Glyphosate Resistant Kochia in The Treasure Valley of E. Oregon

Joel Felix



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Acknowledgements

- Snake River Sugarbeet Growers
 Research Committee
- Joey Ishida & Bill Buhrig
- Amalgamated Sugar Company
- Colleagues
 - Dr. Don Morishita, University of Idaho
 - Dr. Prashant Jha, Montana State University



In This Session

- Glyphosate Use Globally
 - Impact at farm level
- Glyphosate Resistant kochia
- Glyphosate formulations
- Best Weed Management Practices



Glyphosate

- The most widely used agricultural pesticide globally
- In 2012 glyphosate was applied on 316 mil acres worldwide
- Reported gains of about \$32.2 billion globally (from Brookes & Barfoot, 2013)



Average farm economic impact

Table 4. Other GM HT crops summary of average farm level economic impacts 1996–2011 (\$/hectare)

Country	Cost of technology	Average farm income benefit (after deduction of cost of technology)	Type of benefit	References
GM HT canola				
US	12-33	59	Mostly yield gains of +1% to +12% (especially Invigor canola)	Sankala and Blumenthal (2003 ¹³ and 2006 ¹⁴) Johnson and Strom (2008 ¹⁵) And updated to reflect herbicide price and common product usage
Canada	18-32	49	Mostly yield gains of +3% to +12% (especially Invigor canola)	Canola Council (2001 ²²) Gusta et al. (2009 ²³) and updated to reflect herbicide price changes and seed variety trial data (on yields)
Australia	32-41	61	Mostly yield gains of +16% to +22% (where replacing triazine tolerant canola)	Monsanto Australia (2009 ²⁴)
GM HT sugar beet				
US and Canada	130–151	118	Mostly yield gains of +3% to +13%	Kniss (2008 ²⁵) Khan (2008 ²⁶) Armstrong JJQ and Sprague C (2010 ²⁷) Annual updates of herbicide price and usage data

Source: http://www.tandfonline.com/doi/pdf/10.4161/gmcr.24176



GMO Sugarbeet Economic Impact

	Cost of technology	Average farm income benefit after deduction of cost of technology	Type of benefit
US and Canada	\$ 130-151/ha	\$ 118	Yield gains of
	\$ 53 – 61/acre	\$ 48	+3 to +13%

Source: http://www.tandfonline.com/doi/pdf/10.4161/gmcr.24176

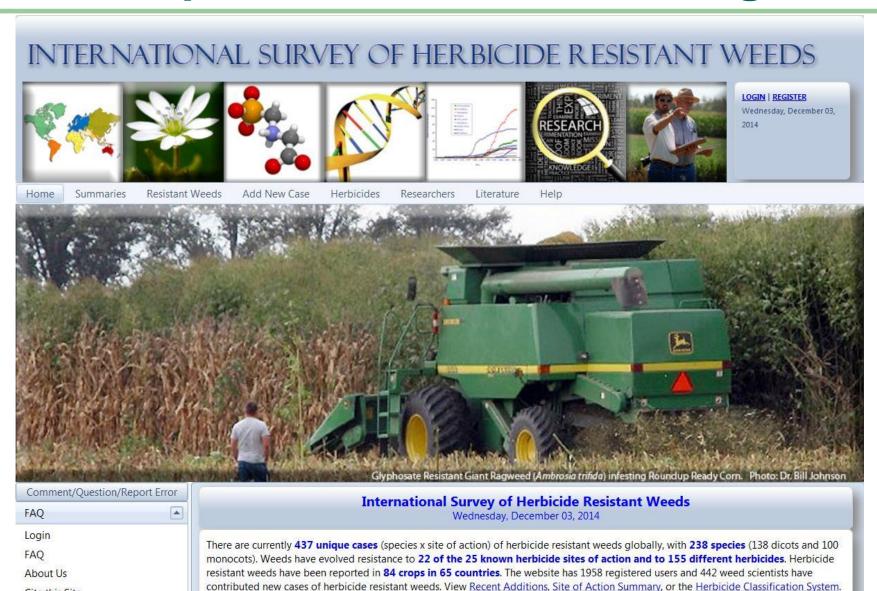


Selection pressure and weeds

- Several weed species have developed resistance to glyphosate
- Recent proliferation of resistance is a cause for concern
- About 31 glyphosate resistant weed species have been reported in the last 18 years



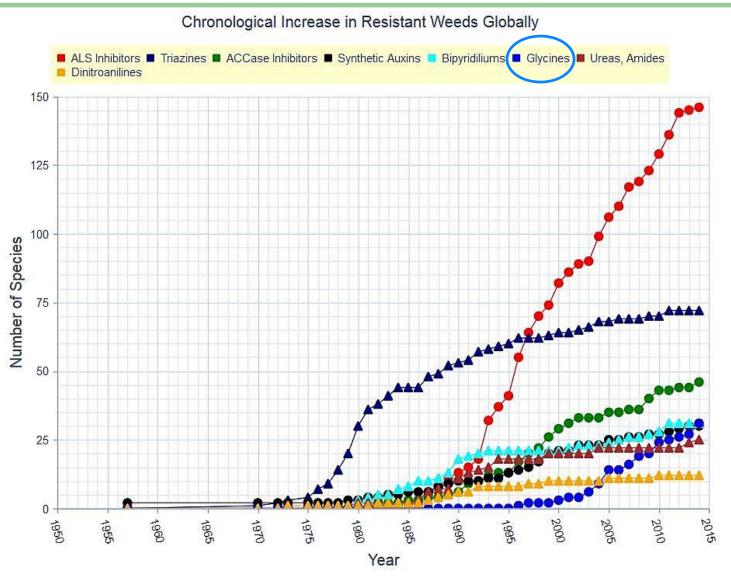
http://www.weedscience.org

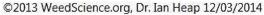




Cite this Site

Increase in herbicide resistant weeds

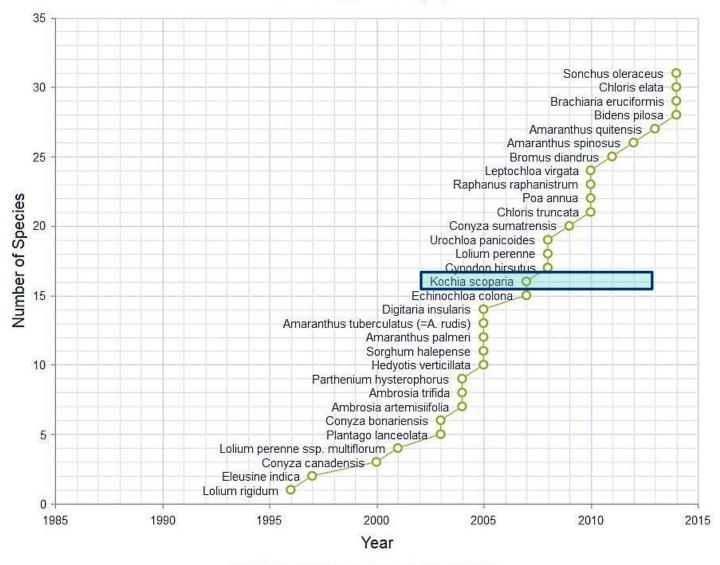




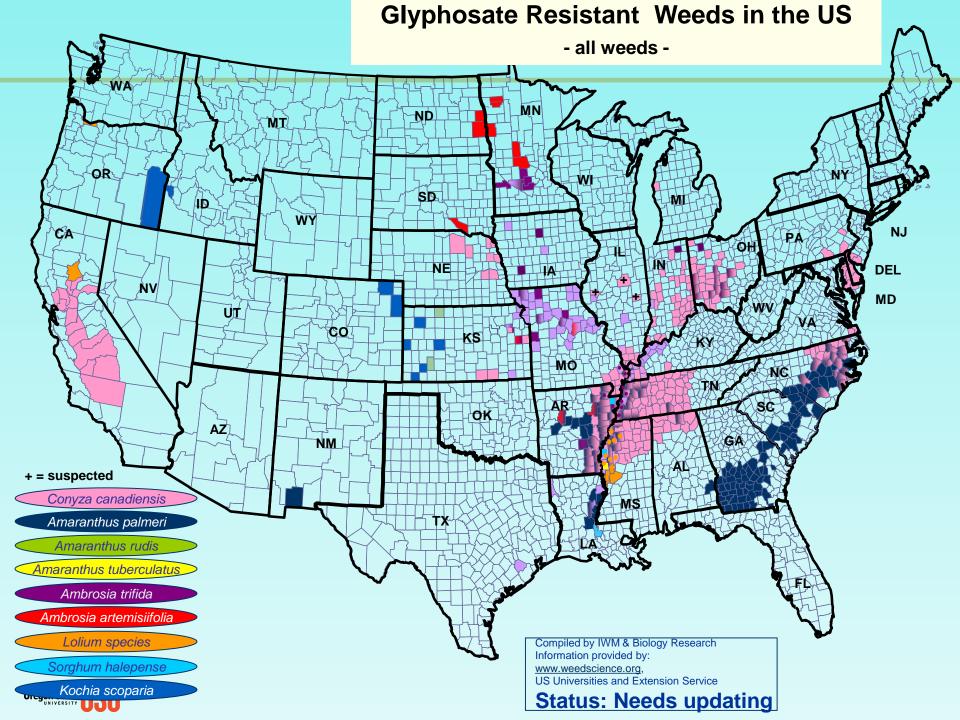


Glyphosate resistance by species

Resistance to Glyphosate by Species







Glyphosate Resistant Kochia

- Between 2007 and 2012 kochia resistance to glyphosate was been confirmed in KS, NE, CO, SD, ND, MT, (and possibly WY in 2013)
- Confirmed in Oregon and Idaho in 2014



Sugar beet field - May 15, 2014





Sugar beet – May 28, 2014





Close up - June 2, 2014





Sugar beet – July 21, 2014





Sugar beet (Vale) - June 17, 2014



Sugarbeet (Vale) - June 17, 2014



Sugarbeet (Vale) - June 17, 2014





Sugarbeet (Vale) - June 17, 2014





Sugar beet (Vale) - June 17, 2014



Samples to Colorado for testing





EPSPS Copy Number in Kochia from Oregon

Tested for Joel Felix
Phil Westra, Todd Gaines, Eric
Patterson, Dean Pettinga
CSU Weed Research

Kochia Samples July 2014





- Samples from both AL and VA sites show increased EPSPS copy number relative to CSU kochia line 7710 (glyphosate susceptible)
- This indicates these samples are glyphosate resistant and the mechanism is EPSPS gene amplification



Plants sent to University of Montana and evaluated by Dr. Prashant Jha



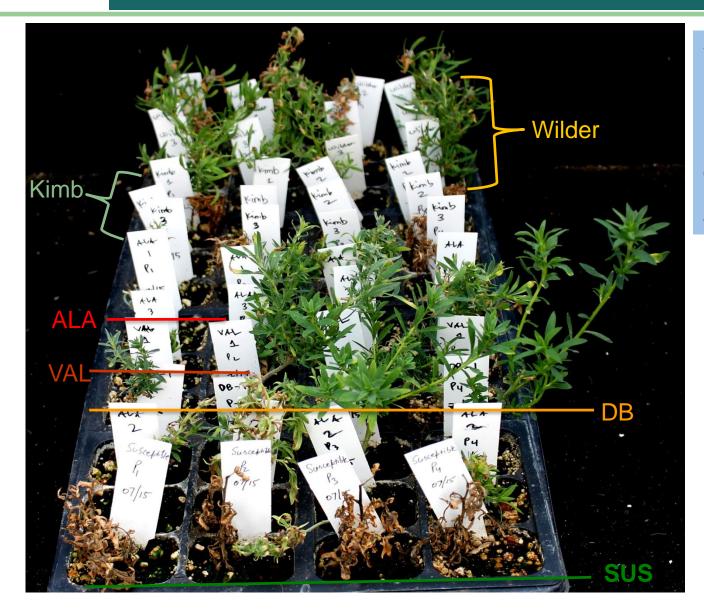
Glyphosate-Resistant Kochia Confirmed in Idaho/Oregon



Don Morishita¹, Joel Felix², Prashant Jha³ University of Idaho¹, Oregon State University², Montana State University³



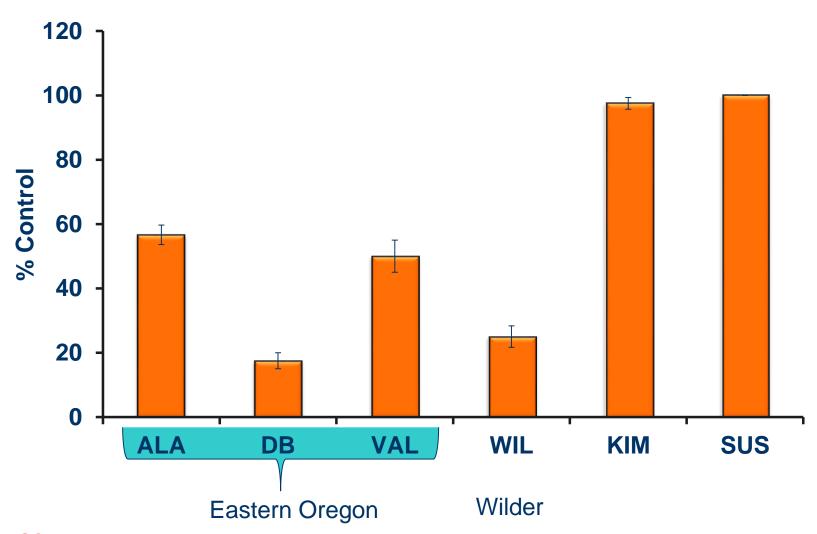
Kochia Survivors at 21 DAA



*Glyphosate (R Powermax) at 1.68 kg ae ha⁻¹ (44 oz/a) + AMS at 2% w/v



Kochia Control 21 DAA 44 oz/a Roundup





Kochia Survivors 44 oz/a Roundup; 110 DAA









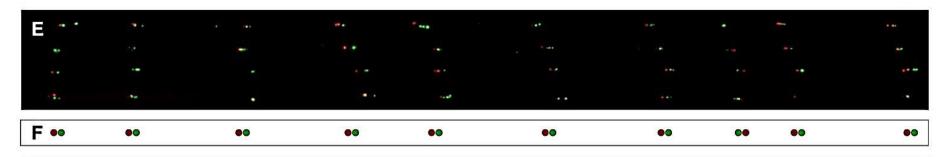


Glyphosate Resistance Mechanism

- No point mutation at the Pro107 position
- No reduced absorption/translocation
- Overexpression of EPSPS gene (Amplification)



EPSPS amplification in GR kochia



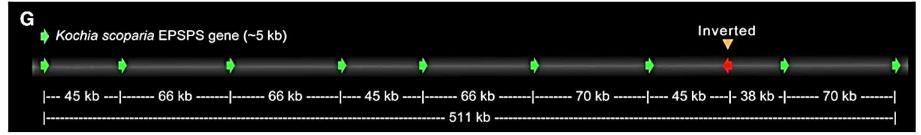


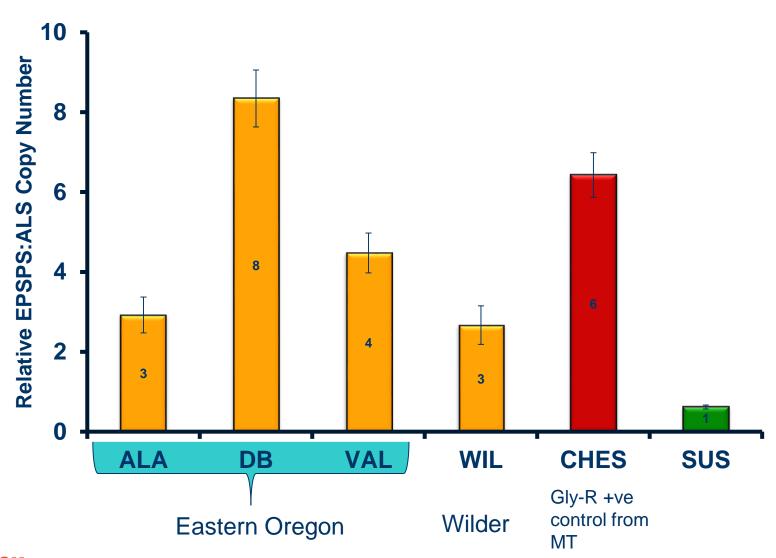
Figure 2.

F and G represent orientation of *EPSPS* copies and estimated distance between two adjacent *EPSPS* copies based on D and E. Red signal (approximately 1.9 kb) and green signal (approximately 2.5 kb) encompass the entire length of *EPSPS* in *K. scoparia*. Measurement of the cluster of *EPSPS* genes was $511.8 \pm 26.0 \text{ kb}$ (n = 7) in length. Bar = $10 \mu \text{m}$.

Jugulam et al., 2014. Tandem Amplification of a Chromosomal Segment Harboring 5-Enolpyruvylshikimate-3-Phosphate Synthase Locus Confers Glyphosate Resistance in *Kochia scoparia*. Plantphysiol.org 166:1200-1207



EPSPS Gene Amplification





On-Going Investigation and Significance of the Problem

- Dose-response for R:S ratio
- Correlation of enhanced EPSPS gene copy numbers with resistance level
- Inheritance pattern investigated
 - Monogenic Mendelian; F2 generation segregate in 3:1 (R:S)

Kochia is highly cross pollinated



Rapid spread of glyphosate-resistant populations, if not managed



Limited options for kochia control in Roundup Ready Sugar beet



Sugarbeet – Eastern Oregon 2014



Sugarbeet – Eastern Oregon 2014



Sugarbeet field – Eastern Oregon 2014





Eastern Oregon – 10/6/2014





Sugarbeet field – Eastern Oregon 2014





Sugarbeet field – Eastern Oregon 2014



Sugar beet field – Eastern Oregon 2014





Ditch bank on the Oregon slope





Glyphosate Res. Kochia Trail in Kansas



Figure 1.1 Trail of kochia plants in a glyphosate-resistant (GR) soybean field near Colby, KS in 2007 that survived three in-season glyphosate applications. The dispersal plant came from an adjacent GR corn field.



Current Glyphosate Formulations

- US patent for glyphosate expired in 2000
- There are now multiple glyphosate products marketed by many companies

Accord, Alecto 41, Atila, Aquamaster, Aqua Neat, Aqua Pro, Avocet, Biomaxx, Buccaneer, Campaign, Catt Plex, Cinco, Clearout, Cornerstone, Credit, Debit, Duplicator, Duramax, Durango, Eagre, Eraser, Fireball, Forest Star, Gly 4, Glyfos, Glygram, Glyphogan, Glyphomax, Gly Pro, Glystar, Glyphomate, Glyphosate 4, Glyphosate 41, Glyphosate Plus, Helosate, HM-2028, Honcho, Kill-Zall, Kleenup, Knockout, Mad Dog, Makuze, Mirage, Pondmaster, Pronto, Prosecutor, Ranger, Rascal, Rattler, Razor Pro, Terminator, Remuda, Rodeo Roundup, RT, Strike Out, Supersate, Touchdown, Traxion, Wise Up (and many many others)



Components of a glyphosate product

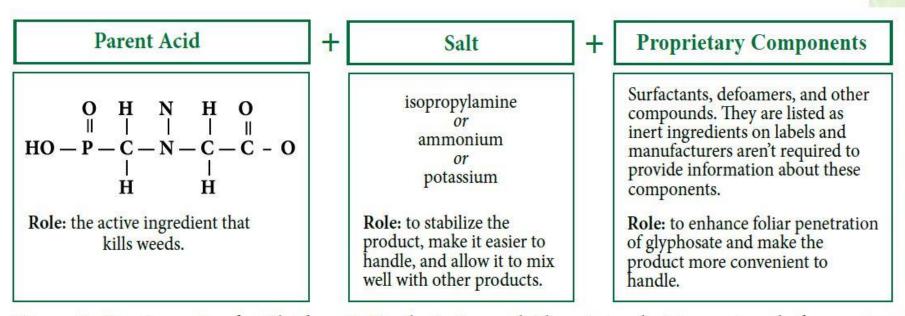


Figure 1. Components of a Glyphosate Product. Every glyphosate product is composed of three parts: the parent acid, salt, and proprietary components.



Some Glyphosate Formulations

Trade Name	Formulated Salt	Concentration		0.75 lb ae product rate
		lb ai/gal	lb ae/gal	(oz/acre)
Roundup WeatherMax	K	5.5	4.5	22
Roundup PowerMax	K	5.5	4.5	22
Roundup Ultra	IPA	4	3	32
Touchdown CT	K	4.17	3.5	24
Touchdown HiTech	K	6	5	19
Touchdown Total	K	5	4.2	24
Durango DMA	DA	5.4	4	24
Glyphomax XRT	IPA	5.4	4	24
Cornerstone	IPA	4	3	32
Cornerstone 5 Plus	IPA	5.4	4	24
Extra Credit 5	IPA	5	3.7	26



Roundup PowerMax Label





Specially formulated for Roundup Ready*crops

GROUP 9 HI

Complete Directions for Use

EPA Reg. No. 524-549

AVOID CONTACT OF THIS HERBICIDE WITH FOLIAGE, GREEN STEMS, EXPOSED NON-WOODY ROOTS OR FRUIT OF CROPS (EXCEPT AS SPECIFIED FOR INDIVIDUAL ROUNDUP READY® CROPS), DESIRABLE PLANTS AND TREES, AS SEVERE INJURY OR OF STRUCTION COULD BESULT.

Herbicide for Roundup Ready Crops

Selective broad-spectrum weed control in Roundup Ready crops

Non-selective, broad-spectrum weed control for many agricultural systems and farmsteads

Not all products listed on this label are registered for use in California. Check the registration status of each product in California before using.

Read the entire label before using this product.

Use only according to label instructions.

Read the "LIMIT OF WARRANTY AND LIABILITY" statement at the end of the label before buying or using. If terms are not acceptable, return at once unopened.

THIS IS AN END-USE PRODUCT. MONSANTO COMPANY DOES NOT INTEND AND HAS NOT REGISTERED IT FOR REFORMULATION. SEE INDIVIDUAL CONTAINER LABEL FOR BEDACKACHUS LIMITATIONS.

1.0 INGREDIENTS

ACTIVE INGREDIENT

*Glyphosate, N-(phosphonomethyl)glycine, in the form of its potassium salt

THE RINGREDIENTS: \$1.3%

100.0%

*Contains 660 grams of the active ingredient glyphosate, in the form of its potassium

salt, per liter or 5.5 pounds per U.S. gallon, which is equivalent to 540 grams of the acid, glyphosate, per liter or 4.5 pounds per U.S. gallon (39.8% by weight).

This product is protected by U.S. Patent No.s. 5.668.085, RE 37.866 and 6.365.551.

This product is protected by U.S. Patent No's. 5,668,085, RE 37,866 and 6,365,551 Other Patents Pending. No license granted under any non-U.S. patent(s).

2.0 IMPORTANT PHONE NUMBERS

 FOR PRODUCT INFORMATION OR ASSISTANCE IN USING THIS PRODUCT,

CALL TOLL-FREE, 1-800-332-3111
2. IN CASE OF AN EMERGENCY INVOLVING THIS HERBICIDE PRODUCT, OR FOR MEDICAL ASSISTANCE, CALL COLLECT, DAY OR NIGHT.
(314)-934-4000

3.0 PRECAUTIONARY STATEMENTS

2.1 Hazards to Humans and Domestic

1.0 INGREDIENTS

ACTIVE INGREDIENT:

*Contains 660 grams of the active ingredient glyphosate, in the form of its potassium salt, per liter or 5.5 pounds per U.S. gallon, which is equivalent to 540 grams of the acid, glyphosate, per liter or 4.5 pounds per U.S. gallon (39.8% by weight).

socks, shoes, and chemical resistant gloves made or any waterproof material such a polyethylene or polyvinyl chloride.

Follow manufacturer's instructions for cleaning/maintaining PPE (Personal Protective Equipment). If no such instructions for washables exist, use detergent and hot water. Keep and wash PPE separately from other laundry.

Discard clothing and other absorbent materials that have been drenched or heavily contaminated with this product's concentrate. Do not reuse them,

When handlers use closed systems, enclosed cabs, or aircraft in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides (40 CRT 170 240 (i) (4-61), the handler PPE requirements may be reduced or modified as specified in the WPS

IMPORTANE When reduced PPE is worn because a closed system is being used, handlers must be provided all PPE specified above for "applicators and other handlers" and have such PPE immediately available for use in an emergency, such as a spill or equipment breakdown.



Drexel Imitator® Plus

41% Glyphosate Concentrate with Full Surfactant Load. For use on Roundup Ready® crops, including Flex cotton.



GROUP 9 HERBICIDE

Imitator[®] Plus

Herbicide

Avoid herbicide contact with foliage, green stems, non-woody roots or fruit of crops, desirable plants a because severe injury or destruction may result.

ACTIVE INGREDIENT:

Glyphosate in the form of its isopropylamine salt*.....

OTHER INGREDIENTS:

TOTAL:....

* Contains 480 grams per liter or 4 pounds per U.S. gallon of ingredient glyphosate, in the form of its isopropylamine sal lent to 356 grams per liter or 3 pounds per U.S. gallon of glyphosate.

KEEP OUT OF REACH OF CHILDR

CAUTION See FIRST AID Below

ACTIVE INGREDIENT:

Glyphosate in the form of its

TOTAL:...... 100.0%

* Contains 480 grams per liter or 4 pounds per U.S. gallon of the active ingredient glyphosate, in the form of its isopropylamine salt. Equivalent to 356 grams per liter or 3 pounds per U.S. gallon of the acid, glyphosate.



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Are these superweeds?

- The media has christened herbicide resistant weed 'superweeds'
- The Weed Science Society of America (WSSA) conducted a Summit on the "Wicked" Problem of Herbicide Resistance
 - http://wssa.net/weed/resistance-summit-ii/
- Weed Scientists Uproot Common "Superweed" Myths



Superweed Myths

- Fallacy 1: Superweeds are a product of rampant gene transfer from genetically modified field crops.
- The truth: There is no evidence that gene transfer is a major factor in the development of herbicide resistance.
 - The true culprit, is overreliance on a single class of herbicides to control weeds, resulting in selection for weeds that can survive the products in that class.



Superweed Myths

- Fallacy 2: Superweeds have supercharged abilities to muscle out competing plants in new and more aggressive ways.
- **The truth:** All weeds herbicide resistant or not can outcompete desirable plants for water, nutrients, sunlight and space.
 - They grow by leaps and bounds and can be prolific seed producers.
- The key to keep weeds from causing dramatic changes in crop production is to adopt effective management strategies.

http://wssa.net/2014/10/weed-scientists-uproot-common-superweed-myths/



Mixed Messages



- Control kochia in each crop in a rotation
- Do not ignore fencelines and ditch-banks



 It takes more than yourself using resistance management practices to prevent the spread



Fence-lines Could be the Main Source







Kochia, Greeley County Kansas



Hitching a Ride

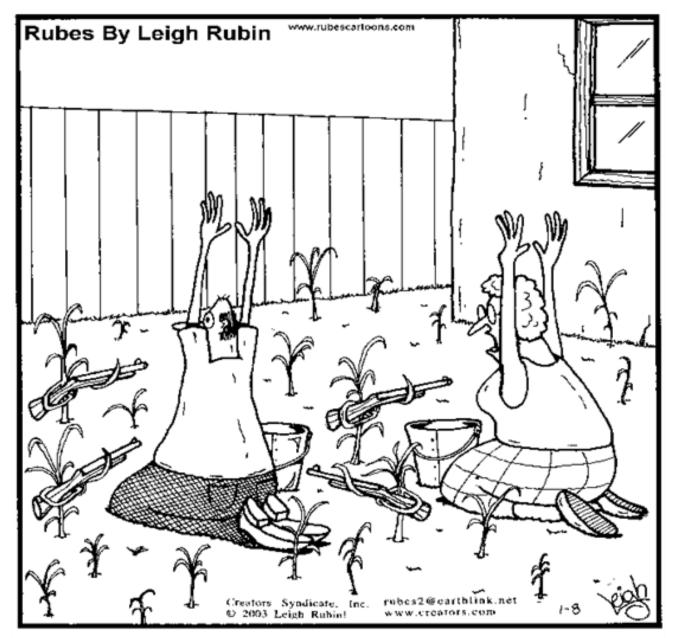




Take Home Message

- Good weed control in sugarbeet will increasing be dependent on management in rotational crops
 - Use diverse crop rotations
 - Multiple herbicide modes of action
 - Do not allow weeds to go to seed if possible
 - Avoid using glyphosate every year in the same field





"We never should have waited this long ... Now the weeds have *completely* taken over."