Contamination of soy for food and feed by intended use of herbicides: The case of Roundup Ready GM soy

Thomas Bøhn PhD
Research Professor
GenØk Centre for Biosafety, Tromsø, Norway

Genetically modified organisms (GMOs)

Open use (agriculture) | Contained use (medical)

GM plants

Maize Soybean Cotton Canola

(Major food/feed products globally)

GM traits

Insect resistance (Bt-toxins)

Herbicide resistance (Roundup)

~ 85 %

Resistance Evolution

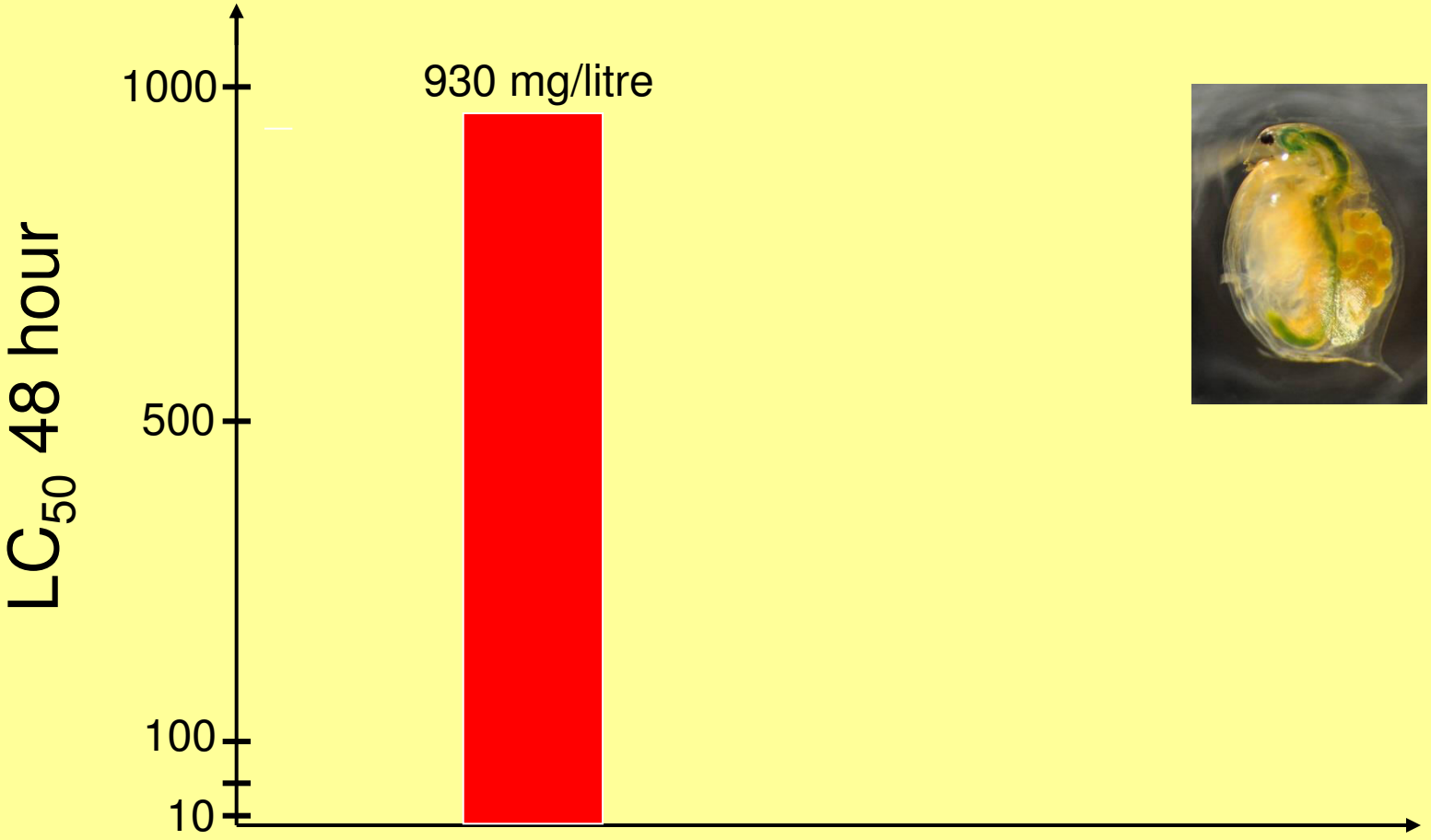
Work done with the *Daphnia* model, part I

- Roundup and glyphosate
  - "The environmentally friendly herbicide"
  - "Practically non-toxic"

Daphnia magna

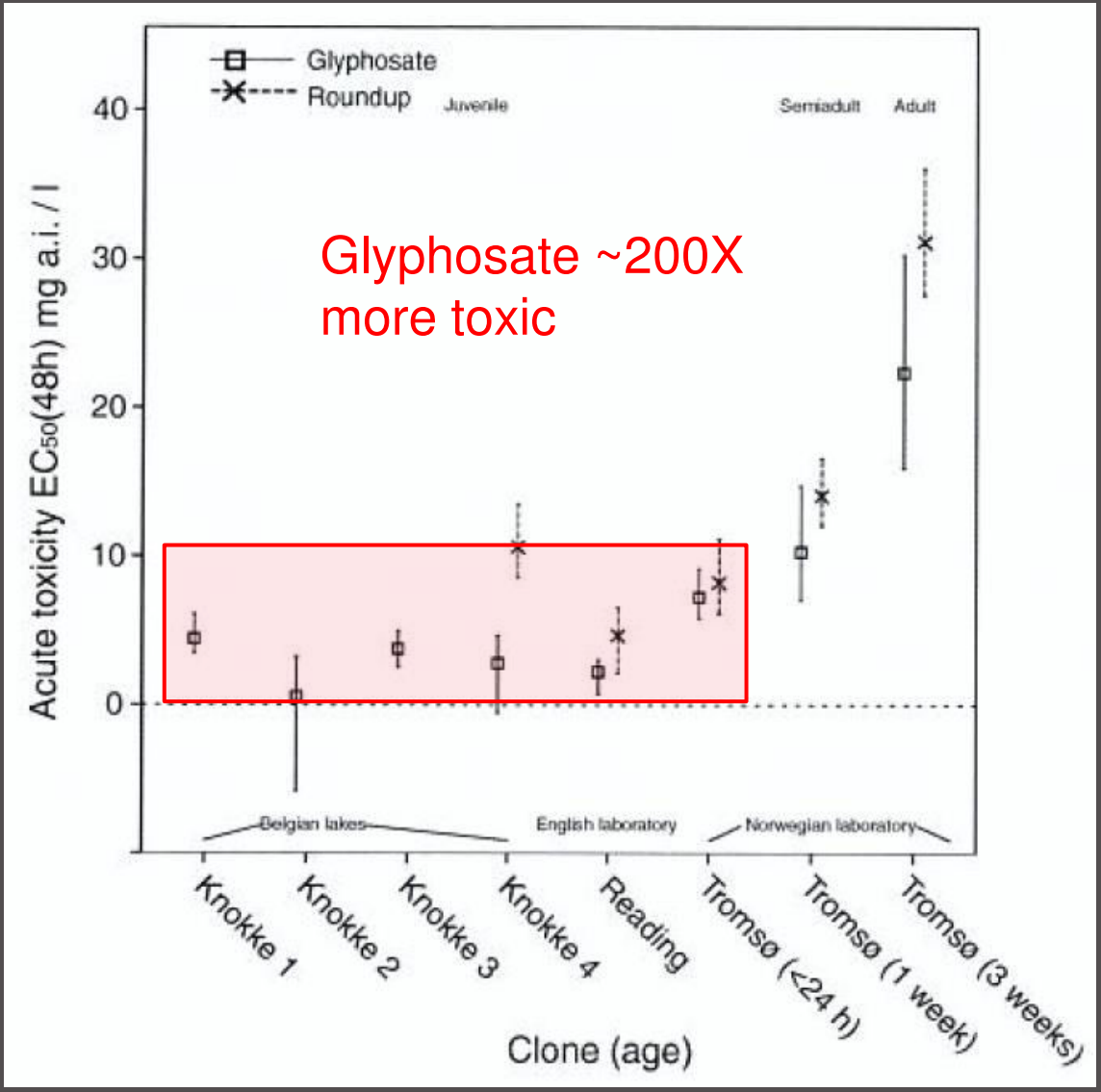
gen øk

Acute Toxicity of glyphosate on *Daphnia magna*



Early Monsanto studies for EPA
(McAllister and Forbis 1978)

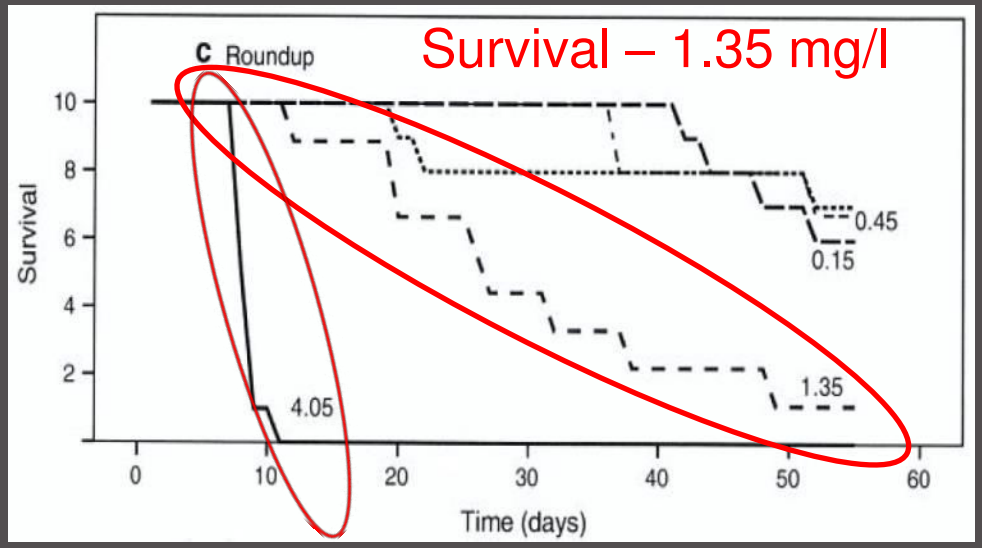
Acute toxicity revised

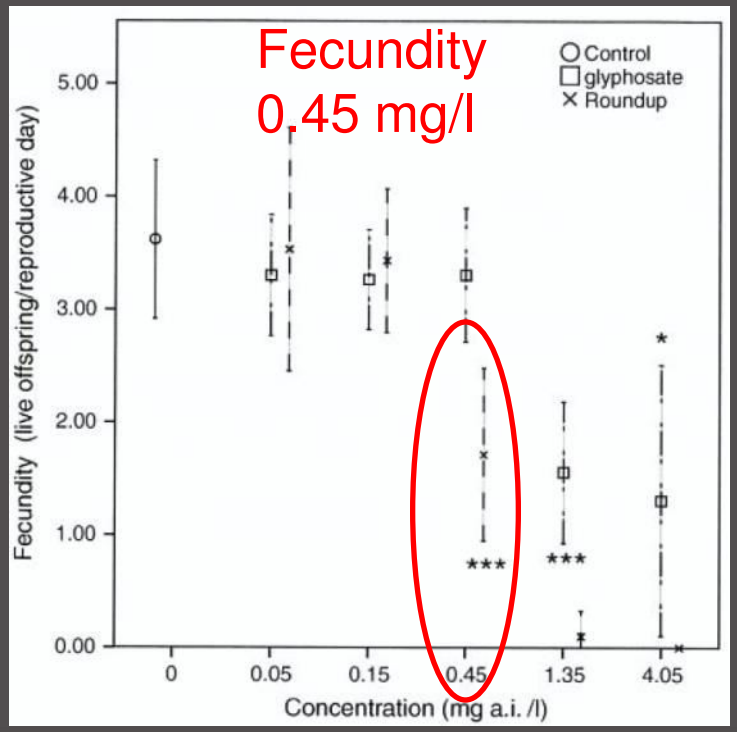


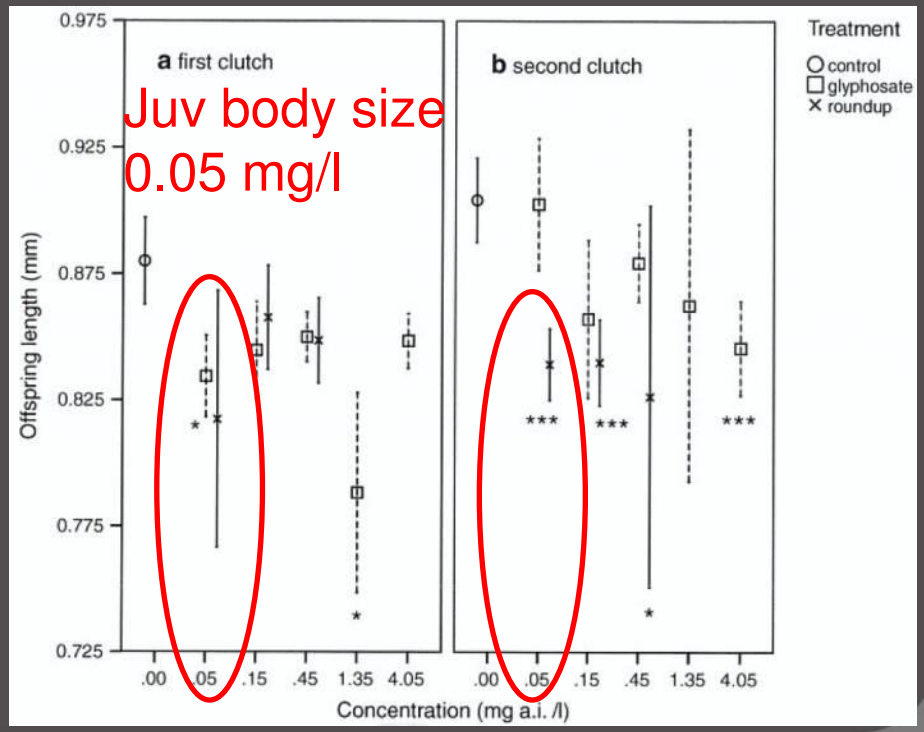
From Cuhra et al. 2013 *Ecotoxicology*

Chronic toxicity

- Significant effects below environmental concentrations accepted in the US (0.7 mg/l)







From Cuhra et al. 2013 Ecotoxicology

Work done with the *Daphnia* model, part II

- "Roundup Ready", Herbicide Tolerant GM soy

The global number 1 GM trait and plant

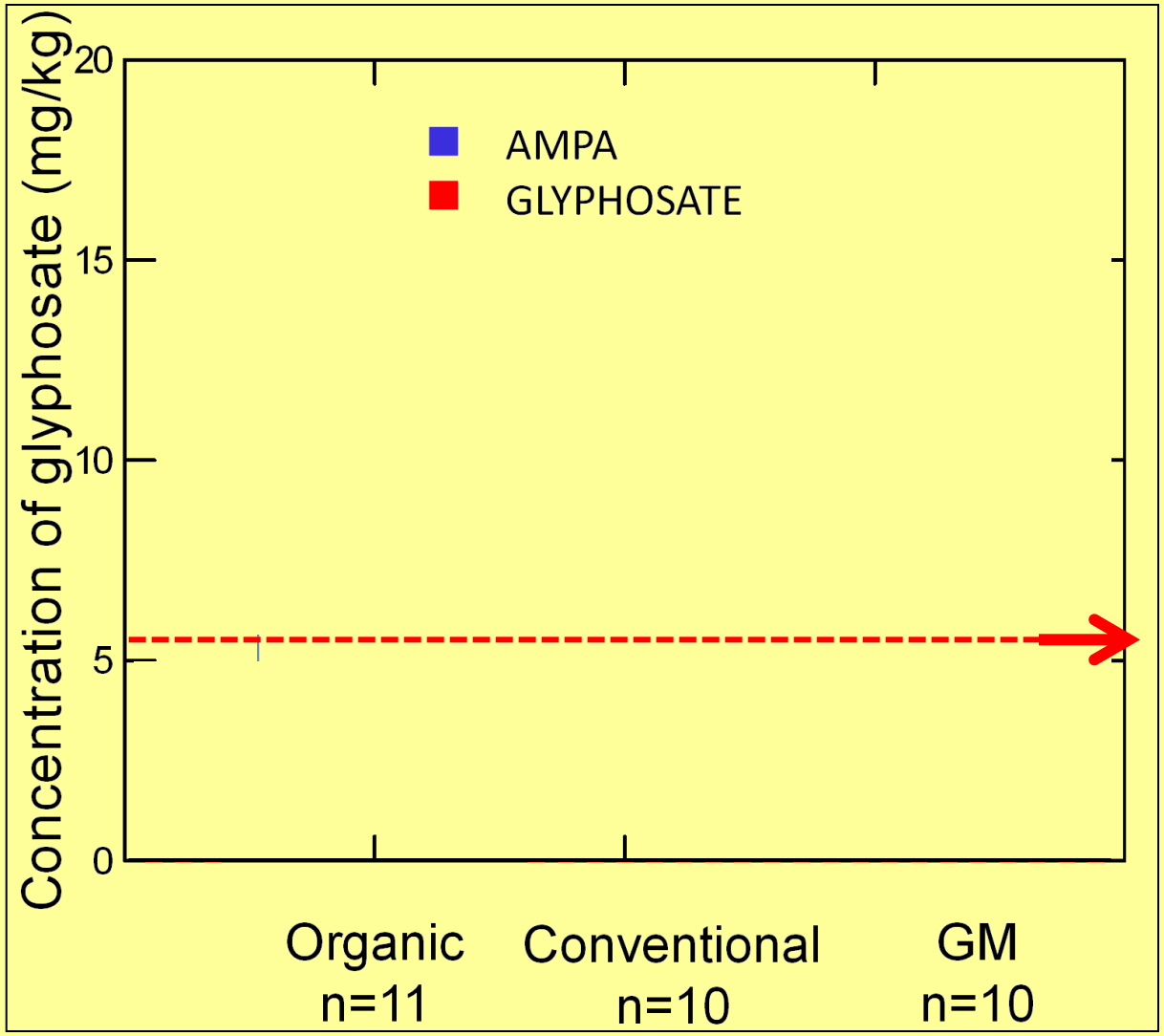
- RR GM soy is dominating world soy production (81 %)
- Sprayed with Roundup/glyphosate herbicides in the growing season

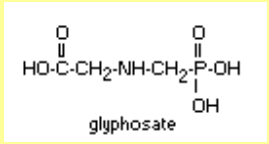
Soy material for testing

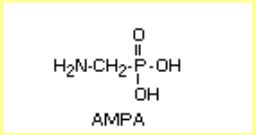
Iowa farmers
(n=31)

- GM (n=10)
- Conv. (n=10)
- Organic (n=11)

Glyphosate and AMPA in soybeans







"Extreme levels and far higher than those typically found"
(Monsanto 2011)

From Bøhn et al. 2014 *Food Chemistry*

Negative effects in food?

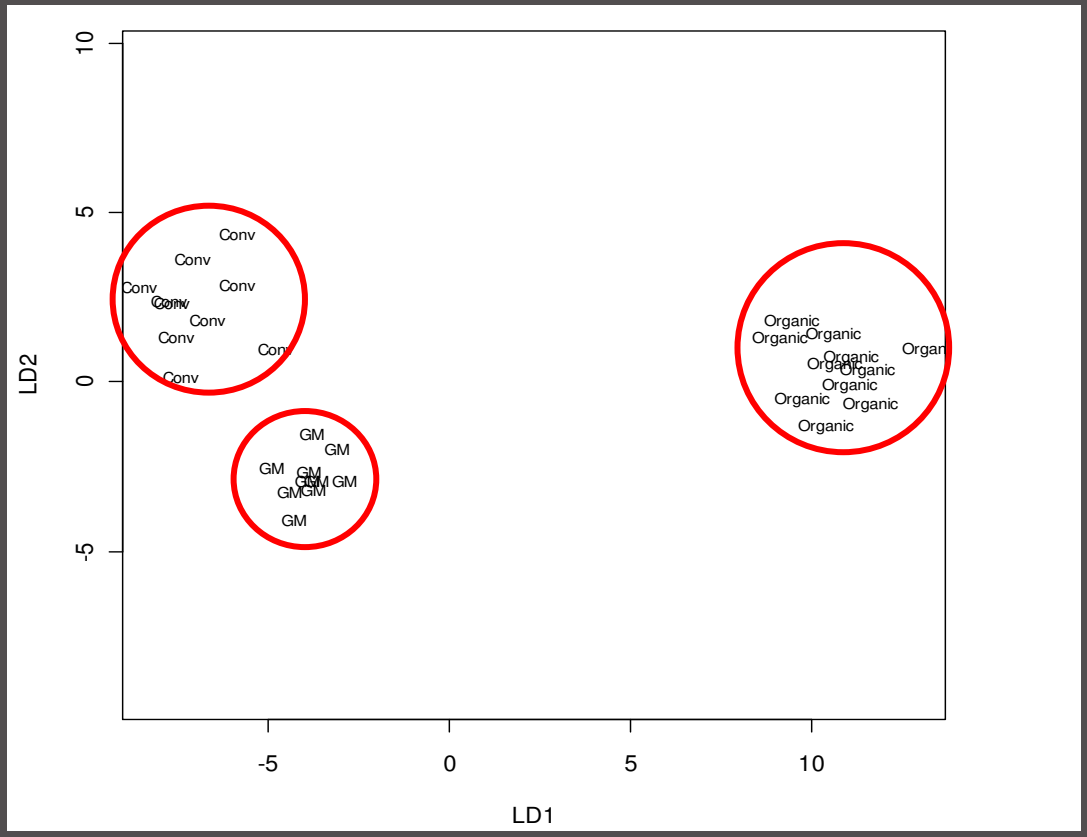
- In *Daphnia magna* model
  - 0.05 – 1.35 mg/L of glyphosate give negative effects
- In food and feed
  - 9.0 mg/kg of glyphosate residues in GM soybeans on the market

Elemental composition in soy

	GM	SD	Conv.	SD	Organic	SD	Anova
Proximate composition							
Dry matter (%)	89.4	1.4	88.1	2.0	88.2	2.6	ns
Protein (%)	34.6 [b]	1.3	34.3 [b]	1.5	36.3 [a]	1.1	p=0.003
Fat (%)	19.0	0.8	19.1	1.3	18.3	0.9	ns
Ash (%)	4.6 [ab]	0.2	4.5 [b]	0.2	4.7 [a]	0.2	p=0.005
Amino acids (mg/g)							
Methionine	4.2	0.3	4.0	0.3	4.0	0.4	ns
Lysine	22.1 [b]	1.5	22.2 [b]	1.3	24.2 [a]	0.9	p=0.002
Histidine	8.9	0.3	8.9	0.4	9.0	0.6	ns
Isoleucine	15.2	0.7	15.0	0.7	15.6	0.5	ns
Leucine	26.3 [ab]	0.9	26.2 [b]	1.1	27.4 [a]	1.0	p=0.02
Phenylalanine	18.0	0.6	17.7	0.7	18.0	1.2	ns
Threonine	13.8	0.4	13.8	0.5	14.3	0.6	ns
Valine	15.9	0.7	15.7	0.7	16.3	0.6	ns
Arginine	24.0 [ab]	0.9	23.4 [b]	1.1	24.9 [a]	1.8	p=0.04
Sum of IAAs [1]	142.3	5.4	140.8	5.2	147.1	5.8	p=0.037
Vitamins (mg/kg)							
Vitamin B6	15.7	1.5	14.9	1.2	14.9	1.4	ns
Fatty acids (mg/g)							
16:0 (palmitic acid)	22.6 [a]	1.2	21.1 [ab]	1.1	21.0 [b]	1.9	p=0.046
Sum Saturated	33.0 [a]	1.4	31.0 [ab]	1.6	29.7 [b]	2.3	p=0.001
18:1n-9 (oleic acid)	41.1	3.0	38.5	2.9	38.5	4.3	ns
Sum Monounsaturated	44.4	3.2	41.5	3.1	41.5	4.5	ns
18:2n-6 (linoleic acid)	115.7 [ab]	5.2	117.8 [a]	5.8	108.4 [b]	9.3	p=0.01
18:3n-3 (linolenic acid)	19.1	4.4	19.6	0.8	18.0	1.6	ns
Elements mg/kg							
Barium (Ba)	6.4 [b]	2.2	6.2 [b]	1.7	11.0 [a]	3.3	p=0.0005
Copper (Cu)	10.4	1.1	10.8	1.1	11.3	1.7	ns
Iron (Fe)	86.8	7.2	84.4	8.7	84.7	11.3	ns
Manganese (Mn)	24.1	2.8	22.8	1.7	24.5	2.3	ns
Molybdenum (Mo)	1.9	1.0	4.5	4.0	2.1	1.1	ns
Selenium (Se)	0.7 [b]	0.1	0.8 [a]	0.2	0.2 [b]	0.2	p=0.0003
Zinc (Zn)	30.4 [b]	2.4	31.7 [b]	2.8	37.0 [a]	3.4	p=0.0002

[1] IAAs Indispensible amino acids (except tryptophan).

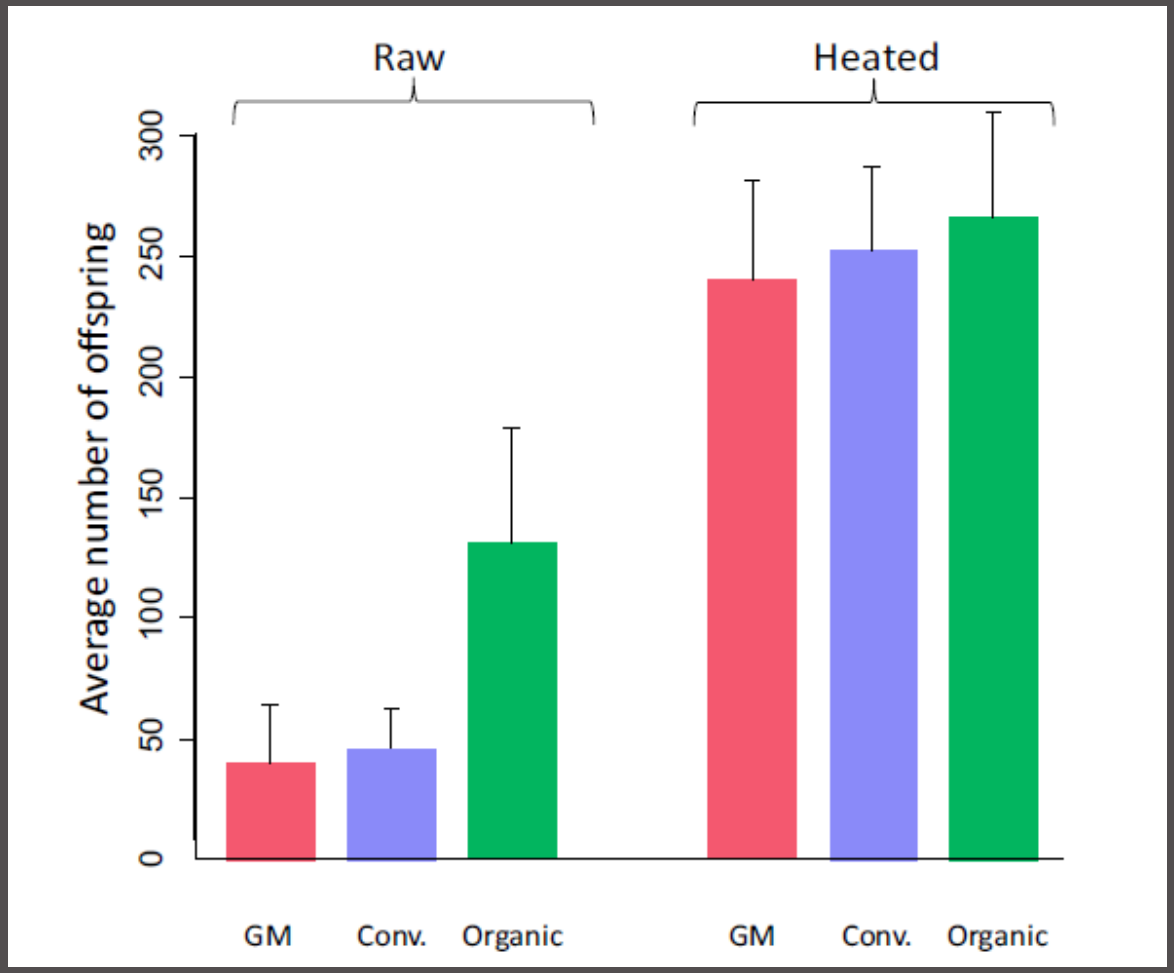
Substantially different!



Discriminant analysis for GM, conventional and organic soy samples based on 35 variables (Glyphosate/AMPA residues are not included)

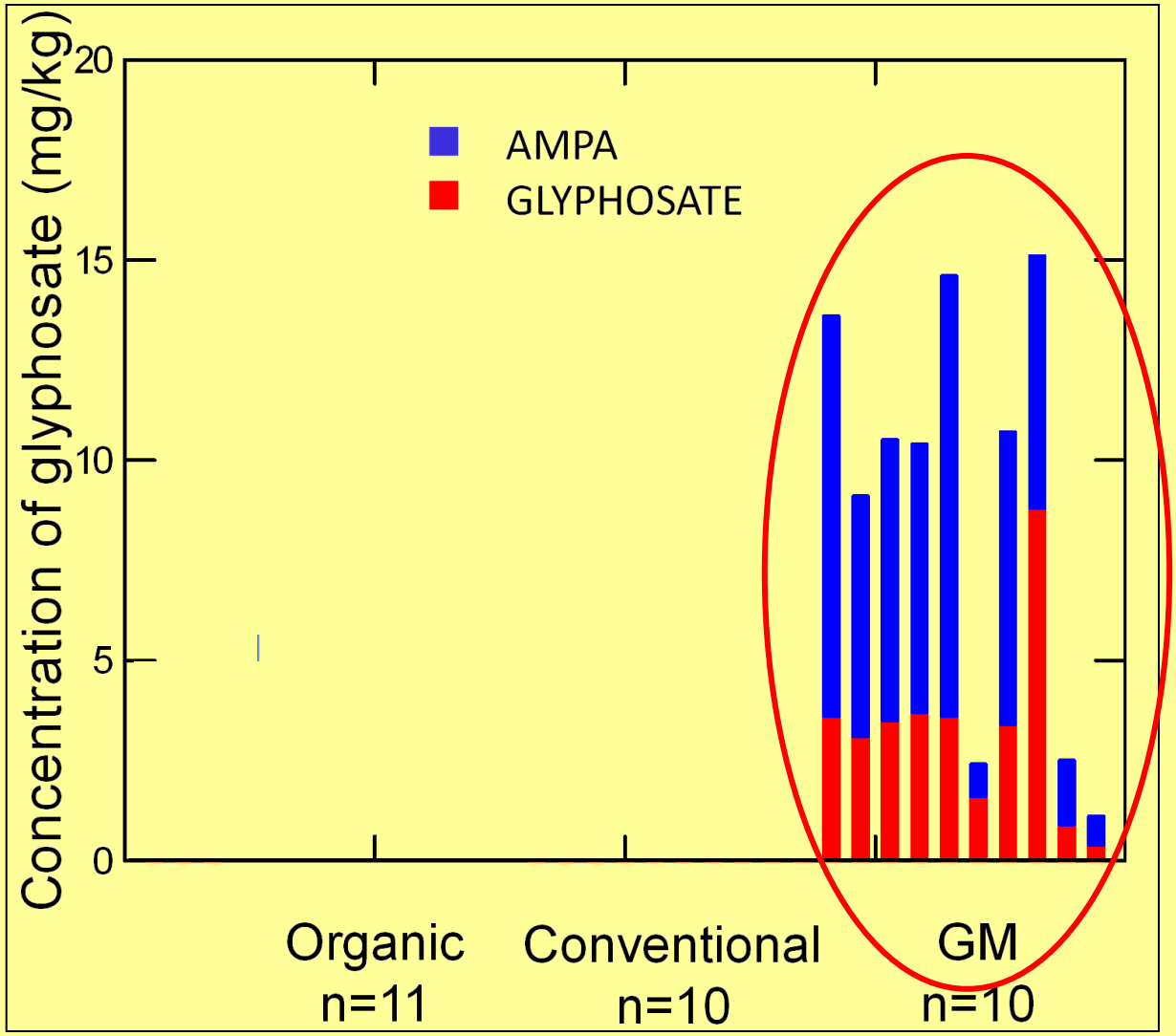
From Bøhn et al. 2014 *Food Chemistry*

Organic soy superior as feed

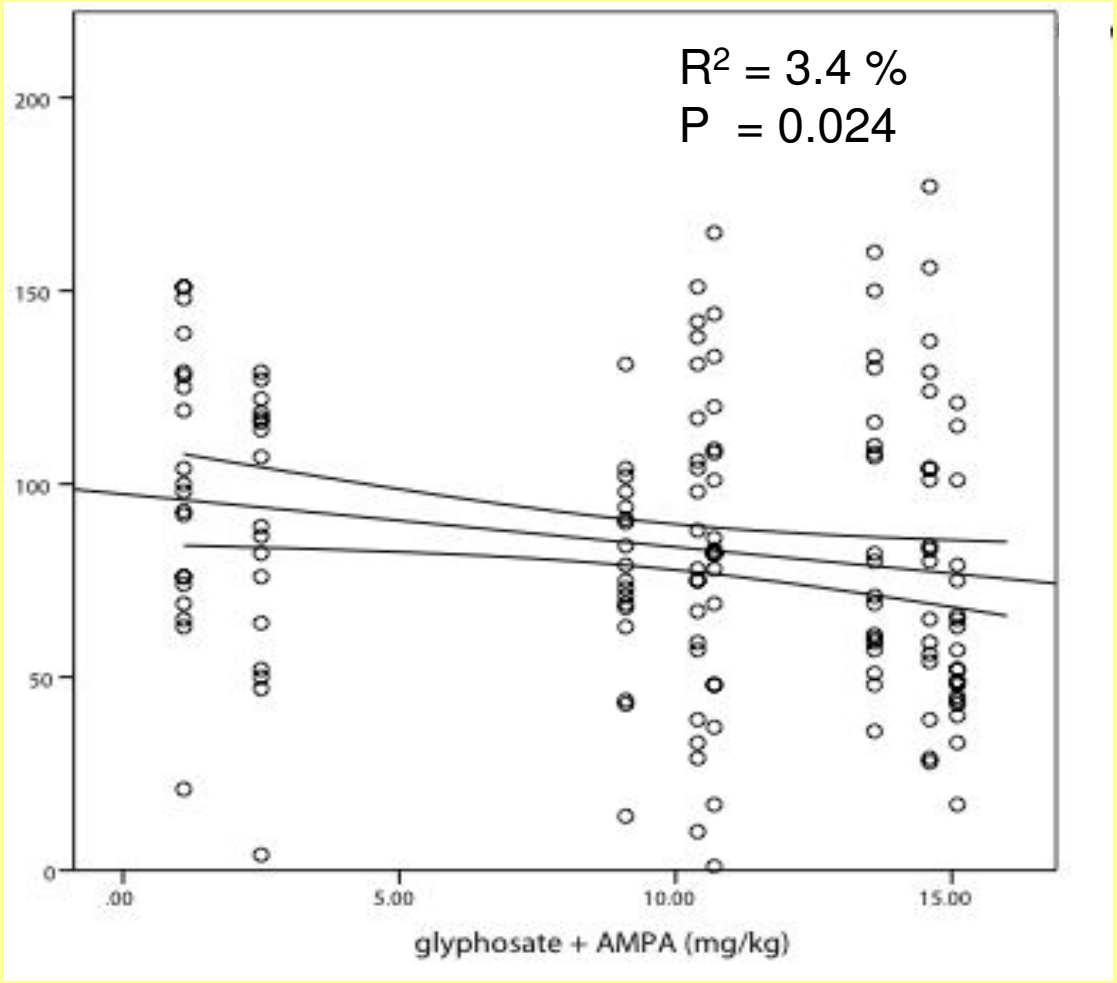


From Bøhn et al. 2015 (In press)

Feeding test with GM soybeans



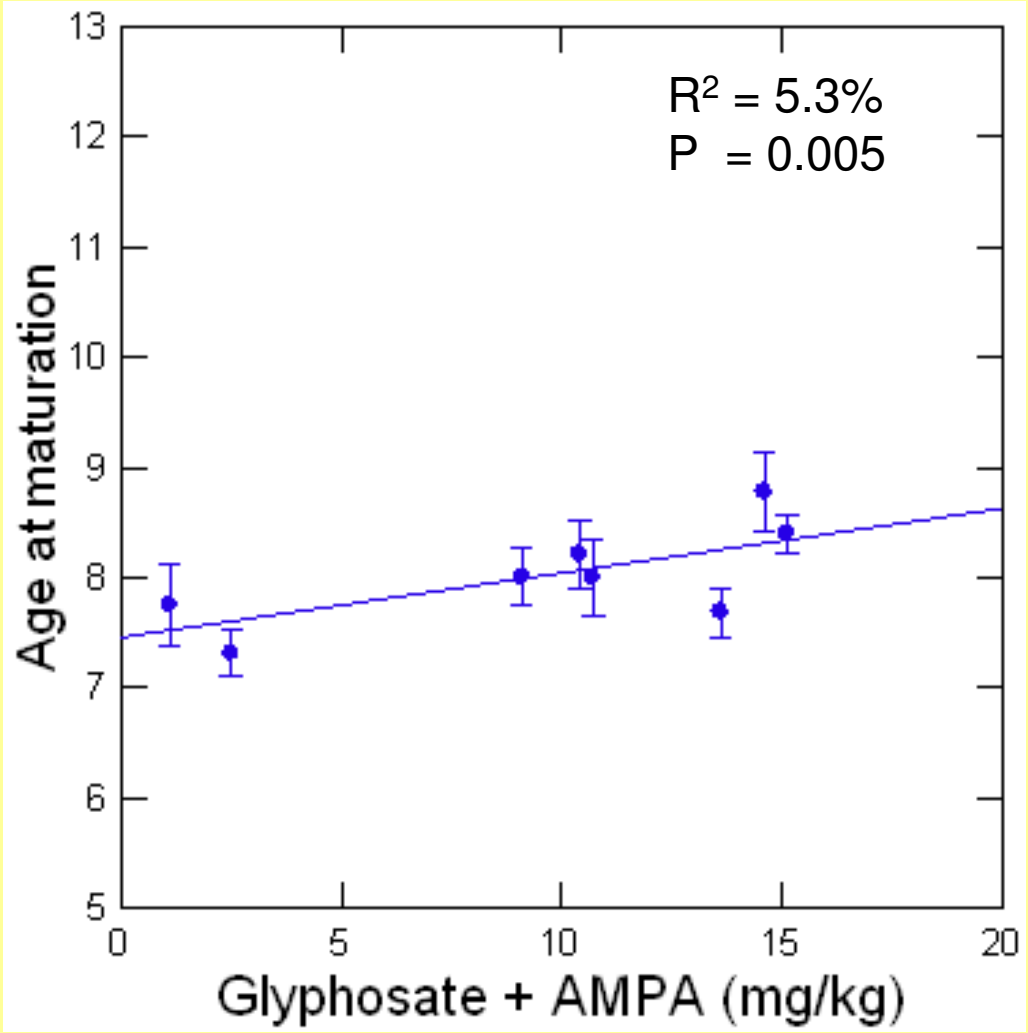
More glyphosate in soybeans – reduced fecundity



Glyphosate in feed (mg/kg)

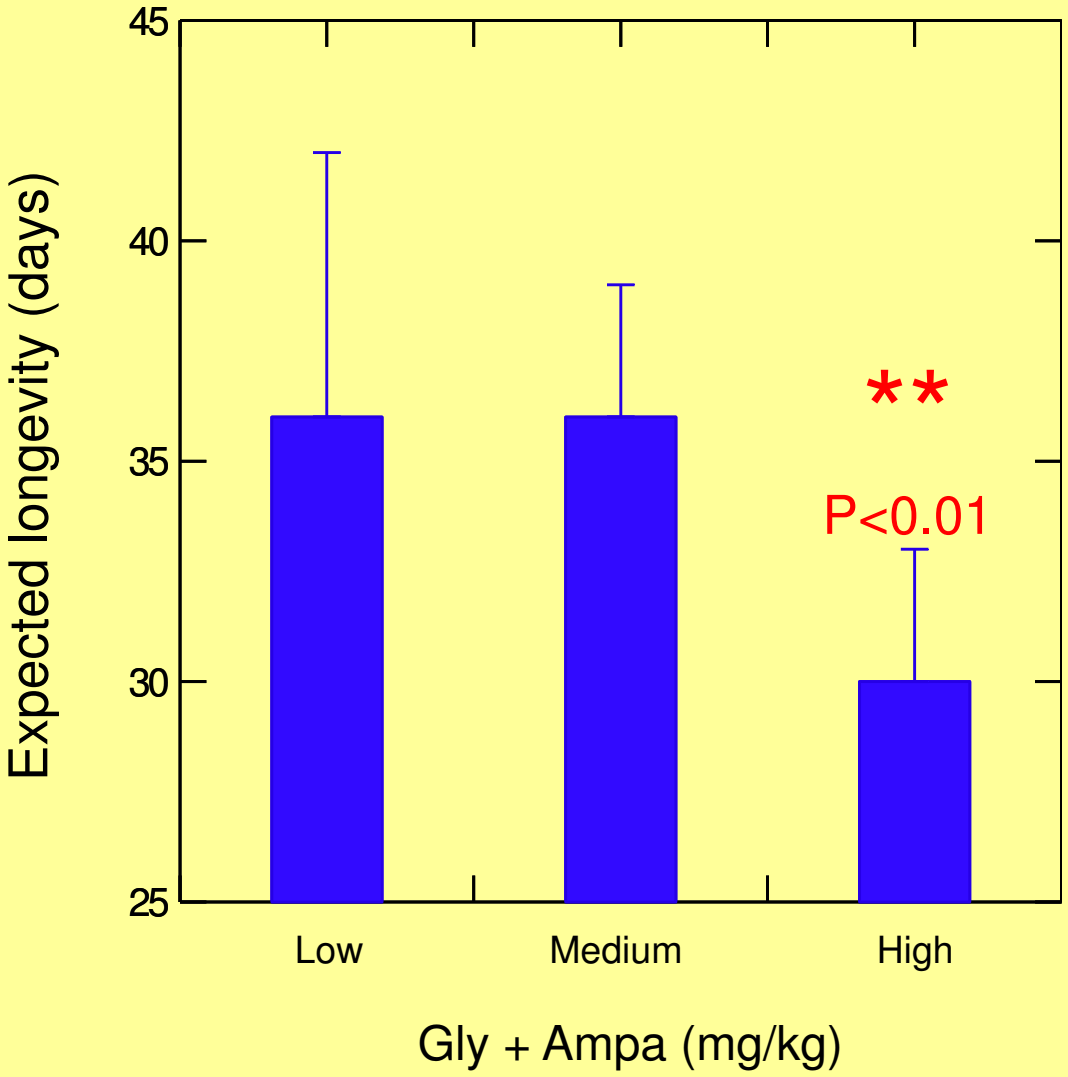
(Cuhra et al. 2015)

More glyphosate in soybeans – delayed reproduction



(Cuhra et al. 2015)

High glyphosate in soybeans – reduced life span



(Cuhra et al. 2015)

Conclusions

- Glyphosate/Roundup is much more toxic than previously believed
- Herbicide tolerant GM soy accumulates glyphosate
- Feeding studies in ecotox model organism *D. magna* support the hypotheses that:
  1. GM soy has inferior quality compared to conventional and particularly organic soybeans
  2. Glyphosate residues negatively affect food/feed quality in GM soybeans

gen øk

Further research in *D. magna*

Toxicity

- Roundup
- Dicamba
- 2,4-D
- Combinatorial tox

Feeding studies to test GM plant quality

- Soy
- Maize
- Multistack plants

Data on phenotype

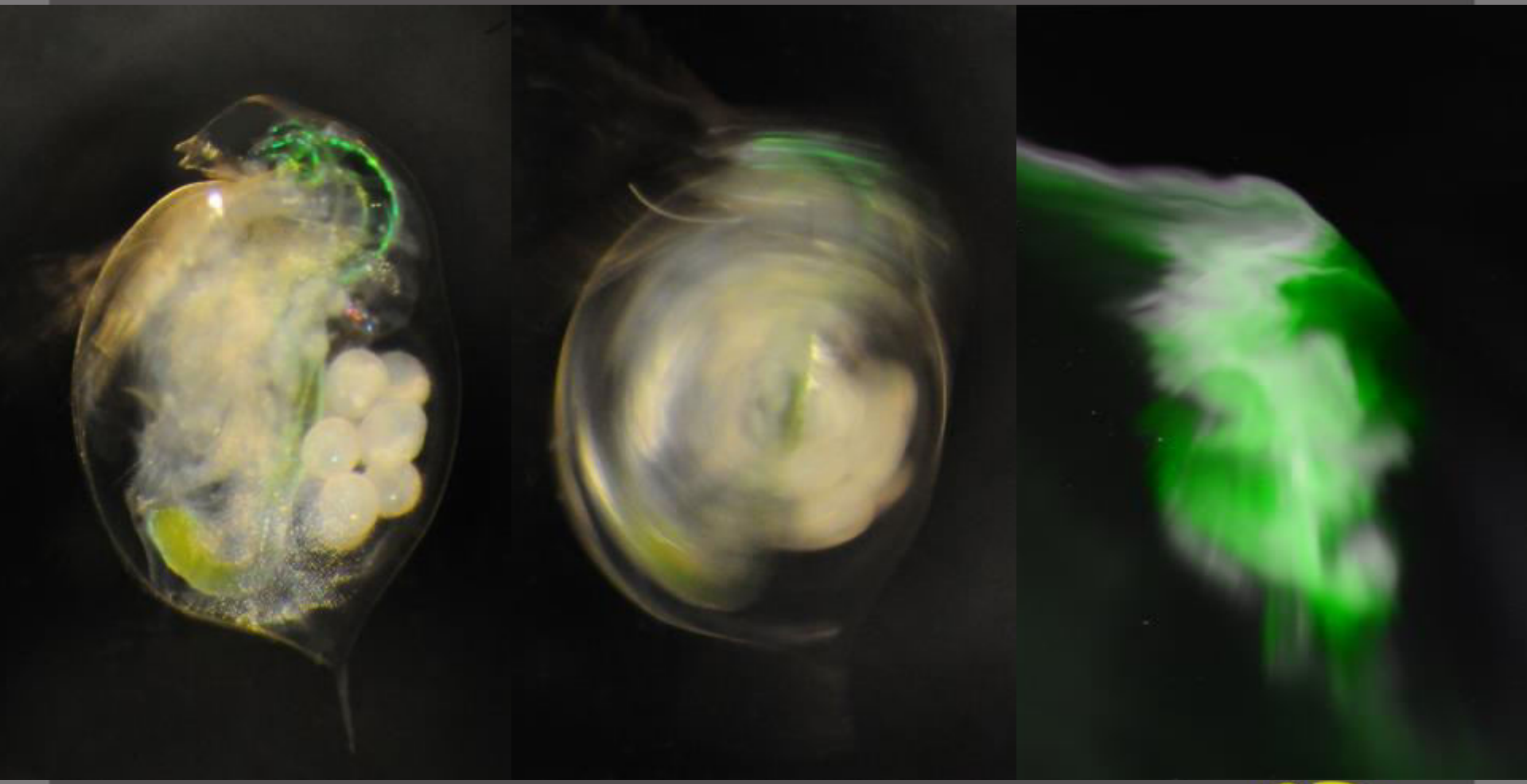
- Survival
- Growth
- Fecundity
- Population effects

Data on genotype

- Transcriptomics
- miRNA
- Pathway analysis
- Link to Birmingham (DGC)

Daphnia magna

“Daphnia borealis”



Discussing GMOs!

Thank you for your attention!