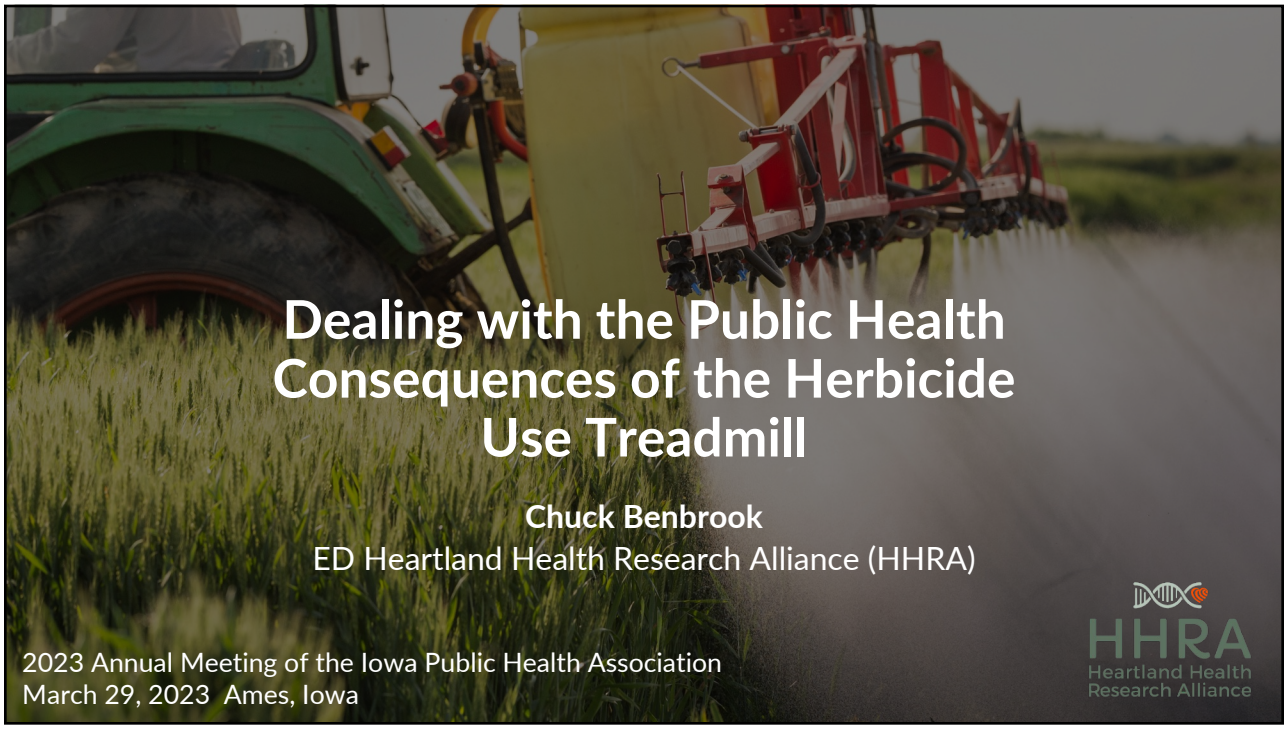
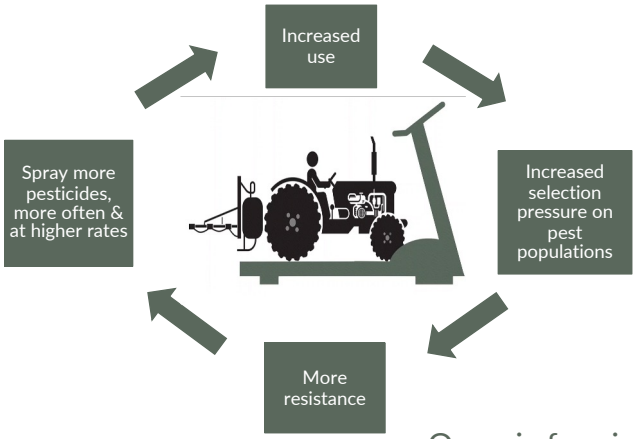


1

What Is Driving Rising Herbicide Use?

GMO Crops ⟶ **The Herbicide Treadmill**

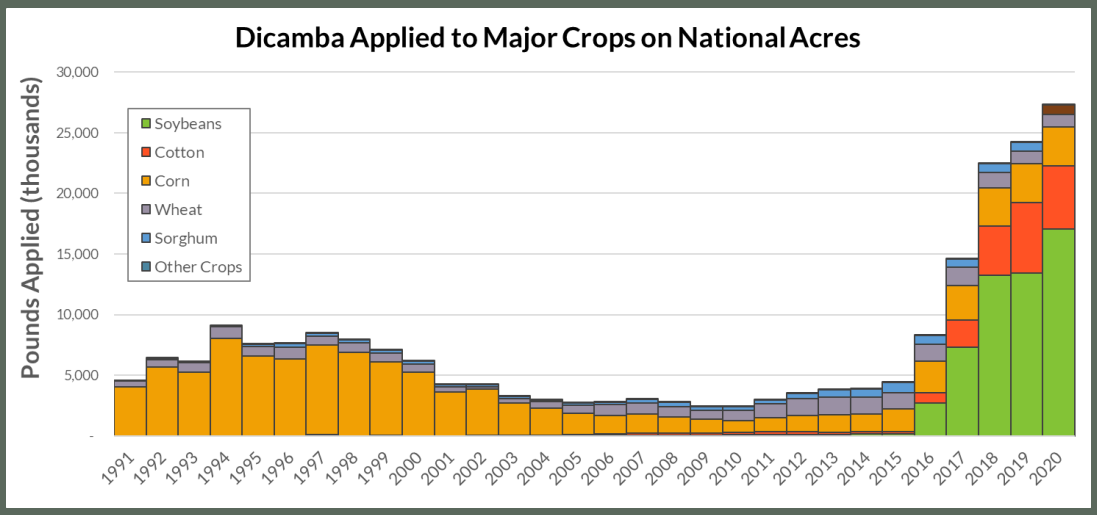


GMO crop systems usually work well for a few years, but then resistance emerges and conventional farmers are drawn onto the herbicide-use treadmill.

Organic farming pulls the plug on the herbicide treadmill. Regenerative ag… who knows?

2

Spread of GLY-Resistant Weeds Creates New Biz Opportunities – Dicamba Use Up Over 12-Fold



3

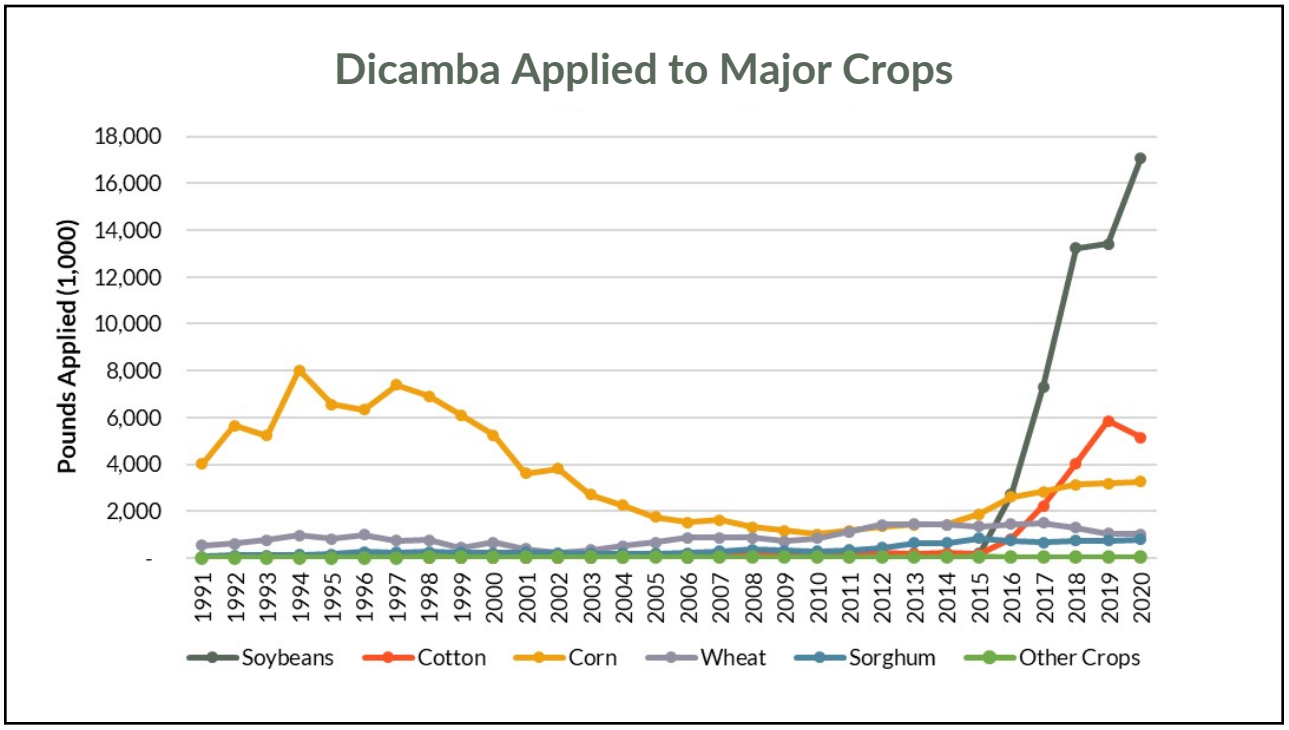
A Failing Technology

High-cost GE seeds resistant to multiple herbicides are the only game in town. Farmers are locked into technology that is failing. Resistance management boils down to spraying multiple modes of action (good for biz).

ROUNDUP READY 2 XTEND® SOYBEANS

Enlist Duo®
COLEX•D® technology
HERBICIDE

4



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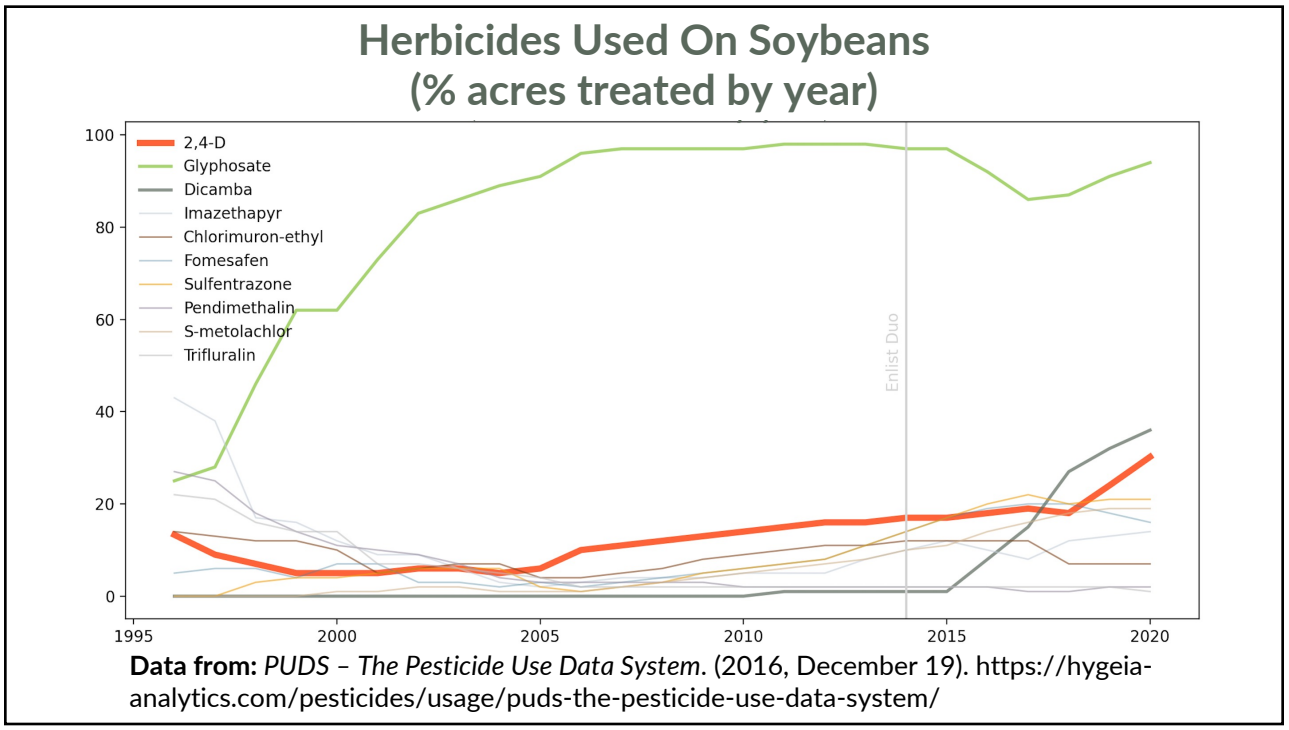


Data from: *PUDS – The Pesticide Use Data System*. (2016, December 19). https://hygeia-analytics.com/pesticides/usage/puds-the-pesticide-use-data-system/

6

What is the Most Hazardous Herbicide Used in Iowa?

CIVIL EATS

Paraquat, the Deadliest Chemical in US Agriculture, Goes on Trial

Amid lawsuits filed by thousands of farmers linking the herbicide to Parkinson's disease, the EPA is reconsidering its analysis of paraquat's risks.

BY GREY MORAN • MARCH 22, 2023

$C_{12}H_{14}Cl_2N_2$

ehp Environmental Health Perspectives

Rotenone, Paraquat, and Parkinson's Disease

Caroline M. Tanner,[1] Freya Kamel,[2] G. Webster Ross,[3] Jane A. Hoppin,[2] Samuel M. Goldman,[1] Monica Korell,[1] Connie Marras,[4] Grace S. Bhudhikanok,[1] Meike Kasten,[5] Anabel R. Chade,[6] Kathleen Comyns,[1] Marie Barber Richards,[2,7] Cheryl Meng,[1] Benjamin Priestley,[1] Hubert H. Fernandez,[8] Franca Cambi,[9] David M. Umbach,[10] Aaron Blair,[11] Dale P. Sandler,[2] and J. William Langston[1]

7

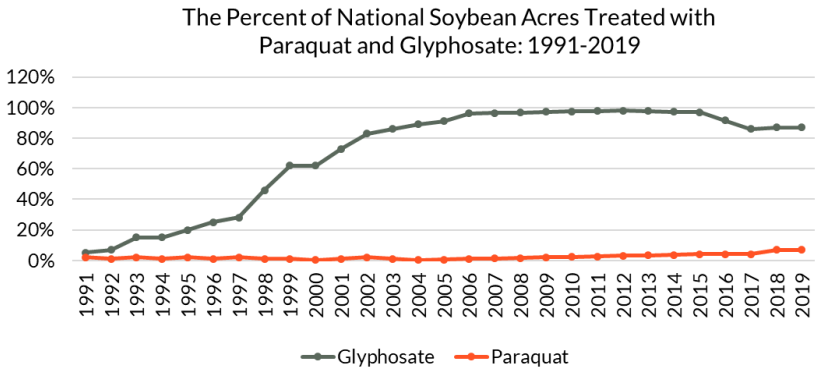
Tradeoffs and Competition Between Glyphosate-based Herbicides (GBHs) and Paraquat

Both kill most everything green with roughly equal efficacy

- Marketed initially for pre-plant weed control, especially in no-till systems, and post-harvest for field cleanup

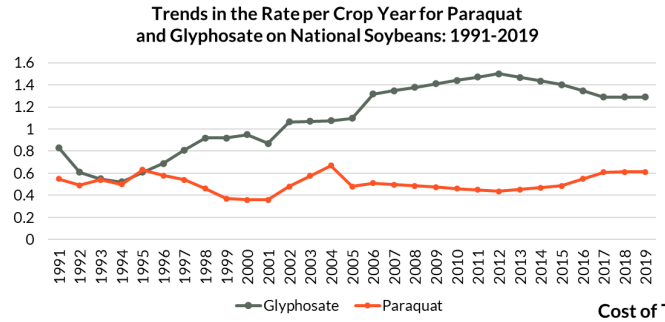
GBHs: Low-tox, hardly any restrictions

Paraquat: Highly hazardous, restricted use

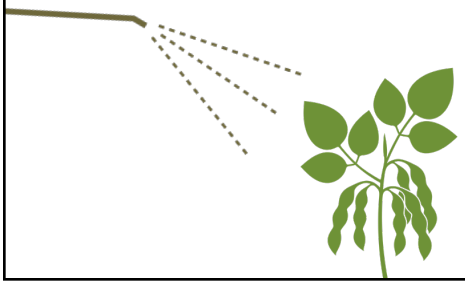


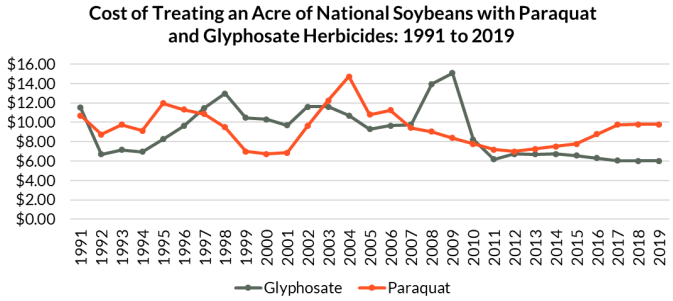
8

Rates and Costs



Slipping GBH efficacy is starting to increase demand for paraquat despite higher paraquat costs per acre treated





9

Soybean Weed Management Technology

What's New for Agronomic Weed Control in 2023

PennState Extension

New herbicide products, label updates, and industry news about weed management are highlighted in the article.

"XtendFlex and Enlist E3 soybean technologies are being used often in our area and around the country."

"In general, while the XtendFlex soybean acres continue to have a strong base, more farmers are opting for Enlist E3 varieties for various reasons. In some parts of the Mid-Atlantic region, ***70% or more of the acres will be planted to E3***."

"Keep in mind that if you plan to use registered dicamba-based herbicides (e.g., Xtendimax, Engenia) in XtendFlex varieties, you must complete the annual dicamba training. If you plan to use Enlist One or Duo in the E3 system, currently no training is required."

https://extension.p su.edu/whats-newfor-agronomicweed-control-in2023

10

New Corteva Products

Kyro: Corteva's Newest Corn Herbicide

"Kyro is a novel formulation–the first of its kind to market–combining the active ingredients acetochlor, topramezone and clopyralid into one premix."

"Resicore XL herbicide (another new Corteva product) ***applied preemergence and Kyro herbicide applied post*** to help ensure clean cornfields through crop canopy for maximum yield potential"

? ***What is in Resicore XL***
Acetochlor
Mesotrione
Clopyralid

So, a farmer taking advantage of these two new Corteva products would apply:

- **Five active ingredients**
- **Two applications of two herbicides (clopyralid and acetochlor)**
- **Cost per acre…take a deep breathe, next slide…**

No doubt at least one application of a GBH will also be applied on most fields!

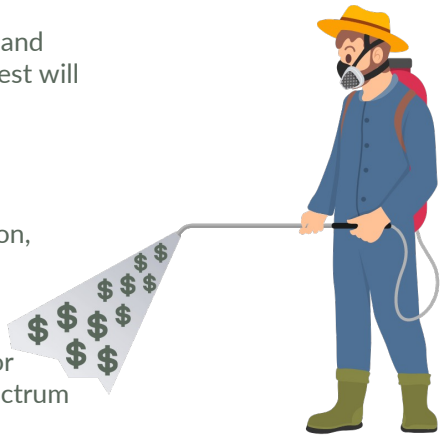
https://www.agweb.com/news/crops/corn/kyro-cortevas-newest-corn-herbicide

11

How High Will Iowa Herbicide Costs Go?

"The days of making $3-an-acre glyphosate applications to control weeds are long gone and won't be coming back. "

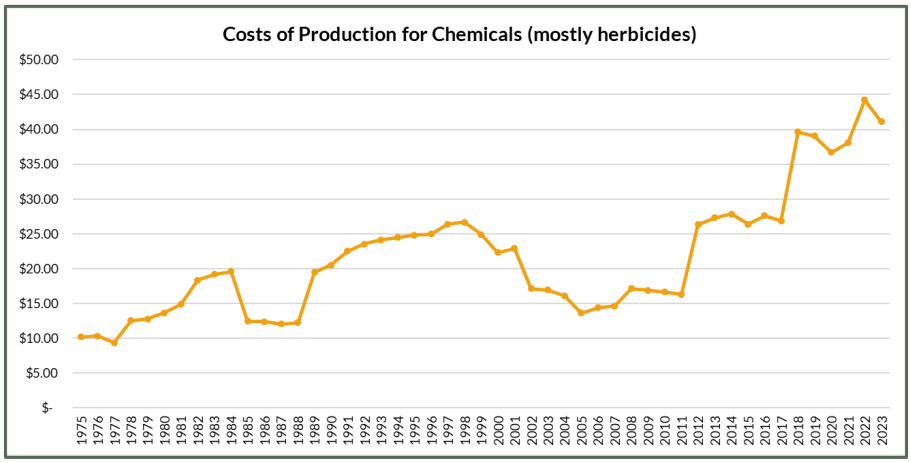
- "On the low side – depending on your specific weed spectrum and infestation level – a robust weed-control program in the Midwest will cost you at least **$50 an acre in 2023**" - Bill Johnson, Purdue University weed scientist.
- "For the mid-South and South, where farmers often overlap herbicides and make three or four applications during the season, Butts says **$85** will be a typical investment. - Tommy Butts, University of Arkansas Extension weed scientist
- "Furthermore, both he and Johnson say **$100 per acre** – just for products alone – will be a common investment for a broad-spectrum weed control program in corn and soybean crops."



https://www.agweb.com/news/crops/corn/100-acre-herbicide-costs-wont-be-unusual-next-season

12

Soybean Chemical Costs Over Time



- "Golden Era" of Iowa soybean weed management: 2002-2011
- Costs have risen nearly 5-fold since the mid-1980s and 4-fold since 2011
- RR technology and drop in post-patent GBH prices reduced costs from the late 1990s through 2005 when resistant weeds began emerging across Iowa crop fields

13

Changes in Soybean Herbicide Use and Costs in Iowa

	Golden Era: 2002-2011	Crop Year 2023	Increase
Number of Herbicides Applied	1.4 to 2	4 to 7	3.2 fold
Number Acre Treatments	1.8 to 2.4	6 to 9	3.6 fold
Pounds Applied	1.1 to 1.6	3 to 5	3 fold
Herbicide Cost/Acre	$14 to $17	$50 to $80	4.2 fold
	Pre-GMO Era		
Seed Cost/Acre	$12 to $13	$65 to $85	6 fold

14

Solid-Encapsulated Technology

First-Ever Solid-Encapsulated Herbicide For Pre and Post Weed Control in Corn

By **RHONDA BROOKS** March 9, 2023

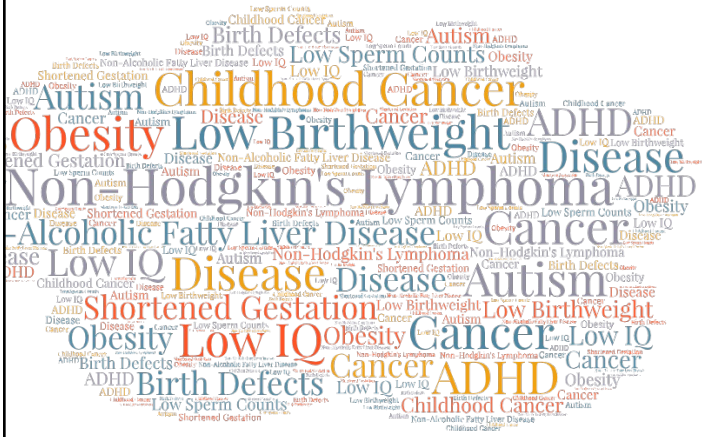
- To expand sales and increase prices of pre-emerge herbicides in fields planted to multi-herbicide tolerant varieties, companies needed to extend efficacy
- Bingo – encapsulated herbicides hit the market in 2023, the same solution adopted to extend efficacy of seed treatments, but there are downsides…

cost, extended period in soil (leaching, soil health, selection pressure)

https://www.agweb.com/news/crops/corn/first-ever-solid-encapsulated-herbicide-pre-and-post-weed-control-corn

15

Key Public Health Questions



- Is rising herbicide use in the Midwest impairing children's development?
- Are problem pregnancies and adverse birth outcomes becoming more frequent and/or more serious?
- Will simultaneous application of multiple herbicides (e.g. ExTend and DuoEnlist technology; 3 and 4-way premixes) magnify risks?

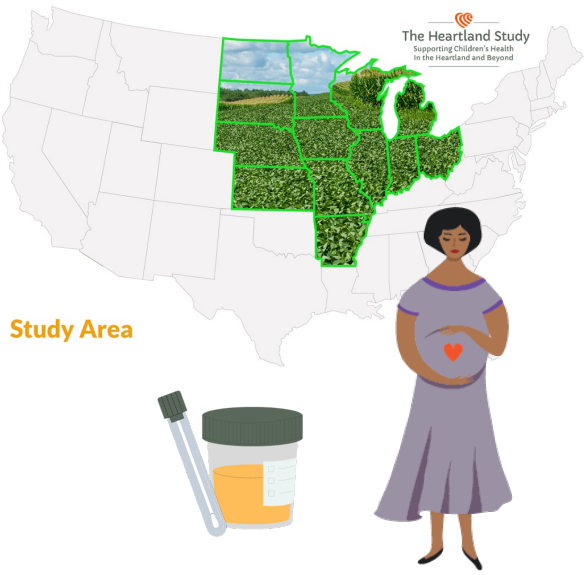
We hope not, but new science is needed now to prevent possible generation-long impacts.

16

The Heartland Study

Welcome University of Iowa!

- Quantifying herbicide levels -- glyphosate, glufosinate, dicamba, and 2,4-D -- in maternal urine samples
- Identifying impacts of prenatal herbicide exposures in newborns (Phase 1)
- Tracking health and developmental outcomes through regular, standardized medical follow-up of children (Phase 2)
- Heartland Study goal – enroll our ***2,000th mother-infant pair in early 2025***



17

Meet the Santillans

Co-PIs of the Heartland Study Site at the University of Iowa Hospital

LINK

18

Risk = Exposure x Toxicity

Human exposure to herbicides comes through three major routes:

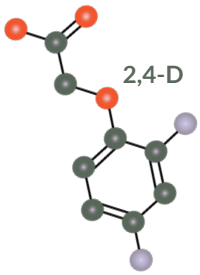
1. Food and beverages, especially drinking water (relatively steady year-round)
1. When spray solution lands on skin, i.e. dermal exposure (spray season)
2. Inhalation exposure (growing concern with volatile herbicides during spray season)

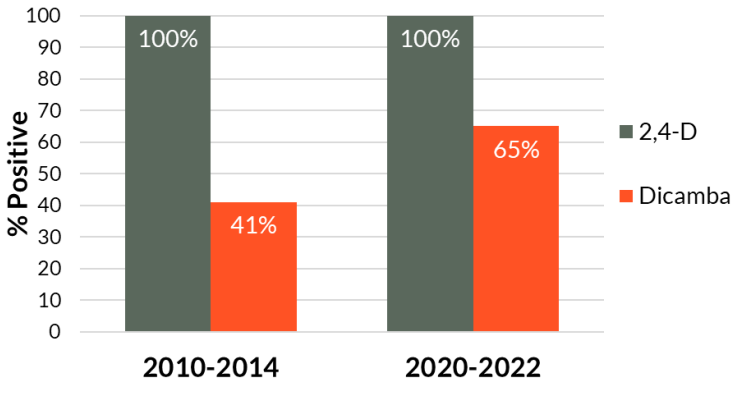
On most days, the average Iowan in farm country is exposed to 5-10 herbicide active ingredients and metabolites in the spring-fall

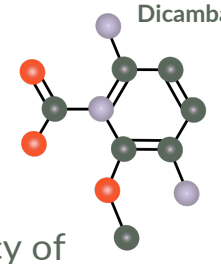
- GLY and AMPA
- 2,4-D
- Dicamba
- Triazines
- Acetanilides
- Glufosinate and 3-MPPA

19

Percent of Urine Samples from Pregnant Women in the Midwest with Dicamba and 2,4-D Residues



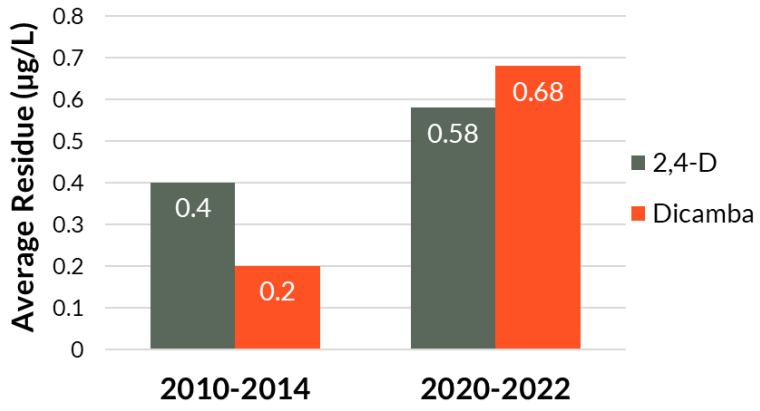




Key Finding: Over a 50% increase in the frequency of detectable levels of dicamba in women's urine

20

Average 2,4-D and Dicamba Residue Levels



Key Finding: More than three-fold increase in the average level of dicamba in urine in just ~10 years, 45% increase in 2,4-D levels

21

New Science is Rocking the Boat

Published papers:

JNCI JOURNAL of the NATIONAL CANCER INSTITUTE

JOURNAL ARTICLE ACCEPTED MANUSCRIPT

Glyphosate Exposure and Urinary Oxidative Stress Biomarkers in the Agricultural Health Study

Vicky C Chang, Phd, Gabriella Andreotti, Phd, Maria Ospina, Phd, Christine G Parks, Phd, Danping Liu, Phd, Joseph J Shearer, Phd, Nathaniel Rothman, MD, MPH, Debra T Silverman, Scd, Dale P Sandler, Phd, Antonia M Calafat, Phd ... Show more

JNCI: Journal of the National Cancer Institute, djac242, https://doi.org/10.1093/jnci/djac242

Published: 11 January 2023 **Article history**

Down the River: Glyphosate Use in Agriculture and Birth Outcomes of Surrounding Populations

Mateus Dias, Rudi Rocha, Rodrigo R Soares

The Review of Economic Studies, rdad011, https://doi.org/10.1093/restud/rdad011

Published: 06 February 2023 **Article history**

ELSEVIER Regulatory Toxicology and Pharmacology

Available online 2 January 2023, 105328

In Press, Journal Pre-proof

Missing the mark -- new methods needed to detect and address high-risk pesticide residues in the global food supply

Charles Benbrook

Vol. 131, No. 3 | Research

Association of Lifetime Exposure to Glyphosate and Aminomethylphosphonic Acid (AMPA) with Liver Inflammation and Metabolic Syndrome at Young Adulthood: Findings from the CHAMACOS Study

Brenda Eskenazi, Robert B. Gunier, Stephen Rauch, Katherine Kogut, Emily R. Perito, Xenia Mendez, Charles Limbach, Nina Holland, Asa Bradman, Kim G. Harley, Paul J. Mills, and Ana M. Mora

22

More New Science

The association between urinary glyphosate and aminomethyl phosphonic acid with biomarkers of oxidative stress among pregnant women in the PROTECT birth cohort study

Jarrod L Eaton [1], Amber L Cathey [1], Jennifer A Fernandez [1], Deborah J Watkins [1], Monica K Silver [1], Ginger L Milne [2], Carmen Velez-Vega [3], Zaira Rosario [3], Jose Cordero [4], Akram Alshawabkeh [5], John D Meeker [6]

Glyphosate exposure in early pregnancy and reduced fetal growth: a prospective observational study of high-risk pregnancies

Roy R. Gerona, Jill L. Reiter, Igor Zakharevich, Cathy Proctor, Jun Ying, Robin Mesnage, Michael Antoniou & Paul D. Winchester

Environmental Health **21**, Article number: 95 (2022) | Cite this article

3489 Accesses | **2** Citations | **222** Altmetric | Metrics

ELSEVIER

Environmental Research
Volume 217, 15 January 2023, 114868

Exposure of children to glyphosate in Morocco: Urinary levels and predictors of exposure

Imane Berni [a], Aziza Menouni [a b], Matteo Creta [b], Ibrahim El Ghazi [a], Radu-Corneliu Duca [b c], Lode Godderis [b d], Samir El Jaafari [a]

Effects of exposure to glyphosate on oxidative stress, inflammation, and lung function in maize farmers, Northern Thailand

Sutthinee Sidthilaw, Ratana Sapbamrer, Chaicharn Pothirat, Klintean Wunnapuk & Supakit Khacha-ananda

BMC Public Health **22**, Article number: 1343 (2022) | Cite this article

1677 Accesses | **2** Citations | **57** Altmetric | Metrics

23

More New Science

ELSEVIER

International Journal of Hygiene and Environmental Health
Volume 246, September 2022, 114039

Higher proportion of agricultural land use around the residence is associated with higher urinary concentrations of AMPA, a glyphosate metabolite

Katrien De Troeyer [a b], Lidia Casas [a b], Esmée M. Bijnens [c d], Liesbeth Bruckers [e], Adrian Covaci [f], Stefaan De Henauw [g], Elly Den Hond [h], Ilse Loots [i], Vera Nelen [h], Veerle J. Verheyen [j k], Stijn Vos [c], Greet Schoeters [j], Hans-Wolfgang Hoppe [l], Helmut Dietrich Köster [l], Tim S. Nawrot [a c]

Urinary concentrations and determinants of glyphosate and glufosinate in pregnant Canadian participants in the MIREC study

Jillian Ashley-Martin [1], Rong Huang [2], Susan MacPherson [3], Orly Brion [4], James Owen [5], Eric Gaudreau [6], Jean-Francois Bienvenu [7], Mandy Fisher [8], Michael M Borghese [9], Maryse F Bouchard [10], Bruce Lanphear [11], Warren G Foster [12], Tye E Arbuckle [13]

Affiliations + expand

PMID: 36410462 DOI: 10.1016/j.envres.2022.114842

A Human Biomonitoring Study Assessing Glyphosate and Aminomethylphosphonic Acid (AMPA) Exposures among Farm and Non-Farm Families

by Alison Connolly [1,2,*], Holger M. Koch [2], Daniel Bury [2], Stephan Koslitz [2], Marike Kolossa-Gehring [3], André Conrad [3], Aline Murawski [3], James A. McGrath [1], Michelle Leahy [1,†], Thomas Brüning [2] and Marie A. Coggins [1]

Toxics **2022**, *10*(11), 690; https://doi.org/10.3390/toxics10110690

Received: 14 October 2022 / Revised: 2 November 2022 / Accepted: 10 November 2022 / Published: 15 November 2022

Urinary glyphosate concentration in pregnant women in relation to length of gestation

Corina Lesseur,[a] Khyatiben V. Pathak,[b] Patrick Pirrotte,[b] Melissa N. Martinez,[b] Kelly K. Ferguson,[c] Emily S. Barrett,[d] Ruby H.N. Nguyen,[e] Sheela Sathyanarayana,[f] Daniele Mandrioli,[g] Shanna H. Swan,[a] and Jia Chen[a,*]

Find more research on our bibliographies page

https://hh-ra.org/project-bibliography/

24

25

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$100 an Acre Herbicide Costs Won't be Unusual Next Season. (2022, December 15). AgWeb. https://www.agweb.com/news/crops/corn/100-acre-herbicide-costs-wont-be-unusual-next-season

Kyro: Corteva's Newest Corn Herbicide. (2022, November 23). AgWeb. https://www.agweb.com/news/crops/corn/kyro-cortevas-newest-corn-herbicide

Moran, G. (2023, March 22). *Paraquat, the Deadliest Chemical in US Agriculture, Goes on Trial*. Civil Eats. https://civileats.com/2023/03/22/paraquat-the-deadliest-chemical-in-us-agriculture-goes-on-trial/

Tanner, C. M., Kamel, F., Ross, G. W., Hoppin, J. A., Goldman, S. M., Korell, M., Marras, C., Bhudhikanok, G. S., Kasten, M., Chade, A. R., Comyns, K., Richards, M. B., Meng, C., Priestley, B., Fernandez, H. H., Cambi, F., Umbach, D. M., Blair, A., Sandler, D. P., & Langston, J. W. (2011). Rotenone, Paraquat, and Parkinson's Disease. *Environmental Health Perspectives*, *119*(6), 866–872. https://doi.org/10.1289/ehp.1002839

What's New for Agronomic Weed Control in 2023. (n.d.). Retrieved March 25, 2023, from https://extension.psu.edu/whats-new-for-agronomic-weed-control-in-2023

26