



NSC 2019 Winter Conference: Silviculture Practices for Changing Forest Landscapes, Values, and Expectations

February 26-27, 2019

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Dr. Lisa Wood
University of Northern British Columbia

LONG TERM PERSISTENCE

*Glyphosate in forest plants –
What do we really know?*



OUTLINE

- What do we know about glyphosate?
- Why are we still studying glyphosate: What don't we know?
- What are the issues?
- How can we identify if there are risks associated with the unknown?
- What are the management implications?





WHAT DO WE KNOW

*Glyphosate in plants
and environment*

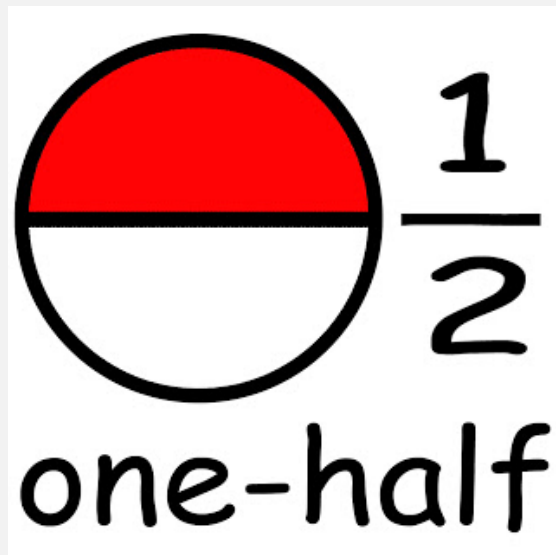


WHAT WE DO KNOW

Acute toxicity well researched.

1. Glyphosate is not acutely toxic to large mammals.
2. Glyphosate is water soluble.
3. Little to no bioaccumulation within animal body.
4. Glyphosate kills plants.





WHAT WE DO KNOW

Up to half-life well researched.

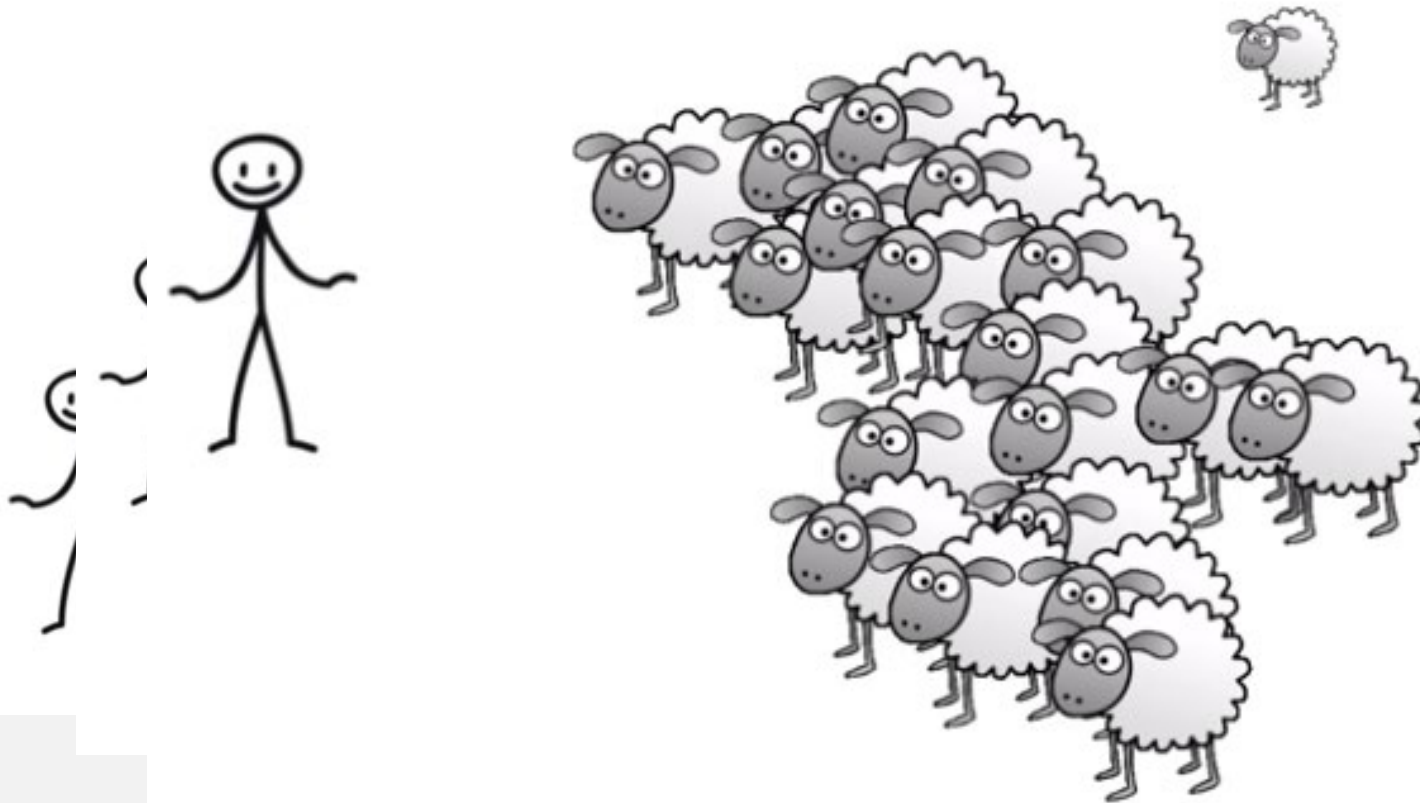
1. Degrades by microbial action *in soil* » Half-life dictated by biological metabolism.



*1 day = half of all black sheep become white and
5 days = all sheep to turn white.*

Half-life = 1 day (when living on Farmer Lisa's land)

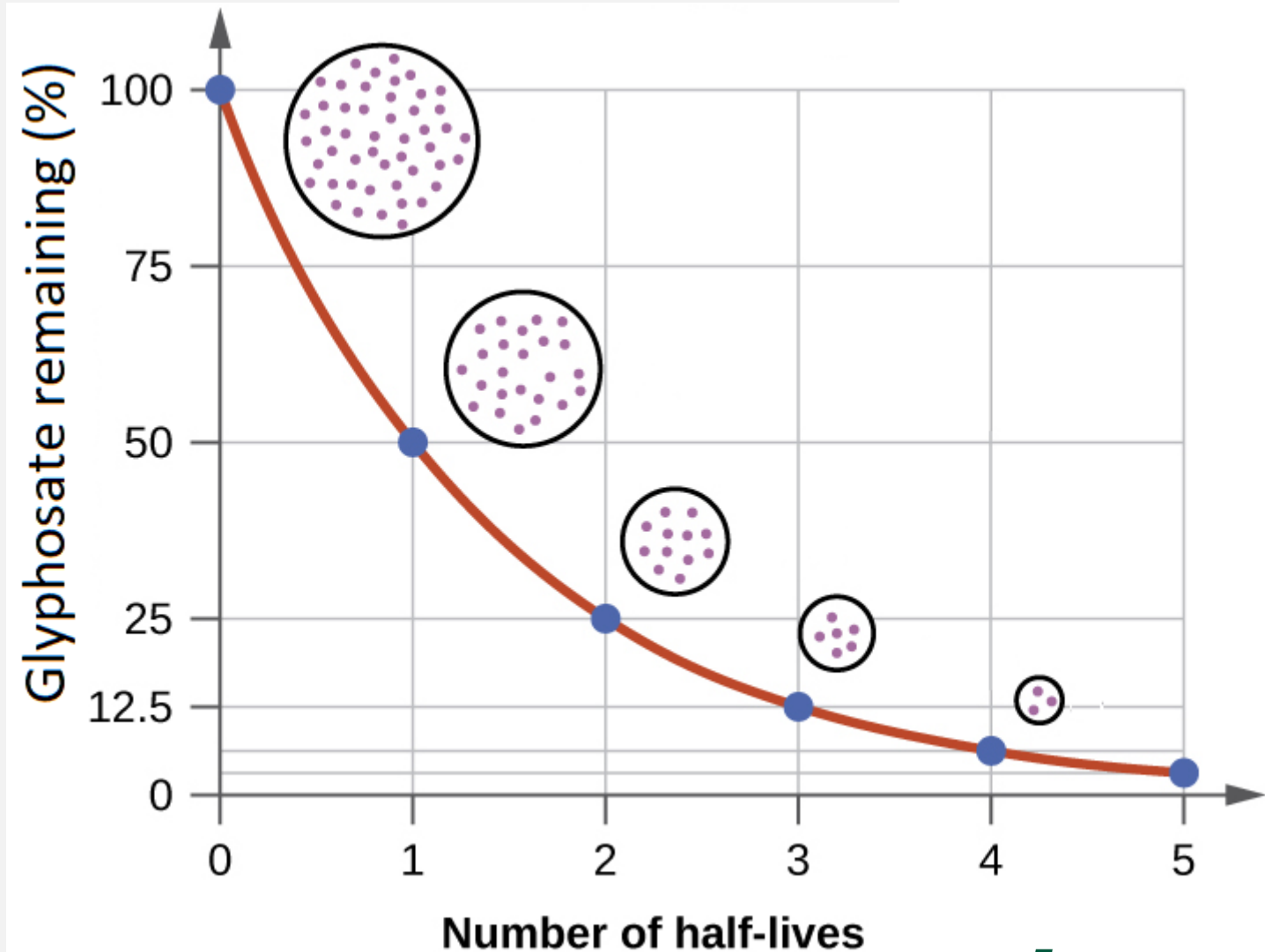
Day 4

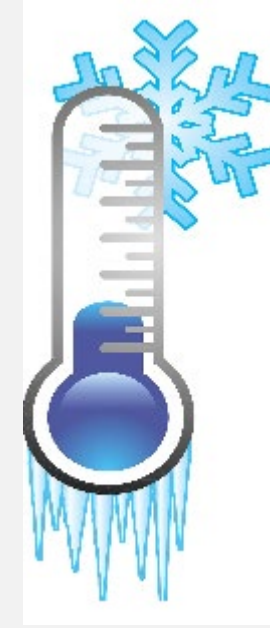
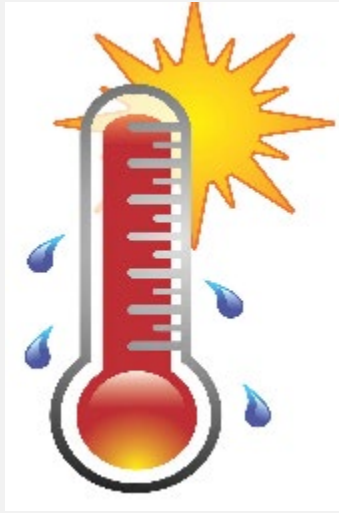


*Depends on substrate
of interaction.*

GLYPHOSATE

7-60 days in soil
*End point depends on
initial concentration*
*End point depends on the
availability and action of
microbes*





What is the difference in half-life by climate zone?

Degrades by microbial action »
Half-life dictated by
biological metabolism.

PLANT SURVIVAL



*Glyphosate doesn't always kill
the plant*

WHAT WE DO KNOW

Plants have different levels of tolerance for glyphosate.

If a plant survives: localization, mutation, metabolism? (mechanisms of tolerance and resistance)



LOCALIZATION

A plant pushes all the glyphosate residue to one spot and keeps on growing.

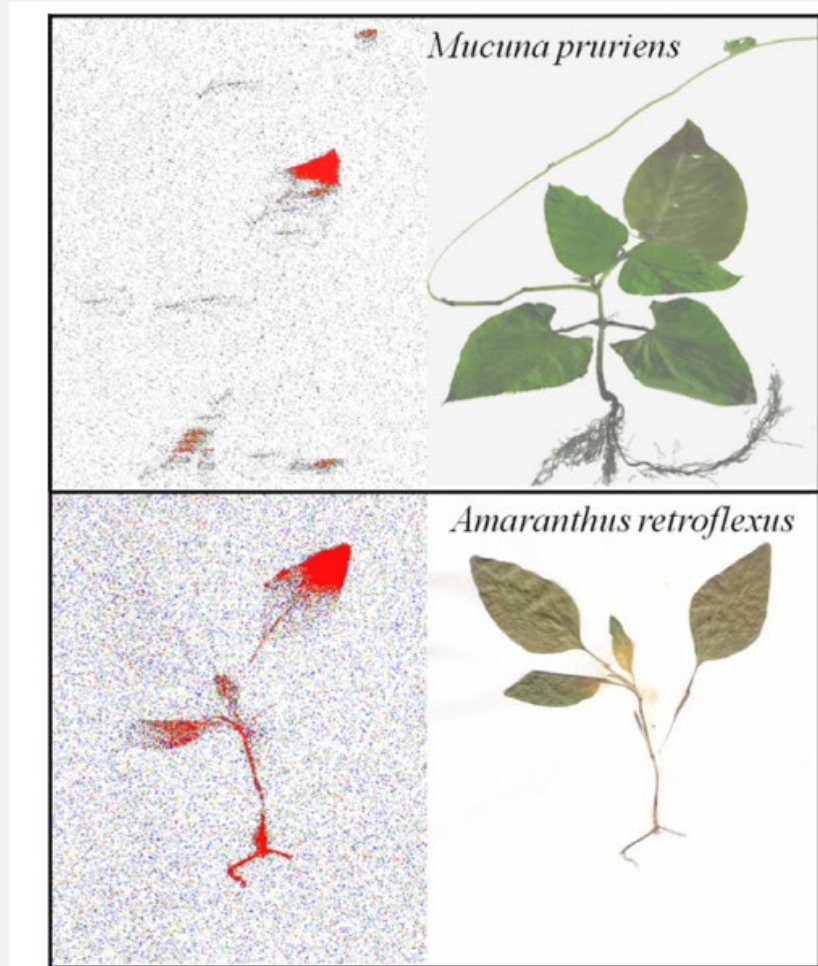


Fig. 5. Phosphor images of *M. pruriens* and *A. retroflexus* 96 HAT. *M. pruriens* plants retained more labeled glyphosate in treated leaves, and translocated less herbicide to the rest of the plant, than did *A. retroflexus* plants.

Rojano-Delgado, AM. et al. /
Phytochemistry 73 (2012) 34–41

Sammons, RD and Gaines TA.
Pest Manag Sci 2014; 70: 1367–
1377

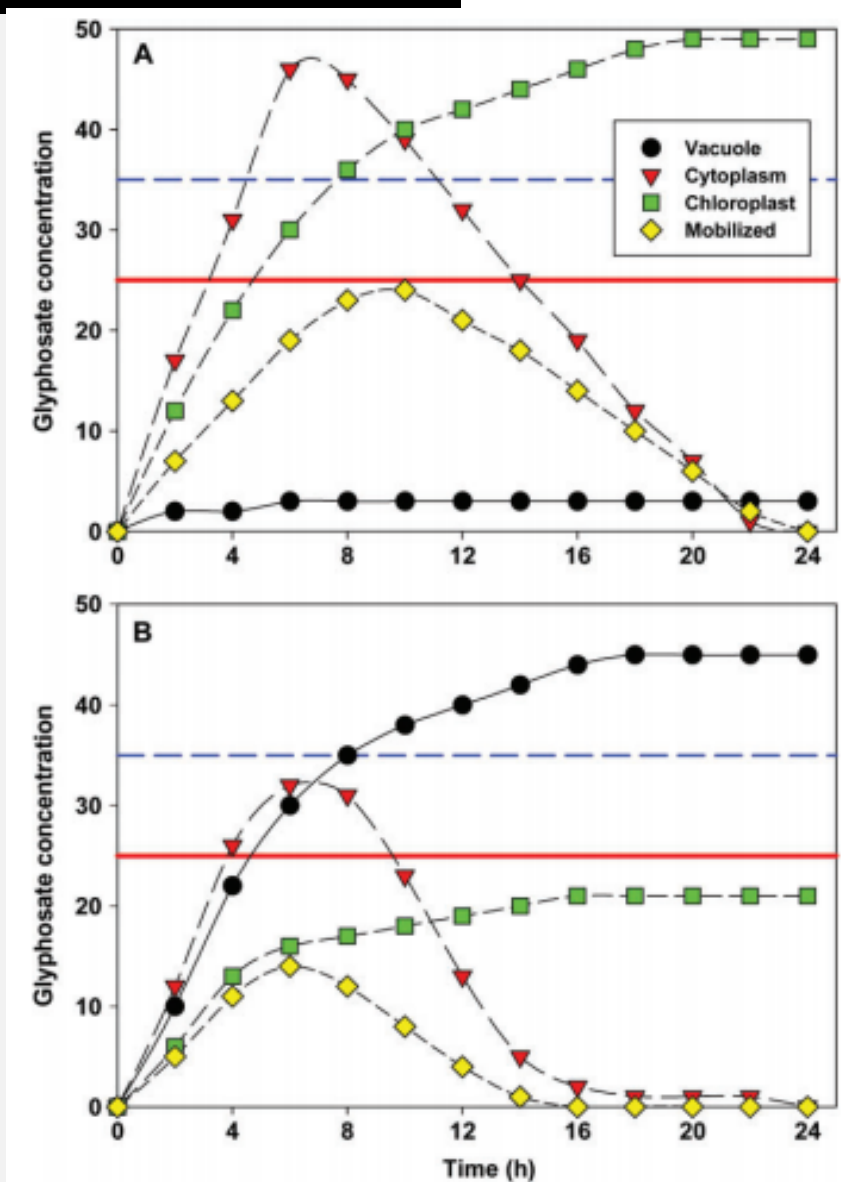


Figure 1. A theoretical cellular-level model of glyphosate uptake and distribution for (A) a normal, glyphosate-susceptible source cell and (B) a glyphosate-resistant source cell using the vacuole to sequester glyphosate. The units for glyphosate are relative concentration, with a theoretical chloroplast minimum inhibitory concentration (25) indicated by a red line, and a chloroplast glyphosate concentration (35) consistent with saturated inhibition indicated by a dashed blue line.

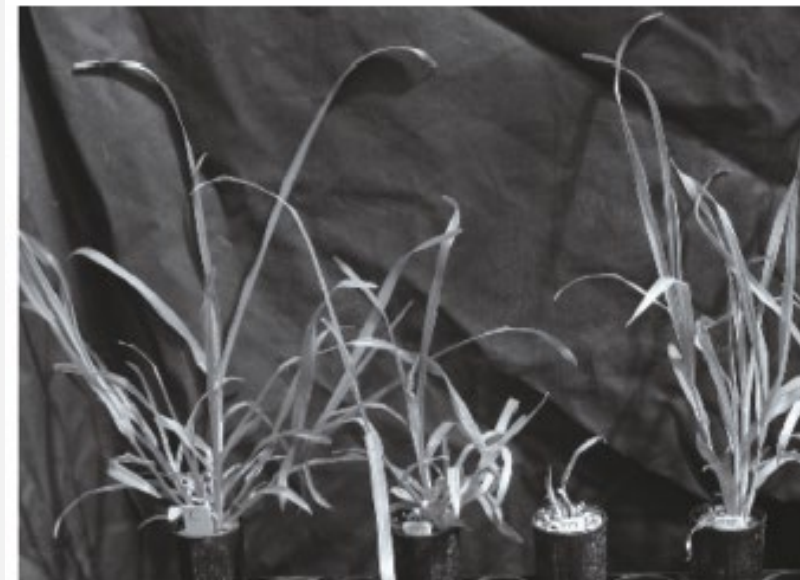
MUTATION

A plant alters the site of interaction (EPSPS) – and keeps on growing.

	103	A	M	R	S/P	L	T	108
TennGR:		GCA	ATG	CGA	TCA	TTG	ACA	
TennGS:		...	...	...	C..	...	...
	142	Q	L	G	A	D	V	147
TennGR:		CAG	CTT	GGT	GCG	GAT	GTT	
TennGS:		...	...	...	..A	...	...
	197	E	I	E	I	I	D	202
TennGR:		GAG	ATT	GAA	ATC	ATT	GAT	
TennGS:		...	...	...	..A	...	...

Fig. 1 Sequence comparison of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) gene from glyphosate-resistant (TennGR) and sensitive (TennGS) plants. Three polymorphisms were found in the exons. Regions of homology are indicated by dots. Numbering is consistent with that used previously for goosegrass EPSPS (GenBank AJ417033) from Baerson *et al.* (2002).

Goosegrass experiment.



Non-treated

PS

PP

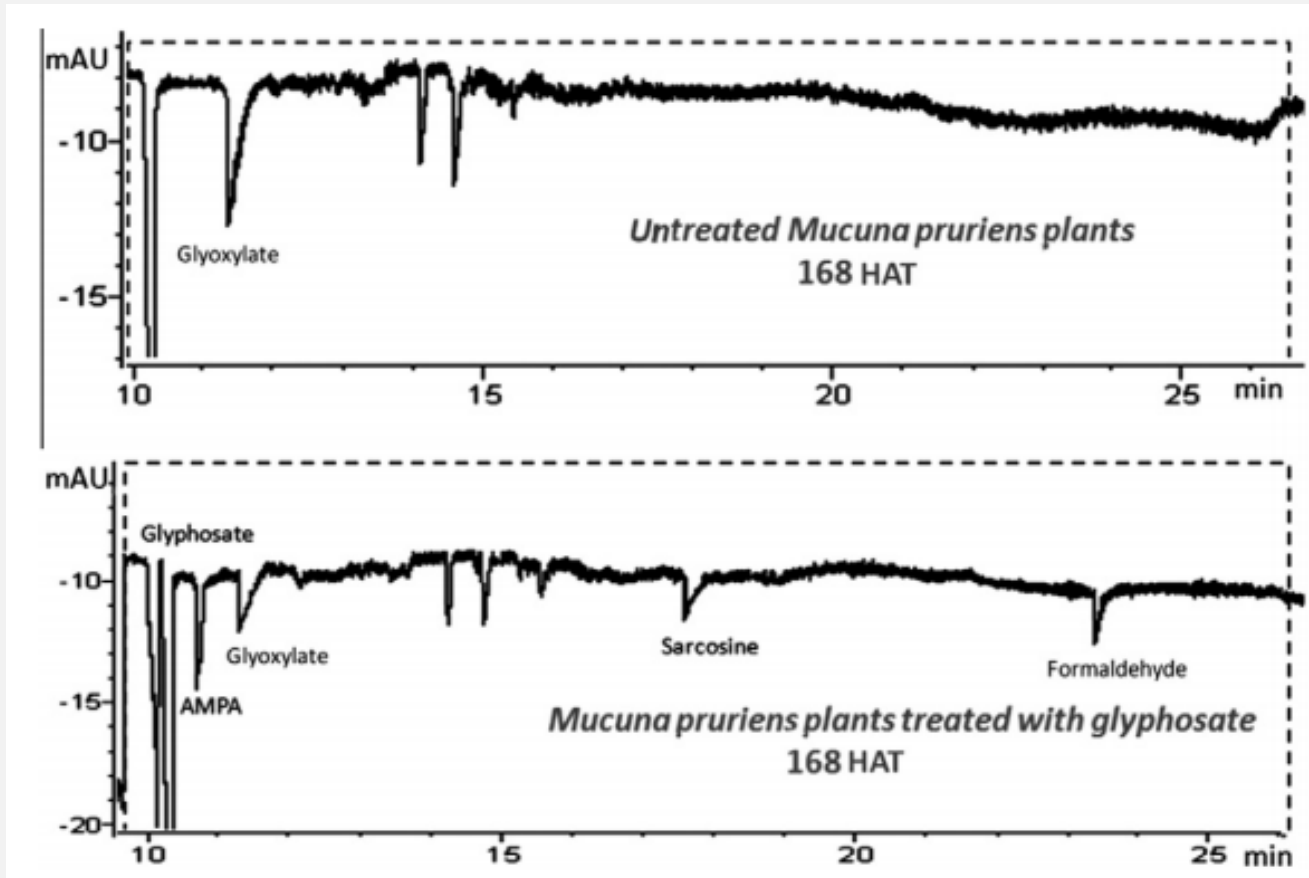
SS

☐ SS Resistant
☒ PS Intermediate
☒ PP Sensitive

Janel L Huffman et al. Journal of Integrative Agriculture
2016, 15(6): 1304–1312

METABOLISM

A plant activates and regulates the breakdown of glyphosate to AMPA, and keeps on growing.



We don't understand HOW.

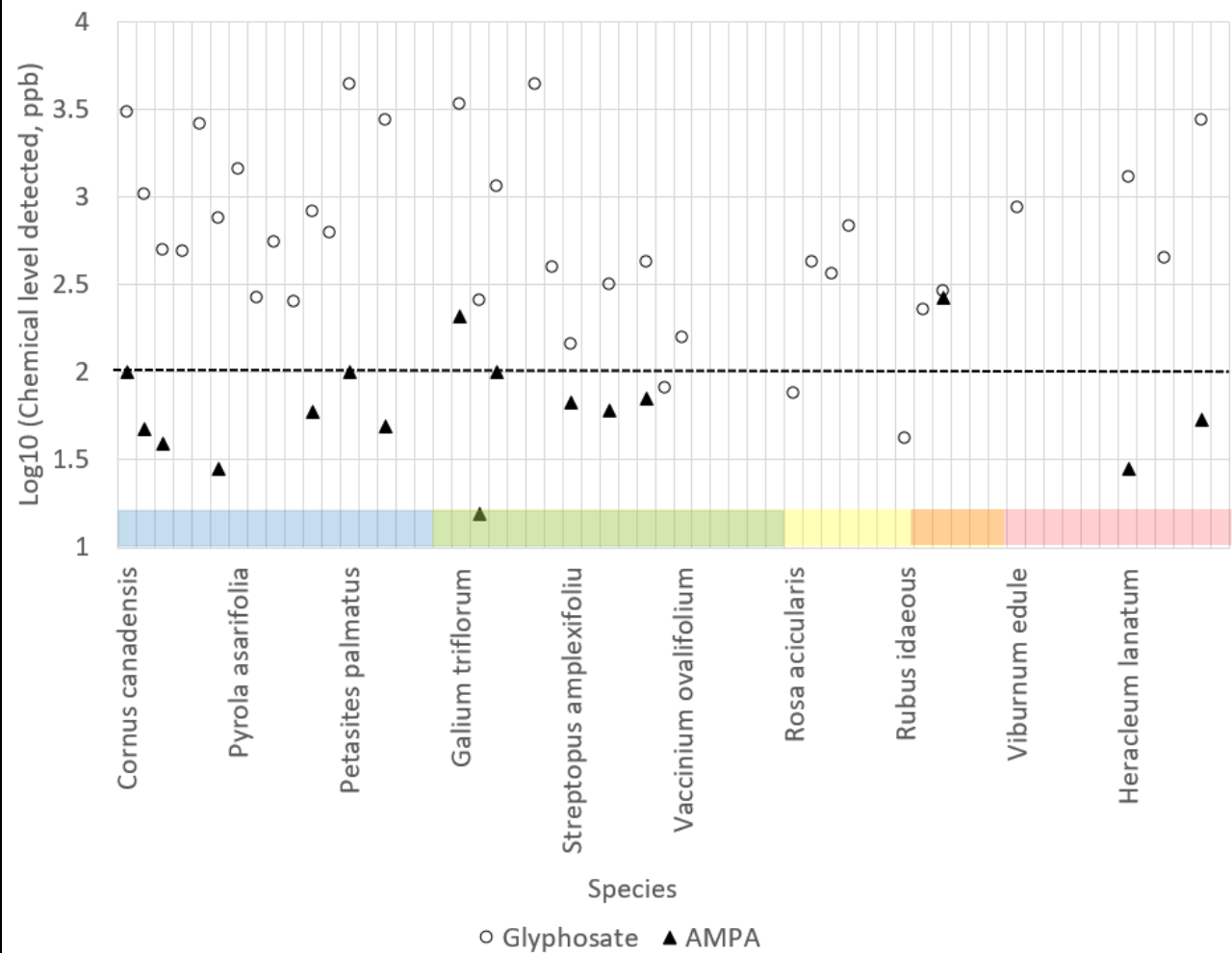
- Breakdown reported by some authors.
- Evidence of a gene responsible through presence of AMPA.
- No identified plant gene...yet.

A.M. Rojano-Delgado et al. / Phytochemistry 73 (2012) 34–41

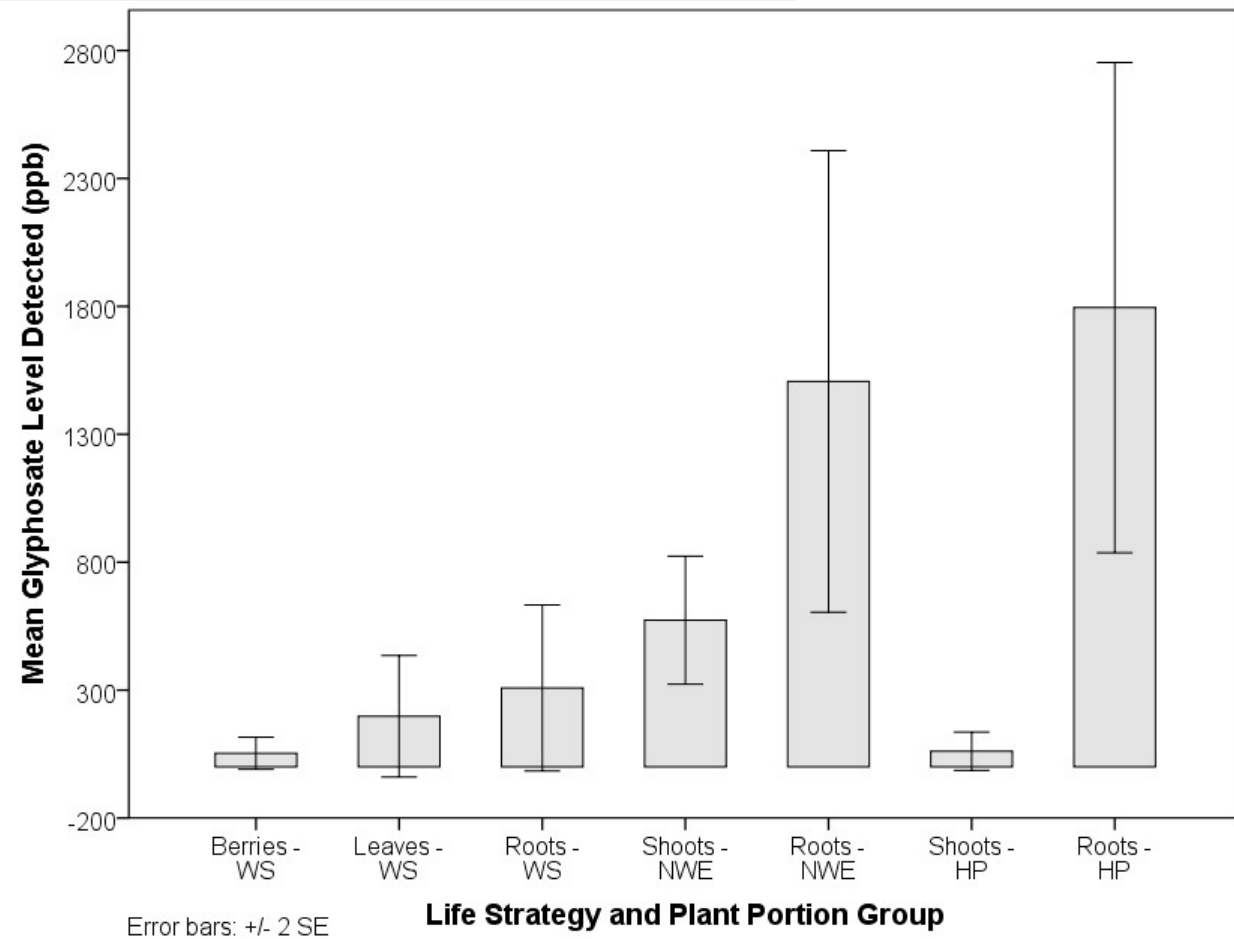
ONE- YEAR OF PERSISTENCE

Average detection

By Species



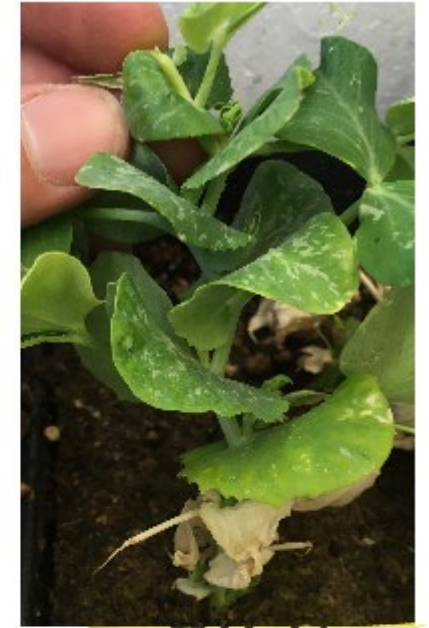
By Perennation Type



PERENNIAL AND ANNUAL PLANTS

Life Strategy:

- Some plants store energy in roots and regrow new shoots as required.
- Some plants allocate all energy to shoot and fruit production in an attempt to maximize reproduction.





WHAT DON'T WE KNOW

*Glyphosate in plants
and environment*

WHAT WE DON'T KNOW

Do low levels of persistent glyphosate
have chronic effects over time?

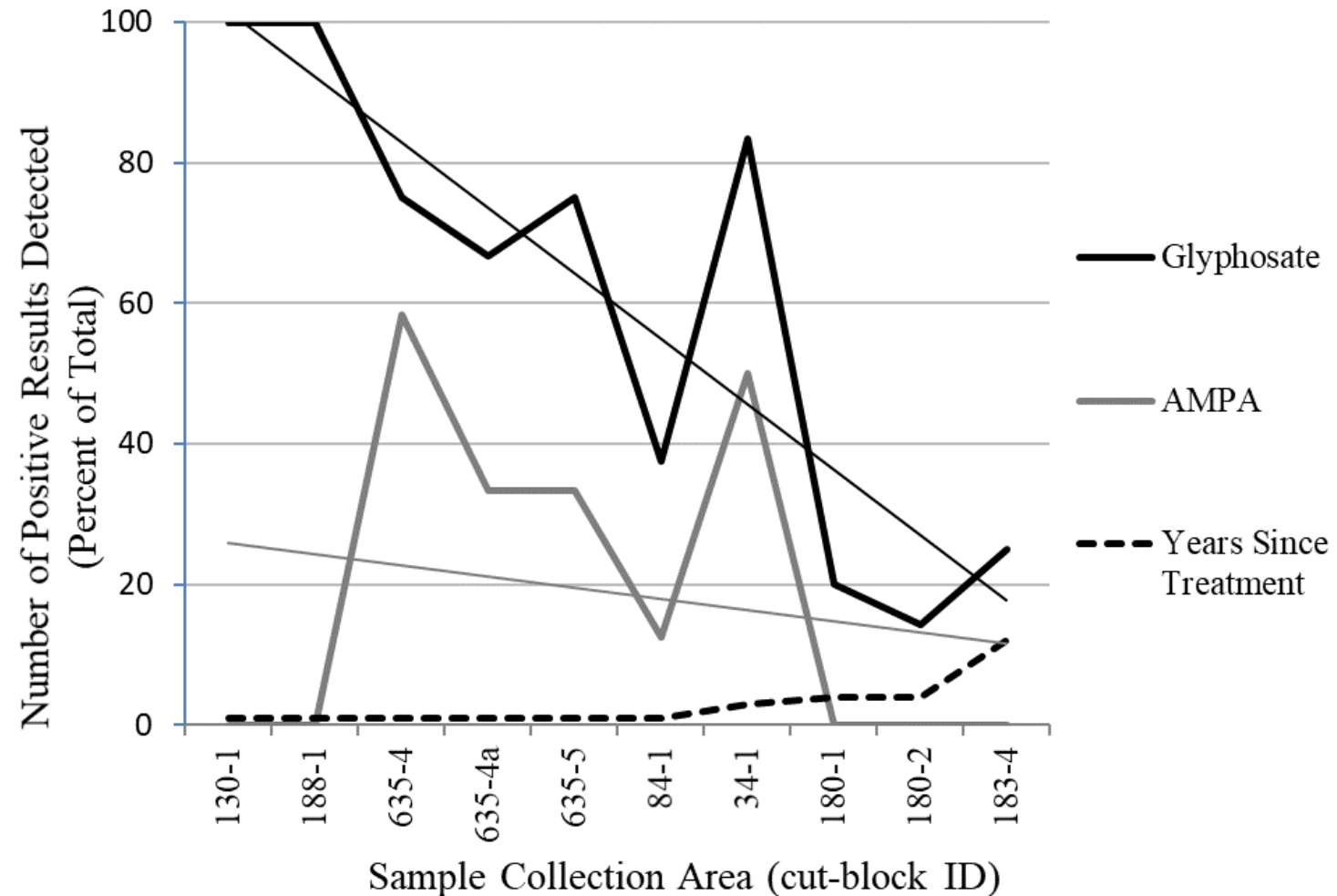


CHRONIC EFFECTS

Low levels of glyphosate are not acutely toxic to most things at applied concentrations, but what about chronic effects?

Evidence of long term persistence in living plants

Perennial plant survives treatment, and does not interact with soil microbes



WHAT WE DON'T KNOW

Do low levels of persistent glyphosate have chronic effects over time?

Does glyphosate interact with other naturally-occurring chemicals or ions?
(and if so, which ones? How? When?)



CHEMICAL INTERACTION

Ions, elements, and compounds like to attract or repel one another.

Contradictory Evidence...

Environ Sci Pollut Res

Table 4
Effect of increasing glyphosate rates on the concentrations of mineral nutrients in mature grains of soybean plants grown under greenhouse conditions. The values represent means of six independent replications.

Glyphosate rate (% of recommended) ^a	N (g kg ⁻¹ DW)	P (g kg ⁻¹ DW)	K (g kg ⁻¹ DW)	Ca (g kg ⁻¹ DW)	Mg (g kg ⁻¹ DW)	Fe (mg kg ⁻¹ DW)	Mn (mg kg ⁻¹ DW)	Zn (mg kg ⁻¹ DW)	Cu (mg kg ⁻¹ DW)
0	46	5.9	14.1	3.9	2.4	71	56	44	11
0.3	46	6.0	14.0	4.0	2.4	65	46	43	10
0.6	46	6.2	13.8	3.7	2.4	76	43	43	9
0.9	50	6.1	14.0	3.1	2.3	61	33	48	12
1.2	62	6.1	14.7	2.9	2.1	36	31	58	13
LSD _{0.05}	3	NS	0.5	0.6	0.2	13	8	5	2

^a Glyphosate was applied to foliage at the concentrations of 0.3% (95 μM glyphosate), 0.6% (189 μM glyphosate), 0.9% (284 μM glyphosate) and 1.2% (379 μM glyphosate) of the recommended application rate (31.55 mM) for weed control.

Stability constants were measured by potentiometric pH titration at a ionic strength of ¹ I = 0; ² I = 0.1 M KNO₃; ³ information not given

WHAT WE DON'T KNOW

Do low levels of persistent glyphosate have chronic effects over time?

Does glyphosate interact with other naturally-occurring chemicals or ions?
(and if so, which ones? How? When?)

What is the extent of the morphological impacts of glyphosate application to plants?



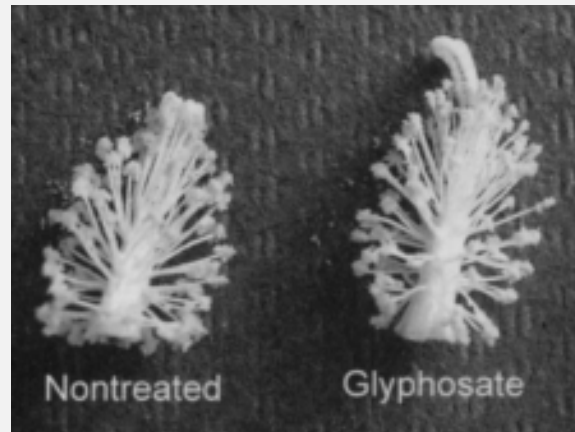
PLANT MORPHOLOGY

It's not always about the residual chemical.



Photo: Nicole Botten

Figure 4: Red raspberry plant, 1-year after treatment by glyphosate-based herbicide.



Very common to see morphological changes in surviving plants

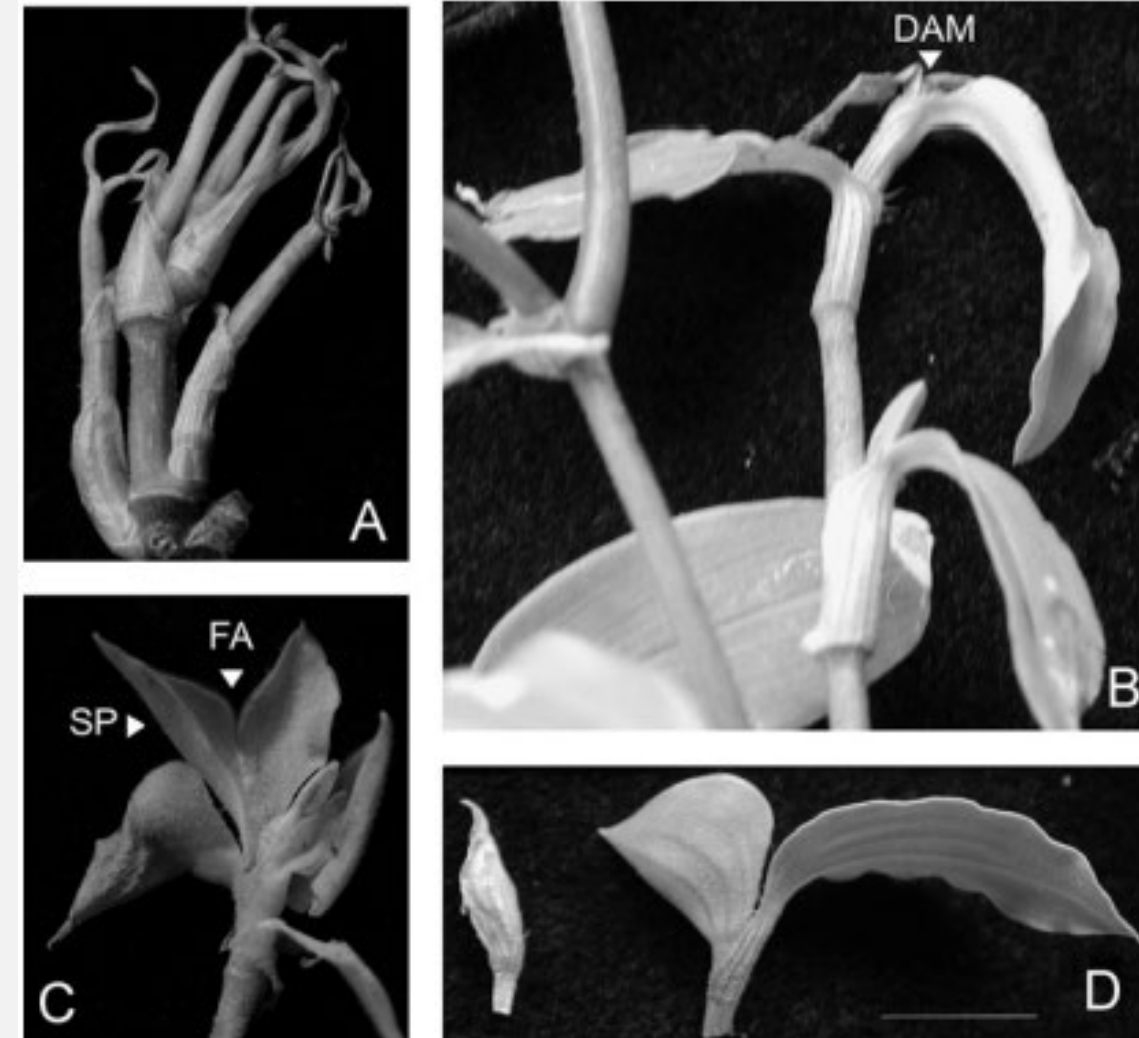


Fig. 3. Effects of the herbicide on the inflorescences and branches. (A) Simultaneous development of the leaf and its axillary bud, (B) death of the apical meristem (DAM), (C) flower abortion (FA), and spathes (SP), (D) small inflorescences. Scale=1 cm.

Pline et al. 2003. Weed Science, 51:19-27.

E.S. Panigo et al. / Ecotoxicology and Environmental Safety 76 (2012) 135–142

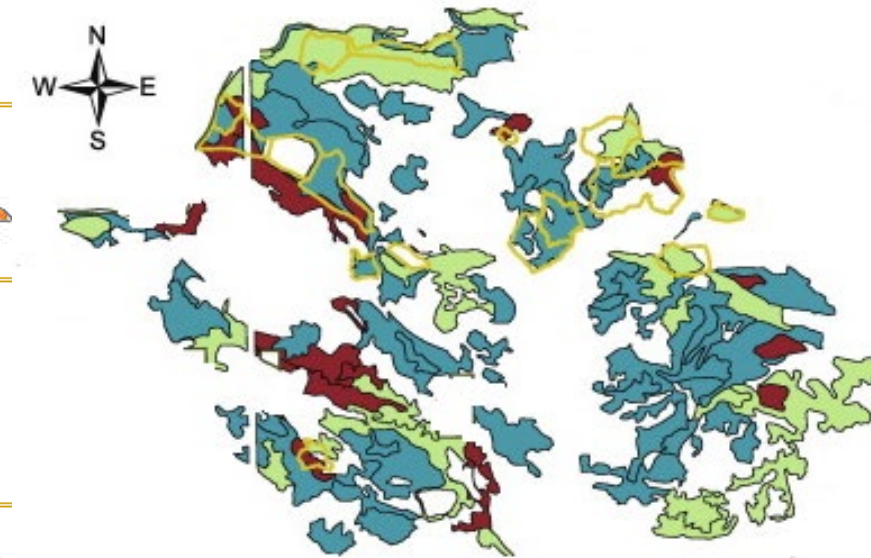
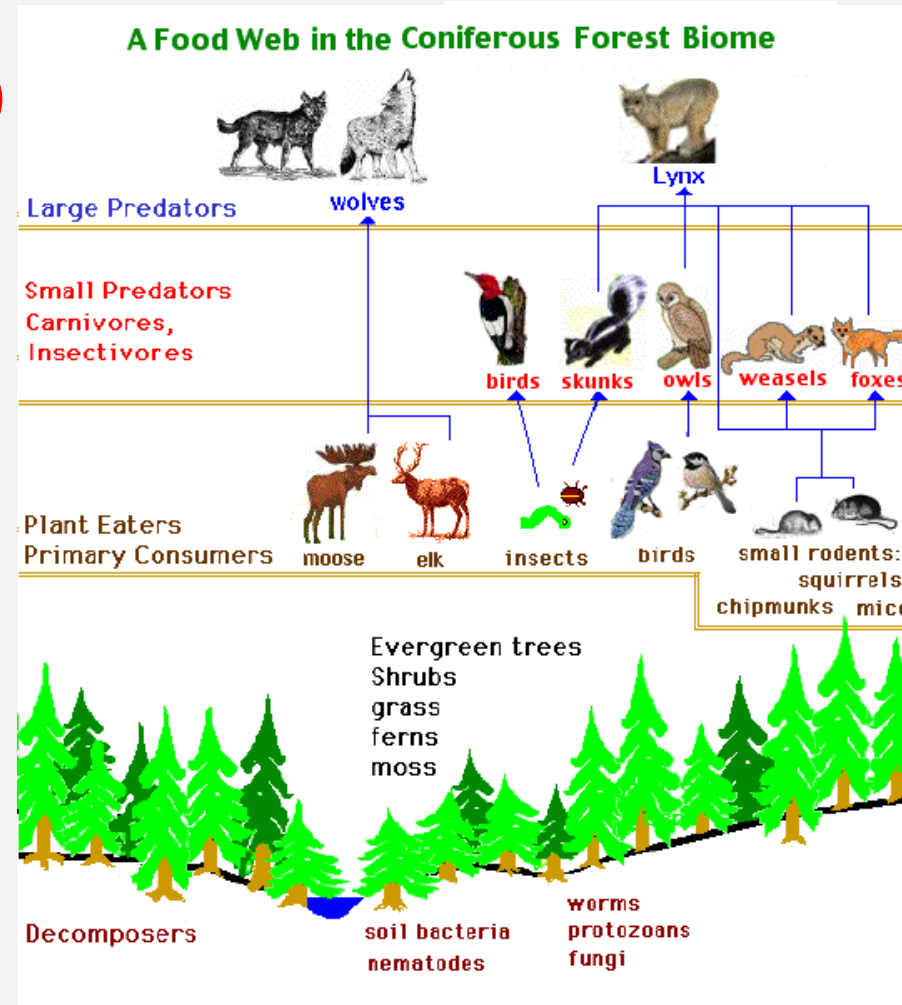
HOW CAN WE IDENTIFY RISK?

PROPER ASSESSMENT. MORE RESEARCH. RISK IS SUBJECTIVE.

- Direct vs Indirect

- Extent

- Human value systems



MANAGEMENT IMPLICATIONS

Awareness:

Applicators and/or decision makers need all the information to make good decisions.

Like all management, transparency is key for social license.

Action:

Development of applied tools to help make decisions.

» Keys based on species and site conditions.



THANK YOU



Dr. Lisa Wood ☎ +1 250 960 5352
Ecosystem Science and ✉ Lisa.wood@unbc.ca
Management, UNBC

