro-sprinklers
  - Interfere with harvest operations
  - Frost considerations
  - Uncontrolled weeds can harbor vertebrate pests
  - fewer weeds means lower humidity around trunks so less chance of crown disease

Before Planting

- Survey weeds several times before you cultivate
- Surveys in late winter, summer and fall help identify full spectrum of species
- Established perennials (bermudagrass, johnsongrass, field bindweed)
  - multiple cultivations and/or
  - timely post emergent application(s)

Young Orchard

- Avoid spraying trunks of young trees
- Wrappers help, but not always

An Effective Herbicide Program

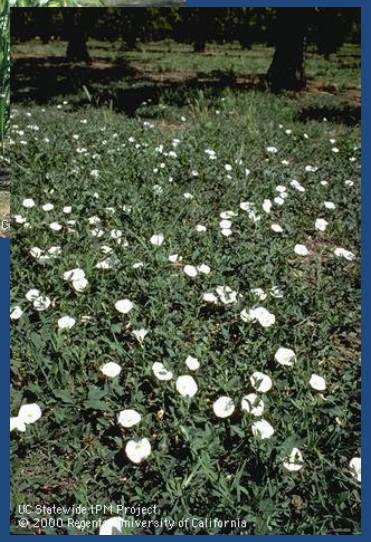
- Correctly identify weed problem(s)
- Select registered herbicide(s) that match the weed spectrum and address YOUR weeds
- Properly apply herbicide(s)
  - Timing and growth stage
  - Rates and adjuvants
  - Calibrated equipment

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

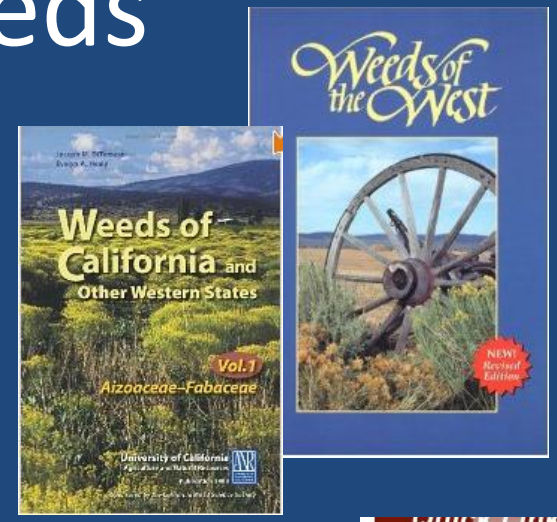
Difficult to Control Weeds

Broadleaves	Grasses
Field bindweed	Dallisgrass
Curly dock	Johnsongrass
Dandelion	Bermudagrass
Horseweed	Junglerice
Hairy Fleabane	Italian ryegrass

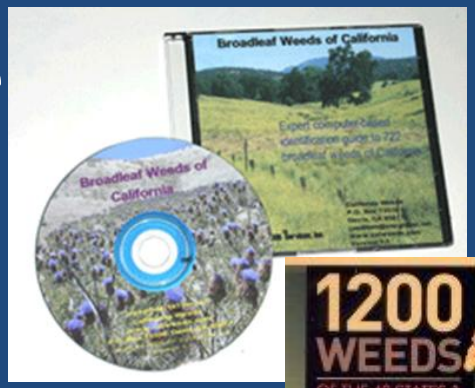


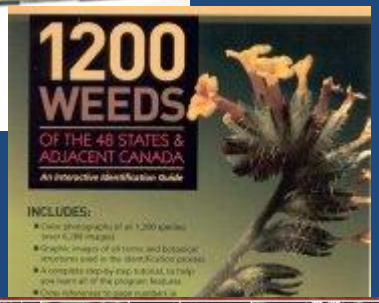
Know Your Weeds

Books and Pamphlets



Weed ID – Software

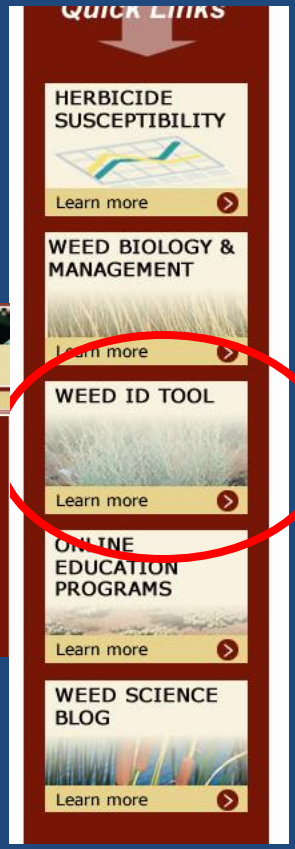




- -UC Davis
- -WSSA
- -WSWS
- - others

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

Herbicide Registration on Horticultural Tree and Vine Crops -(updated December 2012 - UC Weed Science)

	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
			----- tree nut -------				- pome -		---------stone fruit ---------											
Preemergence	dichlobenil *(Casoron)*	L / 20	N	N	N	N	R	R	N	R	N	N	N	N	N	N	N	R	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
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N
	flazasulfuron (Mission)	B / 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N
	flumioxazin (Chateau)	E / 14	R	R	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	NB
	indaziflam (Alion)	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	N	N	N
	isoxaben *(Trellis)*	L / 21	R	R	R	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N
	norflurazon *(Solicam)*	F1 / 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	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
	oxyfluorfen *(Goal, GoalTender)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	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
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	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
	rimsulfuron *(Matrix, Mana)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N
	simazine *(Princep,Caliber 90)*	C1 / 5	R	R	N	R	R	R	N	R*	R	R	N	R	R	N	N	R	N	R
	thiazopyr *(Visor)*	K1 / 3	NB	N	NB	NB	N	N	NB	NB	NB	NB	NB	N	R**	N	N	NB	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
	clethodim *(Prism)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB
	clove oil *(Matratec)*	NC[3]	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
	diquat *(Diquat)*	D / 22	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
	fluazifop-p-butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	NB	NB	NB	R	N	NB
	glyphosate *(Roundup)*	G / 9	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
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	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
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
★	pyraflufen *(Venue)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	N	N	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
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB

Susceptibility of Spring/Summer Weeds to Herbicide Control

Customize list of weeds

ANNUAL WEEDS	Preemergence											Postemergence									Combinations	
	FLM	ISO	NAP	NOR	ORY	OXY	PEN	PRO	RIM	TRI	THI	CAR	CLE	FLU	GLY	MSM	OXY	PAR*	SET	2,4D*	ORY OXY	GLY[1] OXY
Barnyardgrass	C	N	C	P	C	P	C	C	C	C	C	N	C	P	C	N	N	P	C	N	C	C
Cocklebur	—	P	C	C	N	C	N	N	P	N	C	P	N	N	C	P	C	C	N	C	C	C
Crabgrasses	C	N	C	P	C	N	C	C	C	C	C	N	C	C	C	C	P	C	C	N	C	C
Cudweeds	—	P	C	C	N	N	N	N	C	N	C	N	N	N	C	N	P	N	N	P	P	C
Fleabane, Hairy	C	P	N	P	N	P	N	N	C	N	C	N	N	N	C	N	P	P	N	P	P	C
Foxtails	C	N	C	C	C	N	C	C	C	C	C	—	C	C	C	—	N	C	C	N	C	C
Filarees	—	C	C	P	N	C	N	N	C	P	C	C	N	P	P	N	C	P	N	P	C	C
Goosefoot, Nettleleaf	C	C	C	C	C	C	P	C	P	C	C	—	N	N	C	N	P	C	N	C	C	C
Goosegrass	C	N	—	C	C	N	C	C	P	C	C	N	C	C	C	C	N	P	—	N	—	C
Groundcherry	—	C	N	C	P	C	N	C	C	N	C	C	N	N	C	P	C	C	N	C	C	C
Horseweed	C	P	N	P	N	P	N	N	C	N	P	N	N	N	C	N	P	P	N	C	P	C
Junglerice	—	N	C	C	C	P	C	P	C	C	C	N	C	P	C	—	N	P	C	N	C	C
Knotweed, Common	—	C	C	P	C	P	C	C	P	C	P	—	N	N	P	N	P	C	N	P	C	P
Lambsquarters, Common	C	C	C	P	C	C	C	C	P	C	C	C	N	N	C	N	C	C	N	C	C	C
Lettuce, Prickly	—	C	C	P	N	C	N	N	C	N	C	P	N	N	C	N	C	P	N	C	C	C
Lovegrass	C	N	C	P	C	P	C	C	P	C	C	N	C	C	C	P	N	P	C	N	C	C
Nightshades	C	C	N	C	N	C	N	C	C	N	—	P	N	N	C	P	C	C	N	C	C	C
Pigweeds	C	C	C	P	C	C	C	N	C	C	P	C	N	N	C	N	C	C	N	P	C	C
Puncturevine	C	P	N	C	P	C	C	N	P	P	P	—	N	N	C	P	P	C	N	C	P	C
Purslane, Common	C	C	C	P	C	C	C	C	C	C	C	P	N	N	P	P	C	C	N	C	C	P
Sandburs	—	N	C	P	C	N	C	—	—	C	C	N	C	P	C	P	N	P	P	N	P	C
Sowthistles	C	C	C	P	N	C	N	P	C	N	C	N	N	N	C	N	C	P	N	C	C	C
Sprangletops	—	N	C	P	C	N	C	C	P	P	—	N	C	P	C	N	P	P	P	N	—	C
Spurge, Spotted	C	C	N	P	P	P	C	P	C	N	P	—	N	N	C	N	N	C	N	C	P	C
Starthistle, Yellow	—	—	—	—	N	C	N	N	P	N	—	N	N	N	C	N	N	C	N	C	—	C
Thistle, Russian	C	P	C	C	P	P	P	P	N	P	P	C	N	N	C	P	P	C	N	P	P	C
Willowherb, Panicle-leaf	—	P	N	P	P	C	—	—	C	—	—	—	N	N	P	—	N	N	N	C	C	P
Witchgrass	—	N	—	C	P	C	C	C	C	C	C	N	C	C	C	P	N	N	C	N	C	C

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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

Post-emergent

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

Costs

2012 cost study – Buchner et al.

- $38 - Mow/Disc middles 5x
- $78 – Dormant Strip (Surflan, Goal , Roundup)
- $15 – summer strip spray (Roundup)
- $131 – annual total

Hypothetical cost

- $38 - Mow/Disc middles 5x
- $45 –3x post-emergent strip (Roundup)
- $98 – 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**

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

CA prune herbicide use

	Top 10 active ingredients	2009 treated acreage
1	glyphosate	51,066
2	oxyfluorfen (Goal, Goaltender)	19,979
3	paraquat (Gramoxone Inteon)	10,668
4	2,4-D	9,644
5	pendimethalin (Prowl)	6,495
6	oryzalin (Surflan, etc)	5,193
7	flumioxazin (Chateau)	2,295
8	rimsulfuron (Matrix)	2,163
9	carfentrazone (Shark)	1,983
10	norflurazon (Solicam)	534

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

Slide: Hanson

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)

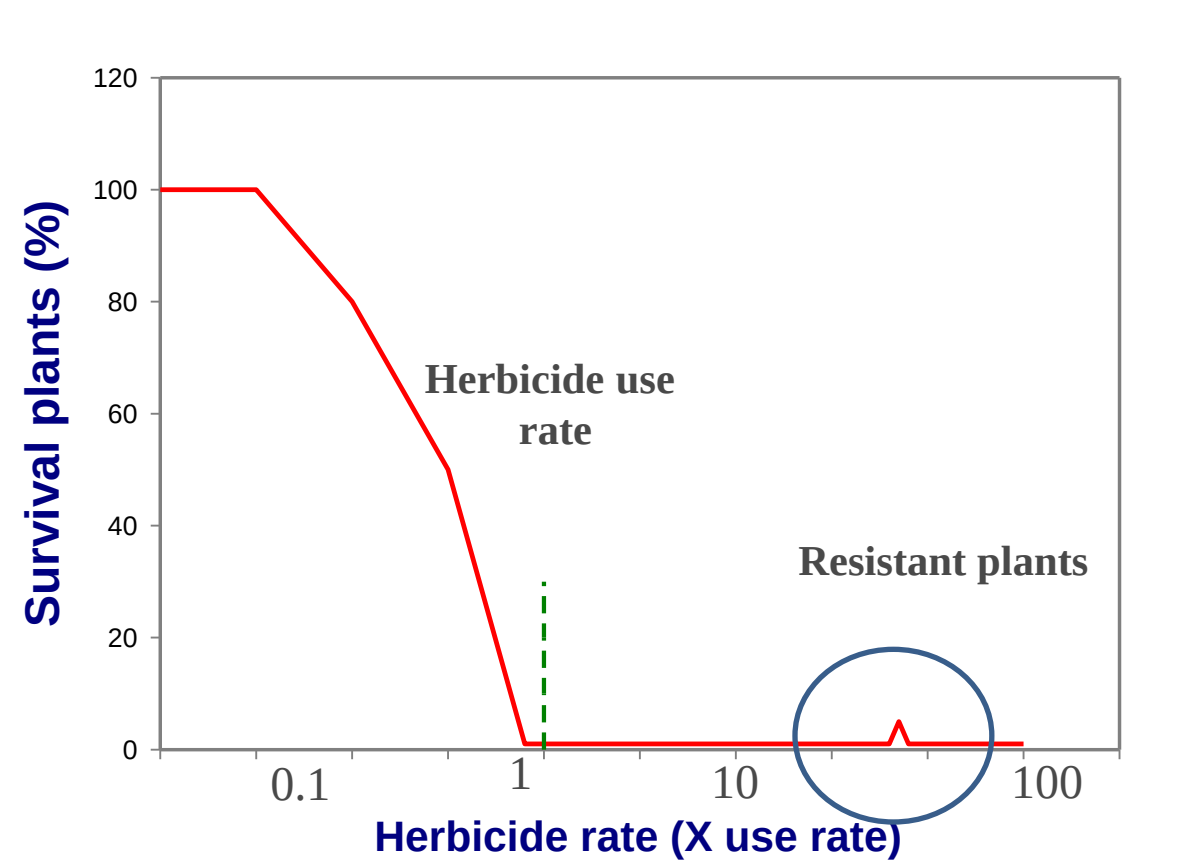
Slide: Hanson

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

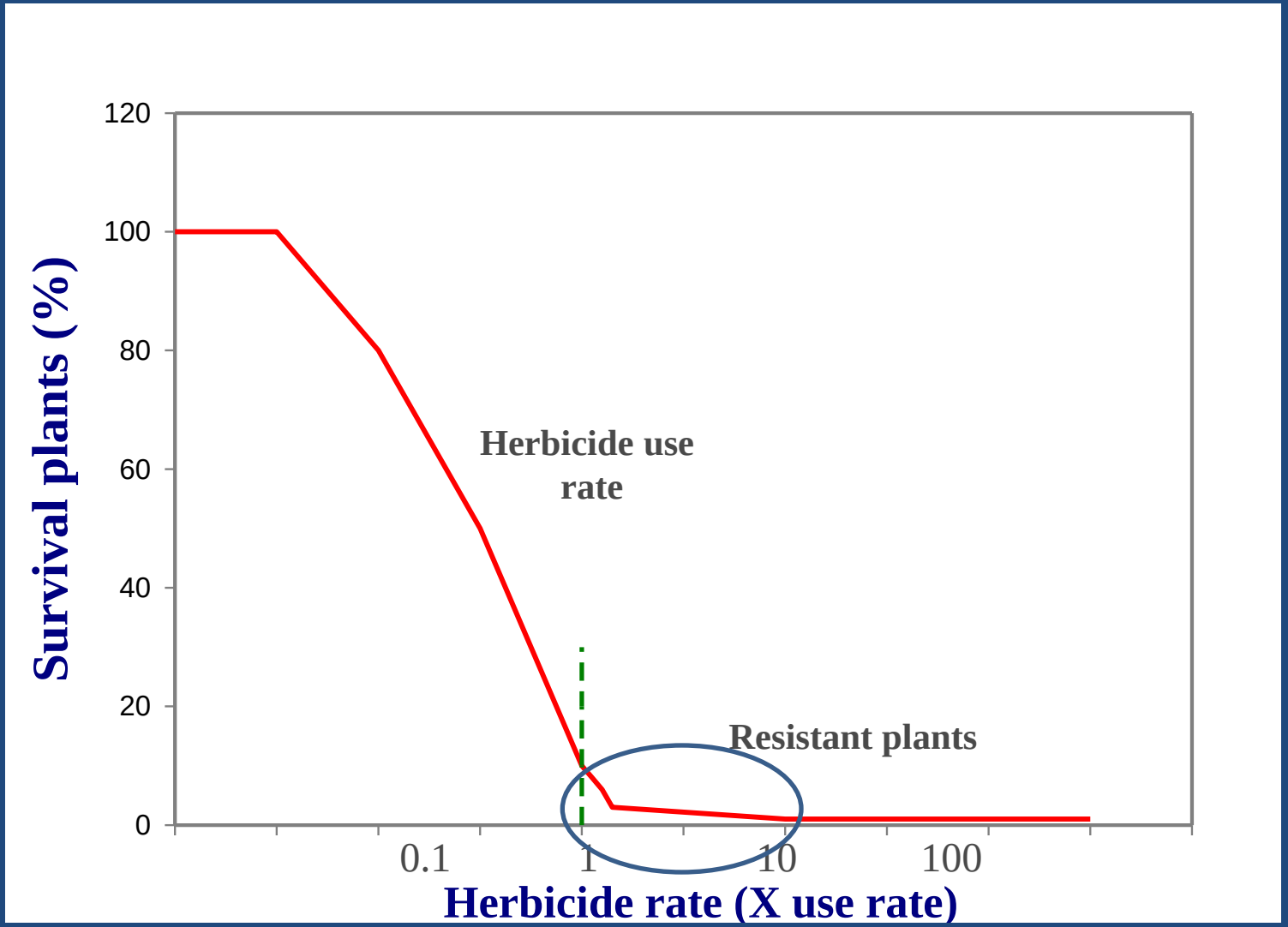
Slide: Hanson

Monogenic Herbicide Resistance



Slide: Hanson

Polygenic Herbicide Resistance



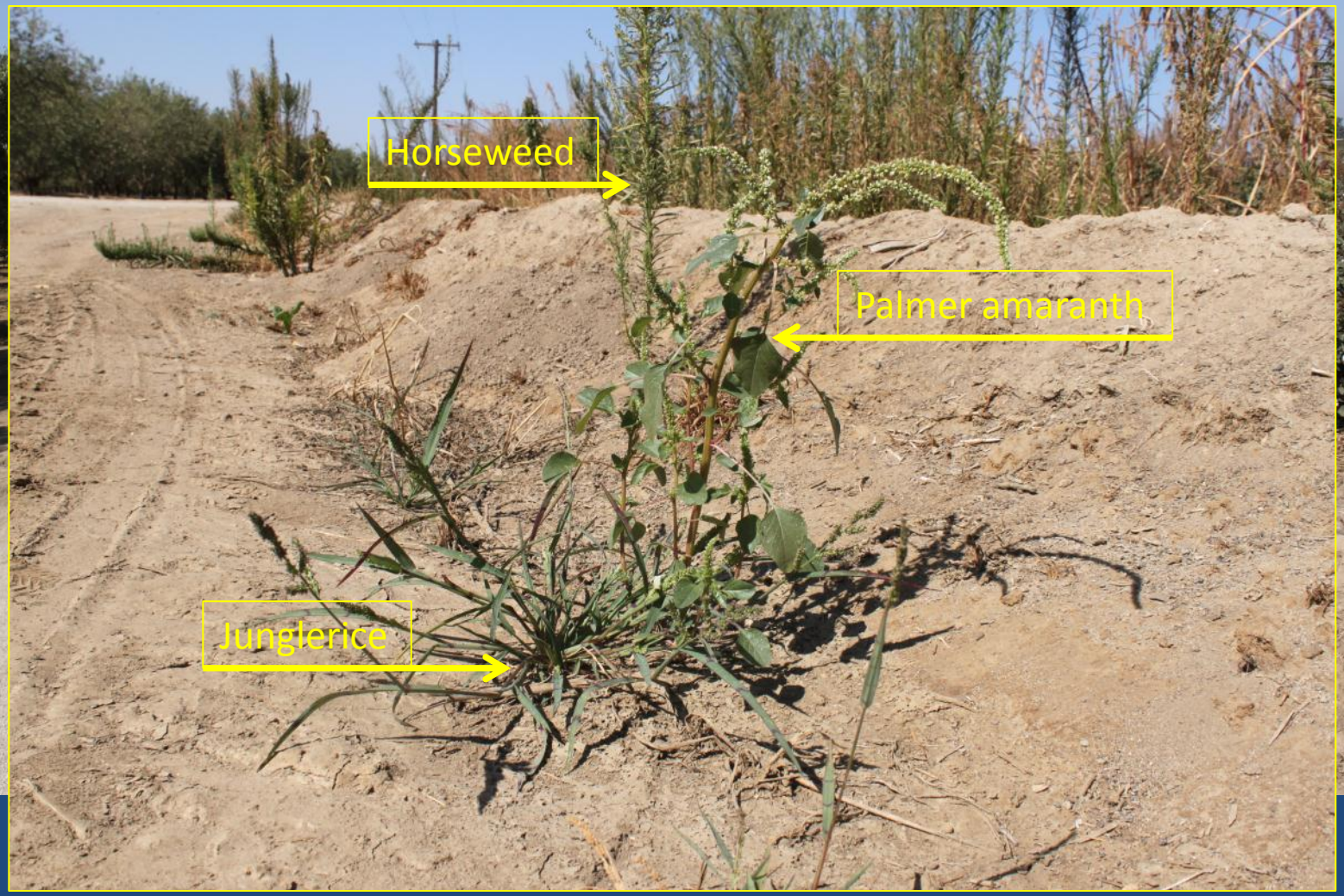
Slide: Hanson

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

What might we be in for?



Hanson

How can I keep HR weeds out of my orchard?

What if I already have HR weeds?

Registered Herbicides in Bearing Prunes

Pre-emergent

flumioxazin (Chateau®)

indaziflam (Alion®)

norflurazin (Solicam®)

oryzalin (Surflan®)

oxyfluorfen (Goal®)

pendimethalin (Prowl H_2O®)

pronamide (Kerb®)

rimsulfuron (Matrix®, Mana®)

Post-emergent

carfentrazone (Shark®, Rage®)

2-4D (Orchard Master®, Clean Crop®)

fluazifop-p-butyl (Fusilade®)

glyphosate (Durango®, Roundup®)

paraquat (Gramoxone Inteon®)

pyraflufen (Venue®)

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?

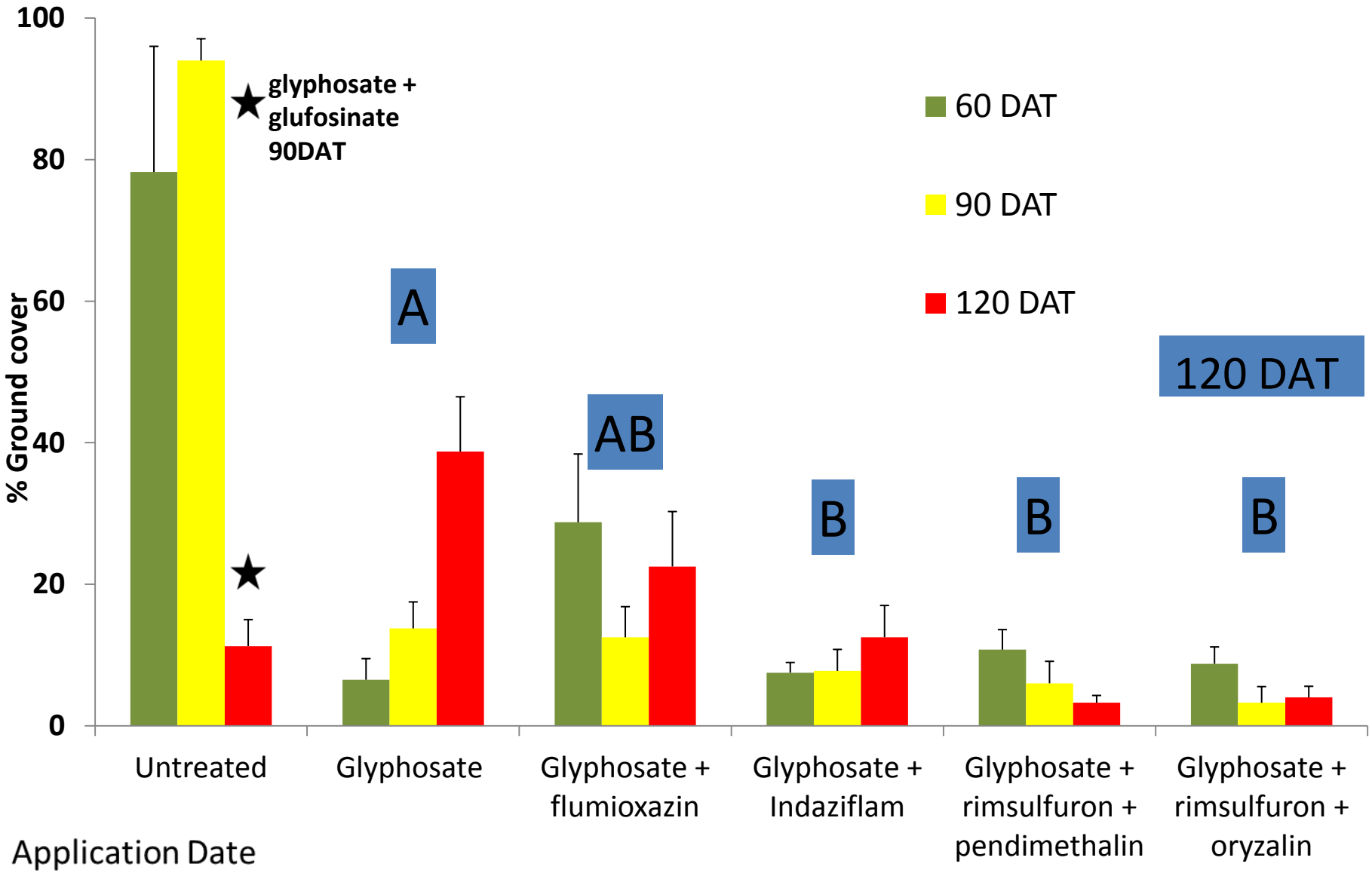
Select the proper materials

Rotate MOA

Clean up escapes

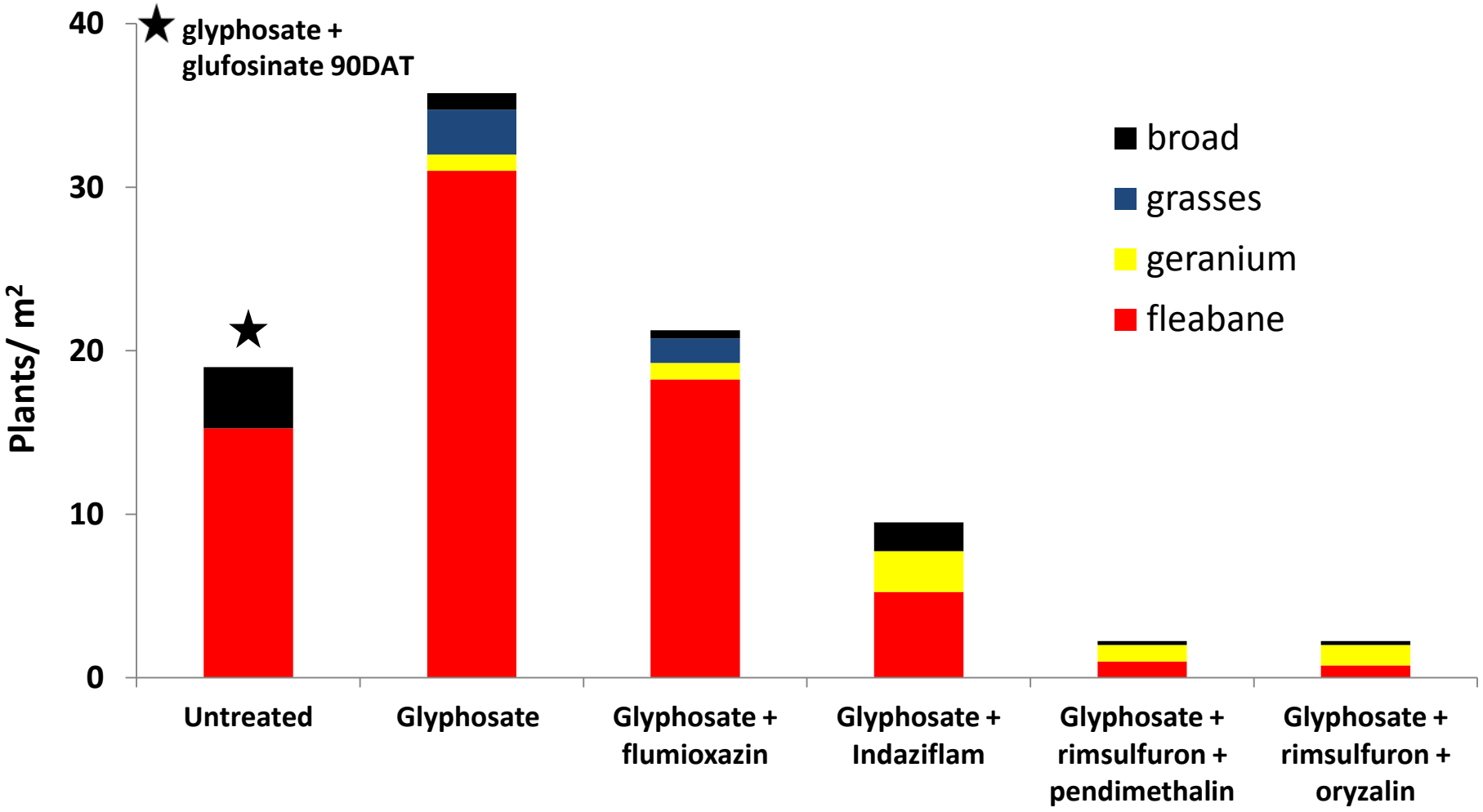
Recent Research from Dr. Hanson and UC Davis tree and vine weed science team

Percent ground cover



Application Date
Feb 20, 2012

Weed Density 120 DAT ~ June 20



Application Date
Feb 20, 2012

Untreated 90 DAT

glyphosate (1 qt) 90 DAT

glyphosate (1 qt) + flumioxazin (12 oz) 90 DAT

(Chataeu®)

glyphosate (1 qt) + indaziflam (6.5 oz) 90 DAT

(Alion®)

Glyphosate (1 qt) +rimsulfuron (4 oz) +pendimethalin (4 oz) 90 DAT

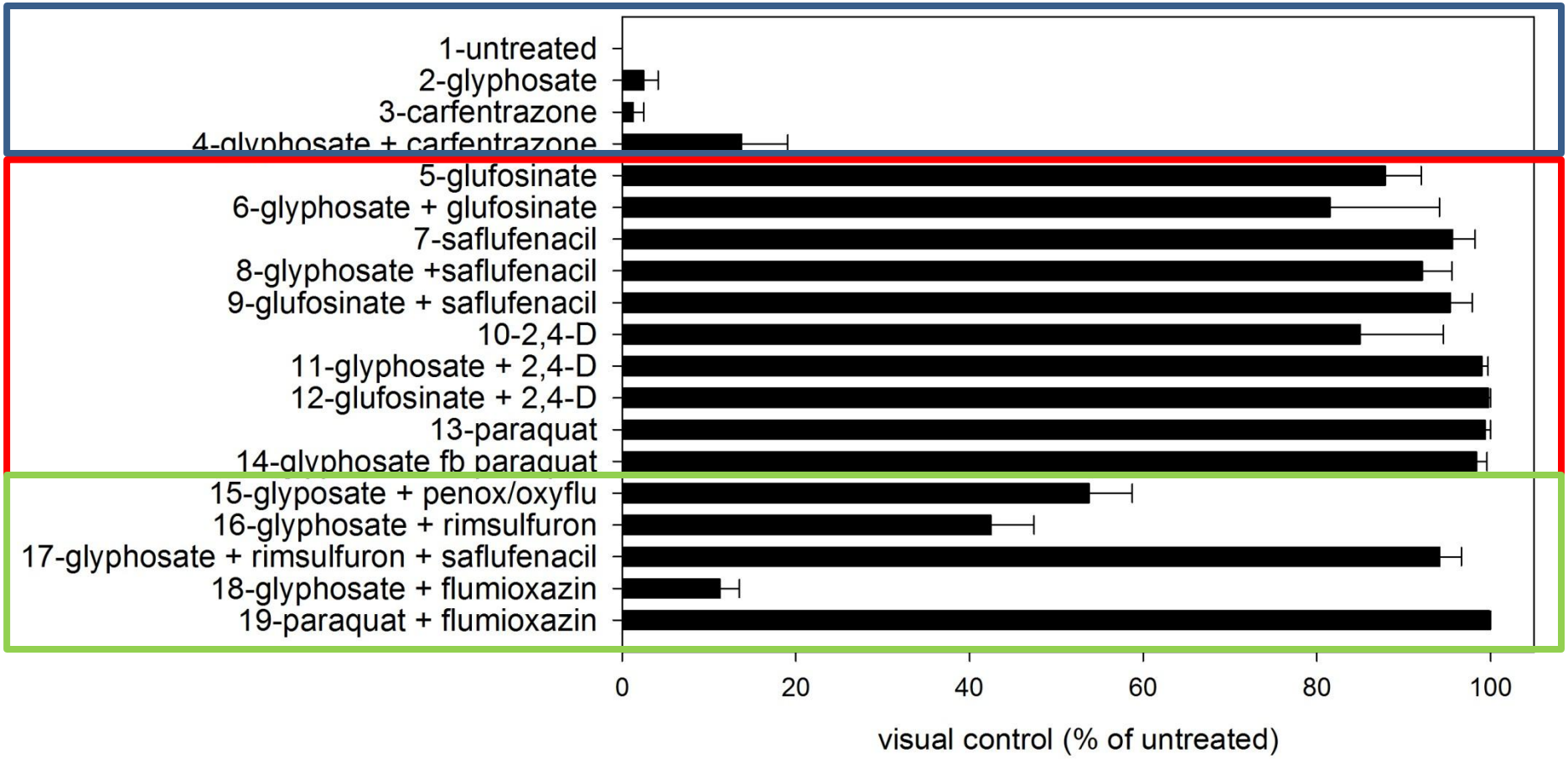
(Matrix®) (Prowl®)

Glyphosate (1 qt) + rimsulfuron (4 oz) +oryzalin (4 qt) 90 DAT

(Matrix®) (Surflan®)

Hairy fleabane control

28 DAT



Application:
July, 2012

Moretti et al. 2013 CWSS presentation

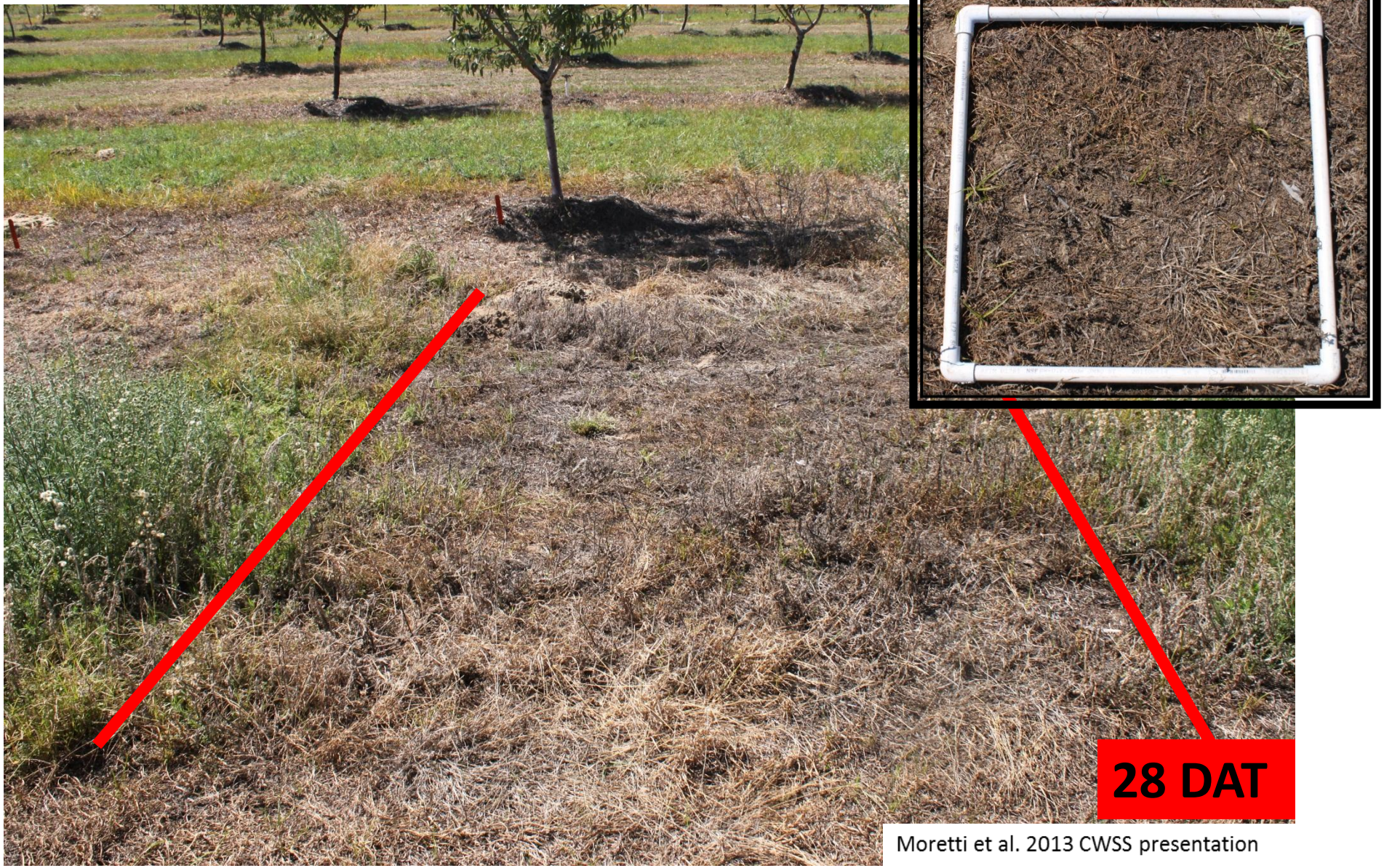
Untreated control

Moretti et al. 2013 CWSS presentation

Glyphosate – (Roundup PowerMax 28 fl oz/A)

Moretti et al. 2013 CWSS presentation

Glyphosate fb paraquat at 14 days



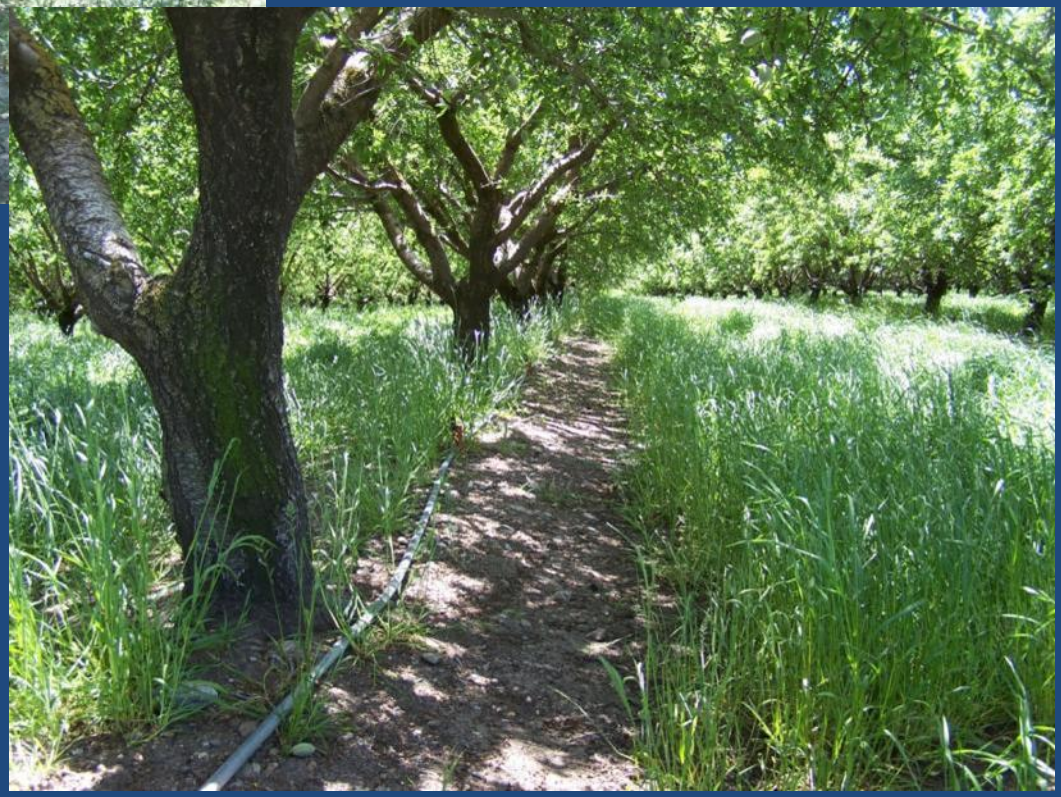
Moretti et al. 2013 CWSS presentation

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!

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/)