In search of strategies to support sustainable agriculture in Canada
IAC/OAQ Congress, 6-9 nov. Loews Concorde, Québec

GMOs, the pesticide industry and Roundup herbicide.

Lessons learned for sustainable agriculture

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Nathalie Boulanger, Devlin Kuyek and Sophie-Anne Legendre

Université du Québec à Montréal, November 2005

« You can not solve the problem with the same kind of thinking that created the problem... »

Albert Einstein

Outline of the presentation

- The Roundup Ready/GM Roundup Ready crops dynamic.

- Transition from Roundup herbicide to GM Roundup Ready crops.
  - Legal and economic issues
  - Sociopolitical issues
  - Sociosanitary issues
  - Sociocultural issues

- GM crops require more pesticides…
- Environmental and health i
- mpacts from the widespread use of Roundup
- Responsible Governance?
- Sustainable Development? Democracy?

The context
Glyphosate herbicide and Roundup

- Glyphosate, the world's largest selling herbicide, is introduced in the early 1970s by Monsanto, the world's dominant producer.
- Patent expires in 2001 in Canada, in 2000 in US, and earlier in other major markets ofr Round-up
- As the patent expires, a number of generic glyphosate producers enter the market, leading to reduced and fluctuating prices (Source: Woodburn, 2000)

Principal producers of glyphosate:1998

Compagnie et location	Capacité (tonne/année)
Monsanto, USA	n/d
Monsanto, Belgique	n/d
Monsanto, Malaysie	n/d
Monsanto, Brésil	n/d
Monsanto, Argentine	n/d
Zeneca, Belgique	environ 5000
Zeneca, UK	environ 8000
Cheminova, Danemark	5000
Alkaloida, Hongrie	2000
Shenzhen Jiangshan C+I, Chine	5000 et +
CAC Chemical Co, Chine	2000
Hahn Jung, Corée du sud	1800
Korea Steel, Corée du sud	1000
AIMCO, Inde	1000
Shin Dar AgChem, Taiwan	5000
Shinung Corp, Taiwan	2000
Comlets Chemical, Taiwan	2000
Nortox, Brésil	1000

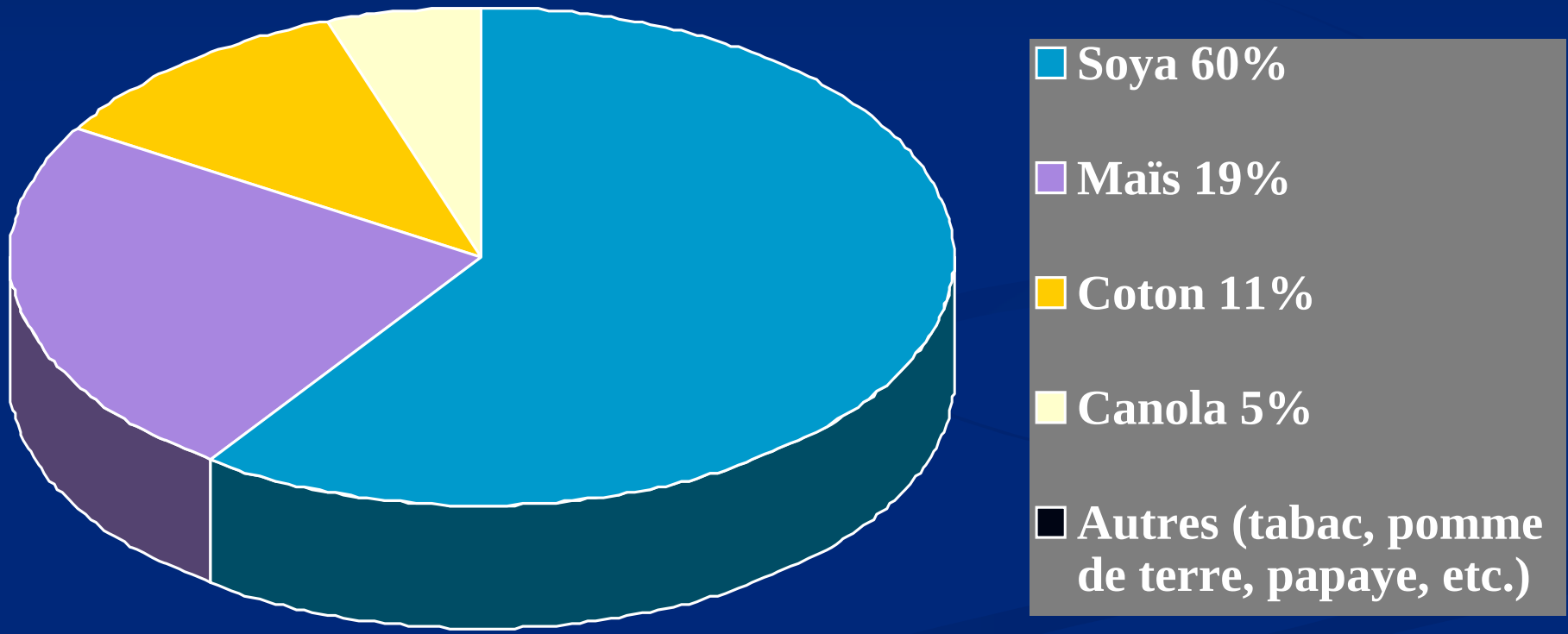
Woodburn, 2000

Roundup Ready Crops: A master stroke!

- With patented Roundup Ready GM crops, which can withstand heavy exposure to Roundup, intellectual property rights (IPRs) on seeds can be subtituted for intellectual property rights on Roundup, thus providing a quintuple protection:
  - Legal: IPRs on seeds prohibiting the re-use of seeds on the farm, creating a quasi-captive market
  - Enforcement: use of private inspectors and informants
  - Recourse to the courts, including cases of contamination
  - Biotechnological: Roundup Ready GM crops require the use of glyphosate and, thus, protect Monsanto's markets
  - Biotechnological: Possibility of imposing genetic use restriction technologies (GURTS) that prevent plants from reproducing or from reproducing specific genetic traits.

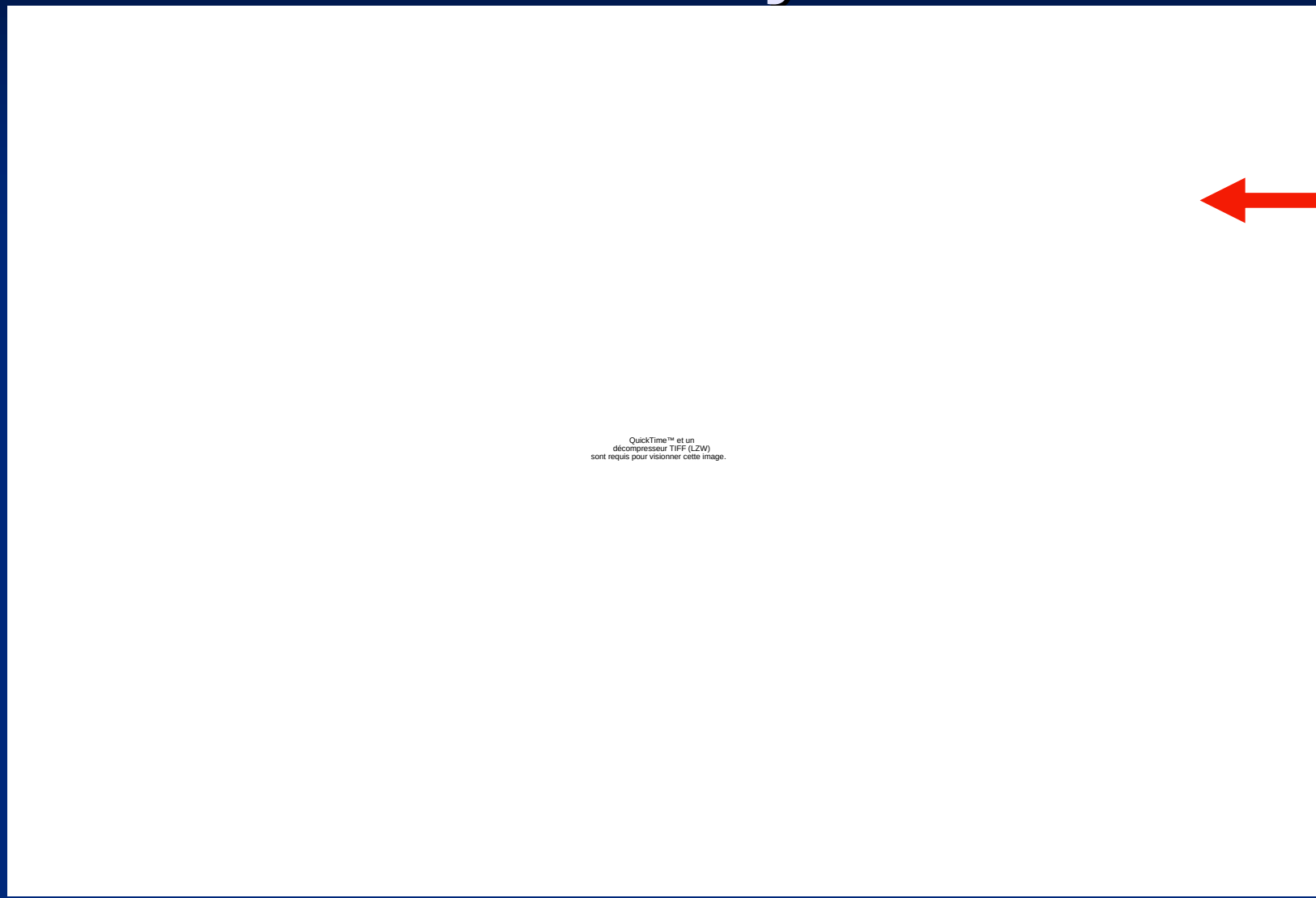
Soybean and corn represent 79% of the GM crops grown in the world

OGM: 4 cultures dont 90% soya/maïs/coton



Source : ISAAA 2005

Percentage according to GM crop variety



Evolution of GM crops by species

ROUNDUP READY SOY

Monsanto Biotechnology Trait Acreage	2005	2004	2003	2002	2001	2000	1999	1998	1997	1
(in millions of acres)										
U.S. Roundup Ready soybean trait	66.4	67.2	63.6	60.0	54.8	45.0	40.5	29.1	7.9	
Argentine Roundup Ready soybean trait	34.6	31.8	29.9	27.1	22.7	17.0	13.6	4.0	0.5	
Brazilian Roundup Ready soybean trait	12.3	7.4								
Roundup Ready soybean trait-other	5.8	2.5	1.6	1	0.6	0.3				
Total Monsanto soybean trait	**119.1**	**108.9**	**95.1**	**88.1**	**78.1**	**62.6**	**54.4**	**33.1**	**8.4**	

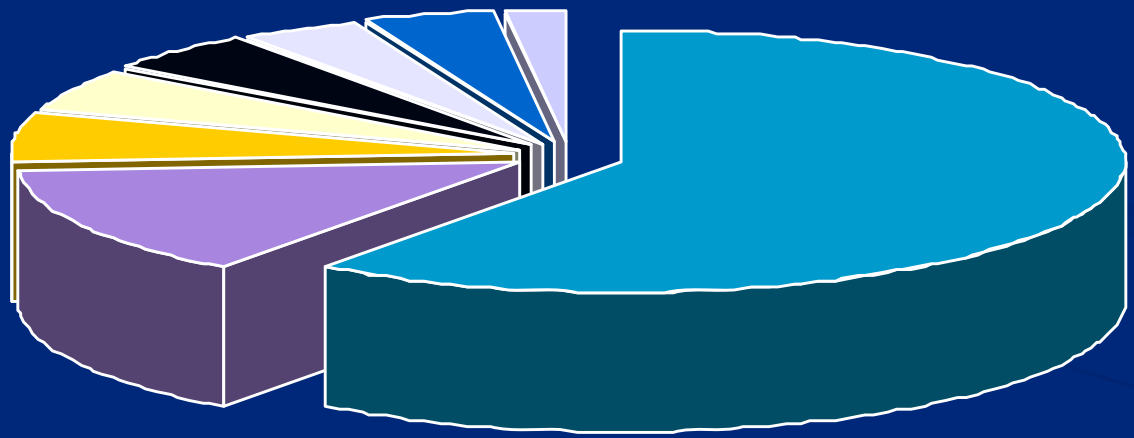
Roundup Ready crops account for 84% of the area planted with Monsanto's GM crops

- Soy 119.1 /119.1= 100%
- Maize 35/51.7= 68% (including stacked traits)
- Cotton 2,9/17,1= 17%
- Canola 6,7/6,7= 100%

- In 2005, Monsanto's Roundup Ready crops accounted for 163.7 of the 194.6 millions acres planted to Monsanto's GM crops-- over 84 % !

- Source Monsanto Biotechnology Trait Acreage: Fiscal Years 1996-2005 Updated: Oct 12: Year-End 2005 Actuals. Site internet Monsant0 4 nov.2005

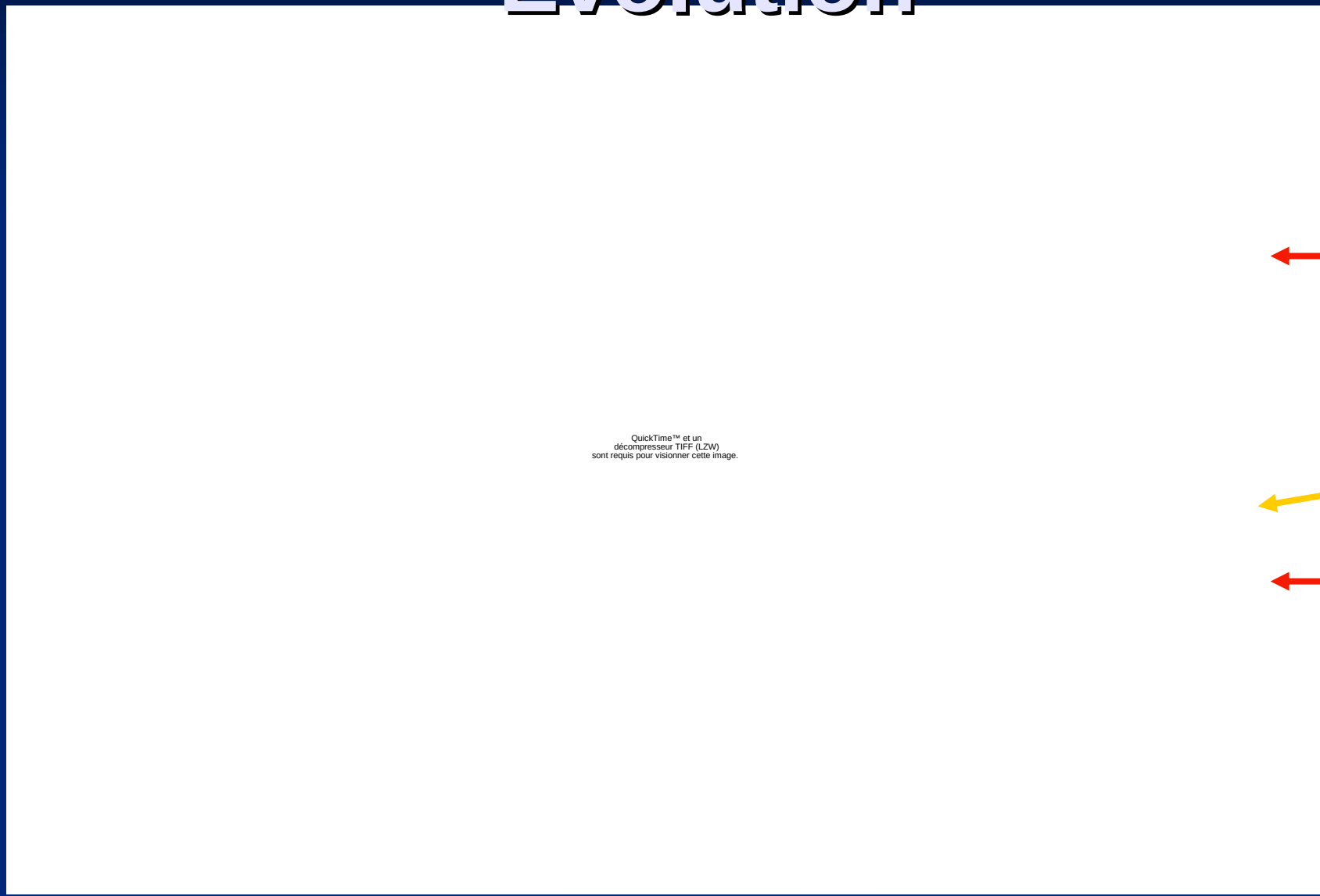
GM crops in 2004 are 99% pesticide plants



- Herbicide Tolerant Soybean 60 %
- Bt Maize 14 %
- Bt Cotton 6 %
- Herbicide Tolerant Maize 5 %
- Herbicide Tolerant Canola 5 %
- Bt/Herbicide Tolerant Maize 4 %
- Bt/Herbicide Tolerant Cotton 4 %
- Herbicide Tolerant Cotton 2 %

Source : ISAAA, Etat mondial des plantes biotechnologiques/GM commercialisées: 2004

GM Pesticide Plants Evolution



ISAAA

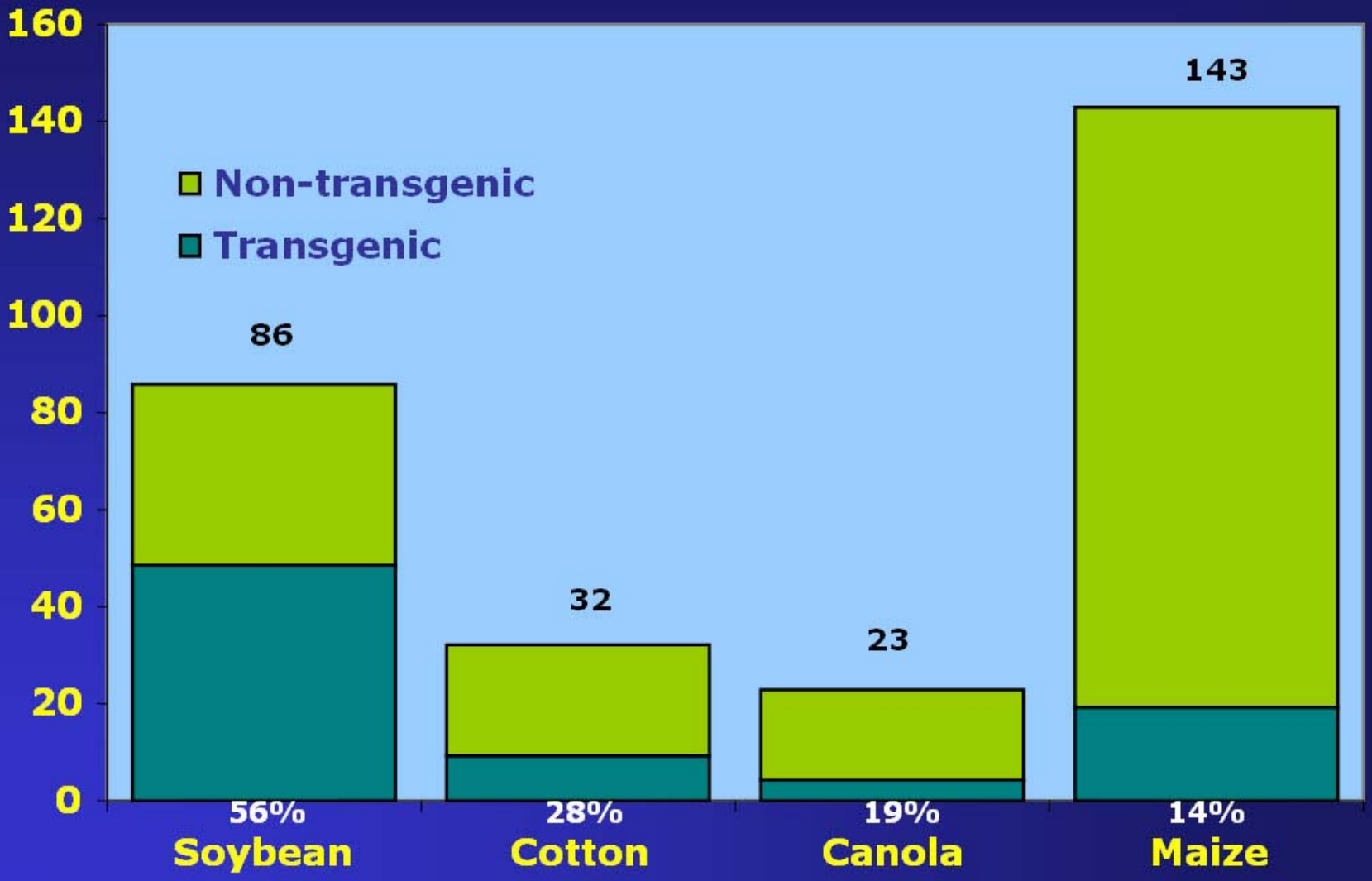
Dominant Biotech Crops, 2004

	Million Hectares	% Transgenic
Herbicide Tolerant Soybean	48.4	60
Bt Maize	11.2	14
Bt Cotton	4.5	6
Herbicide Tolerant Maize	4.3	5
Herbicide Tolerant Canola	4.3	5
Bt/Herbicide Tolerant Maize	3.8	4
Bt/Herbicide Tolerant Cotton	3.0	4
Herbicide Tolerant Cotton	1.5	2
Total	81.0	100

Source: Clive James, 2004

In 2004, 96% of the area planted to GM crops was concentrated in 5 countries, with 59% in the US and 16% in Argentina Source: ISAAA 2004

Global Adoption Rates (%) for Principal Biotech Crops (Million Hectares)



Source: Clive James, 2004

Monsanto’s global sales of Roundup and glyphosate in 2004

QuickTime™ et un
décompresseur TIFF (LZW)
sont requis pour visionner cette image.

(Monsanto, 2004)

Roundup Ready Crops: A master stroke!

- With regulatory frameworks for GM crops in North America based on the principle of substantial equivalence, a concept whose development and acceptance the industry actively supported, the costs of taking a GM crop through the regulatory process, according to Millstone (2005), are around 100 times less than for a new pesticide. As a result, GM producers would have been able to:
  - considerably reduce their costs
  - impose GMOs on consumers
  - put the burden of proof for risks on to citizens
  - transfer the eventual costs of labelling to other actors

GMO REGULATORY REQUIREMENTS: 100 TIMES CHEAPER THAN FOR PESTICIDES

Approaches	Testoptions	Estimated cost as a multiple of the cost of coarse chemical analyses
Recent practice for GM foods and crops in the United States and European Union (EU)	Coarse chemicalanalyses	x1
Currentpractice for GM foods and crops in the EU	À slightlyfiner chemical analysis and some short-term farm-animal feeding studies	x10
Officially envisaged future(in the EU)for GM foods and crops	Farfiner chemical analyses: including proteomics and metabolomics as well as laboratory animal feeding studies ,farm-scale cultivation trials for crops	x50
Currentpractice for additives and pesticides	Chemical analyses plus toxicological tests with bacteria, and studieson (400) live animals, and some immunological testing, but no human trials	x100
Currentpractice for pharmaceutical products	Chemical analyses plus toxico-logical tests with bacteria and live animal studies ,some immunologicaltesting, and some clinicaltrials	x500

■Erik Millstone Evaluating the acceptabilityof GM crops: thescope for autonomy in developing countries. SciDev Net, Jan. 2005

The paradox of Roundup Ready and other GM pesticide crops

The Roundup Ready GM crops helped Monsanto to:

- Protect and expand its sales of Roundup
- Impose its GM crops throughout the world
- Access public funds and venture capital targeted at the knowledge economy and biotechnology.
- Dominate the global market for GM crops

And, all the while, Monsanto claimed, paradoxixally, that these GM plants, able to withstand heavy exposure to Roundup, would reduce the use of pesticides....

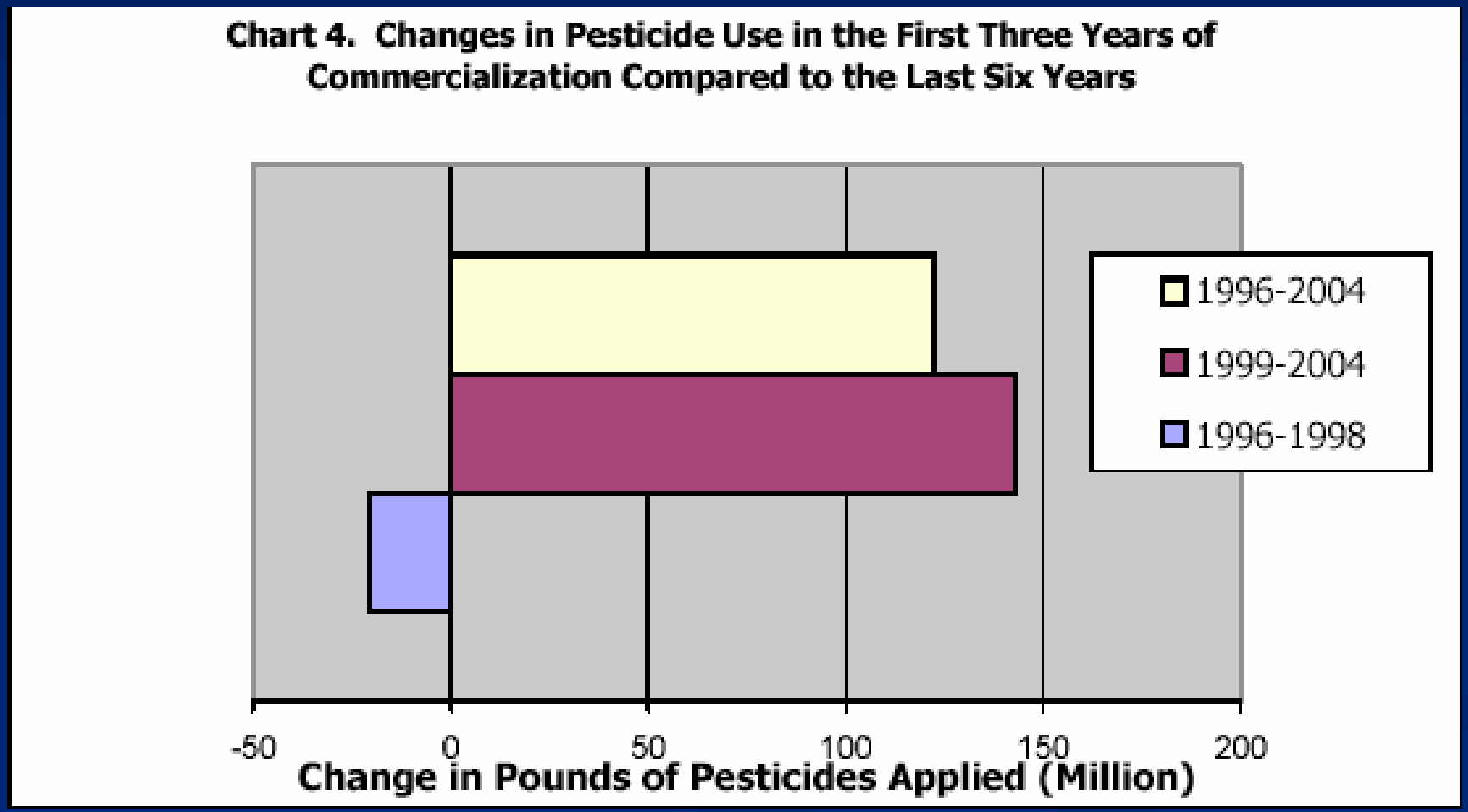
- Just as all supporters of GM crops claim that GM crops will reduce pestide use.
- But what is happening in practice?

GMOs and pesticide use

Benbrook, Charles M. 2004. *Geneticaly Engineered Crops and Pesticide Use in the United States : The First Nine Years*. BioTech InfoNet, Technical Paper Number 7, octobre 2004, 53 pages.

- In the United States, pesticide use did decrease during the **first three years** of commercial production.
- Since 1999, however, the statistical evidence demonstrates an increasing use of pesticides.
- The overall use of pesticides for GM corn, soya and cotton increased by 122 million pounds since 1996 (an increase of 4.1%).
- Heribicde use increased by 139 millions pounds on herbicide tolerant crops, while insecticide use on Bt crops declined by 15.6 million pounds.

GMO and pesticide use: change over time



(Benbrook, 2004)

Reasons for increased use of herbicides on GM crops

- Reliance on a single herbicide for weed management over millions of acres of GM herbicide tolerant crops causes changes in weed populations, leading to the emergence of glyphosate resistant weeds.
- Farmers must then apply additional herbicides and/or increase the quantities applied.
- Reductions to the price of glyphosate with the expiration of patent protection for Roundup and the availibility of lower-cost generic glyphosate products.
- Reductions in the amount of heribicides applied to conventional crops (regulations, innovations within the industry)

(Benbrook, 2004)

Roundup and the environment

Soil persistence

- Decomposition by soil micro-organisms produces a metabolite, l'*aminomethyl phosphonic acid* (AMPA), and ultimately leads to the production of water, carbonic acid and phosphate (Arauujo et al., 2003).
- Study by Mamy et al (2005) comparing the persisitence of glyphosate to the herbicides trifluralin, metazachlor, metamitron et sulcotrione found that glyphosate generally had the shortest half-life, but not in all soil types:
- *« The five herbicides had a low persistence, particularly glyphosate, but in soils where glyphosate adsorption is high (low pH and phosphate content), it is more persistent than sulcotrione and metazachlor…*

Roundup and the environment

Soil persistence

«*…Glyphosate, trifluralin and sulcotrione degradation depend on strength of their adsorption on soils […]. Glyphosate, metazachlor and sulcotrione metabolites were persistent and may accumulate in soil following several applications leading to an increase in environment contamination risks*» (Mamy et al., 2005).

- ***«The environmental advantage in using glyphosate due to its rapid degradation is counterbalanced by accumulation of aminomethylphosphonic acid specifically in the context of extensive use of glyphosate» (Mamy et al., 2005).***

Roundup and the environnement

Persistence in water systems

Study by the Quebec Ministry of the Environment on the presence of pesticides in agricultural water systems:

- Glyphosate (Roundup) was analyzed in water from the Chibouet river: it was present in 38 % of all samples.
- *«Although the concentration levels found in the rivers were generally low, their presence outside of agricultural lands is as undesirable as that for atrazine or metolachlore. The situation makes it clear that replacing one pesticide for another is not a sustainble solution for reducing environmental contamination.»* (Québec, 2002)

Source: Québec. Ministère du développement durable,de l'environnement et des parcs. 2002. *L'utilisation des pesticides dans le maïs et le soya.*
URL http://www.mddep.gouv.qc.ca/pesticides/mais_soya/index.htm

Roundup and the environment
Glyphosate and parasites

- According to Hanson and Fernandez (2003), the use of glyphosate increases disease populations affecting plants (*Pyrenophora tritici-repentis (Died.) Drechs.*, *Fusarium graminearum* et *Fusarium avenaceum(Fr.:Fr.).*
- A recent study by Fernandez et al. (2005), found a significant association between glyphosate use and high levels of Fusarium head blight.

Hanson, K.G. et M.R. Fernandez. 2003. «Glyphosate herbicides affect plant pathogenic fungi» *Canadian Journal of Plant Pathology*, vol. 25, p.120.

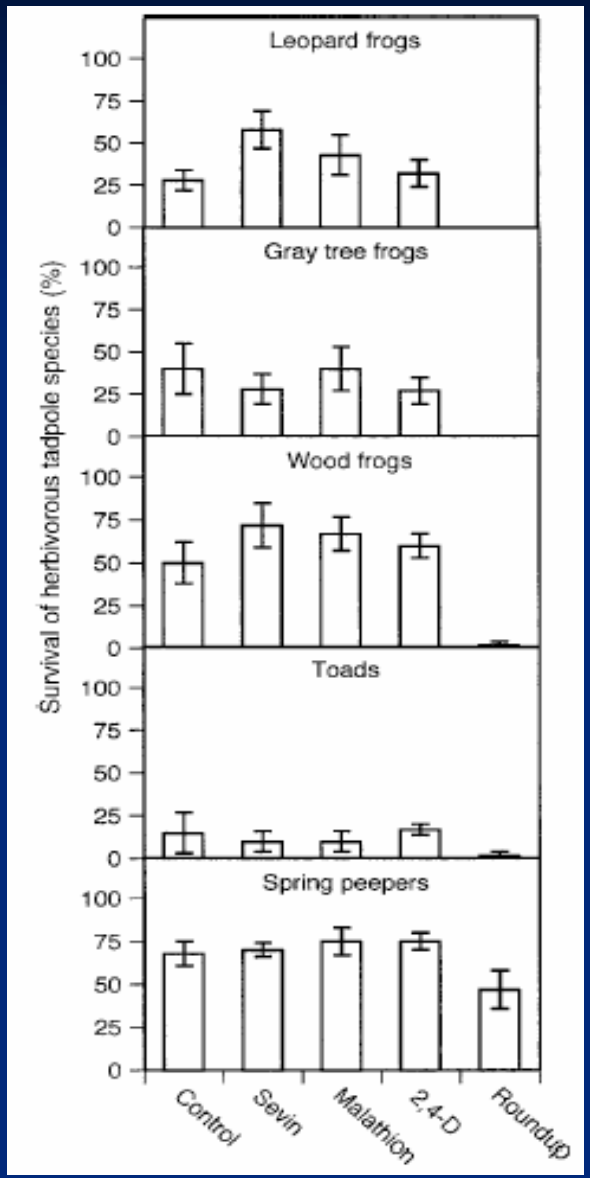
Fernandez, M.R., Selles, F., Gehl, D., DePauw, R.M. et Zentner, R.P. 2005. «Crop Production Factors Associated with Fusarium Head Blight in Spring Wheat in Eastern Saskatchewan». *Crop Science*, vol. 45, p. 1908-1916.

Roundup and the environment
Glyphosate and parasites

- According to Araujo et al. (2003), soils exposed to repeated applications of glyphosate show higher levels of microbial activity than soils not treated with glyphosate over the same period.
- *«…there is a growing body of evidence that glyphosatebased herbicides are affecting plant pathogenic fungi and, in turn, disease levels in fieldcrops» (Hanson et Fernandez, 2003, p. 120.)*

A.S.F. Araujo, Monteiro, R.T.R. et R.B. Abarkeli. 2003. Effect of Glyphosate on the microbial activity of two Brazilian soils. *Chemosphere*, vol 52, p. 799–804.

Roundup and amphibians



(Relyea, 2005)

- Relyea, Rick A. 2005. «The impact of Insecticides and Herbicides on the Biodiversity and Productivity of Aquatic Communities», *Ecological Applications*, vol. 15, p. 618-627
- Roundup caused a 70% decrease in amphibian biodiversity and an 86% decrease in the total mass of tadpoles.
- 2 species of tadpoles (Leopard Frog, Gray Treefrog)were completely eliminated
- Wood Frog tadpoles and toads were nearly completely eliminated
- *«Collectively, the available data indicate that, contrary to conventional wisdom, current application rates of Roundup can be highly lethal to many species of amphibians» (Relyea, 2005, p. 625).*

Roundup and health

Impact on transcription (genetic)

Marc J, Le Breton M, Cormier P, Morales J, Belle R et Mulner Lorillo O. 2005. «A glyphosate-based pesticide impinges on transcription.» Toxicology and Applied Pharmacology. 203, 1-8

- Roundup affects the development of sea otters by inhibiting eclosion.
- Roundup disrupts genetic transcription, a fundamental biological process.
- Glyphosate and the surfactant used in Roundup (POEA) are both implicated in this phenomenon.
- «*The surfactant polyoxyethylene amine (POEA), the major component of commercial Roundup, was found to be* ***highly toxic to the embryos*** *when tested alone and therefore could contribute to the inhibition of hatching*.» (Marc et al., 2005, p.1)
- «*Because transcription is a fundamental basic biological process, the pesticide may be of health concern by inhalation near herbicide spraying at a concentration 25 times the adverse transcription concentration in the sprayed microdroplets* » (Ibid)

Roundup and health

Impacts on cell cycle regulation

Marc, Julie, Odile Mulner-Lorillon, Robert Bellé. 2003. «Glyphosate-based pesticides affect cell cycle regulation. » Biology of the Cell, vol. 96, p. 245–249.

- Roundup affects cell cycle regulation by disrutping DNA damage control.
- This can lead to the developpment of a cancer (potential mecanism of cancerogenesis). The study demonstrates a link between Roundup and cell cycle deregulation but does not establish a direct link with cancer.
- The concentration in pulverised droplets is 500 to 4000 times greater than the minimum level for cell cycle deregulation.
- «Therefore, glyphosate-based pesticides are clearly of human health concern by inhalation in the vicinity of spraying» (Marc et al., 2003)

Roundup and health
Effects of inerts (POEA)

Francisco Peixoto 2005. «Comparative effects of the Roundup and glyphosate on mitochondrial oxidativ phosphorylation ». *Chemosphere*, *In Press*, Corrected Proof, Available online 26 April 2005. doi:10.1016/j.chemosphere.2005.03.044

- Study shows that Roundup alters the process of mitochondrial respiration in the livers of rats.
- No effects were found with glyphosate alone.
- The alterations observed were linked to an adjuvant used in Roundup (POEA) or to a synergistic effect between the adjuvant and glyphosate.
- «*Bearing in mind that mitochondria is provided with a variety of bioenergetic functions mandatory for the regulation of intracellular aerobic energy production and electrolyte homeostasis, these results* ***question the safety of Roundup on animal health****» (Peixoto, 2005)*

Roundup and health

Toxic effects and endocrine disruption

- Richard S, Moslemi S, Sipahutar H, Benachour N, Seralini GE. 2005. «Differential effects of glyphosate and Roundup on human placental cells and aromatase» *Environmental Health Perspectives*, vol. 113, no. 6, juin, p. 716-720.
- A study by a team led by Pr. Gilles-Eric SERALINI at the University of Caen in France on the toxicity of Roundup demonstrates that:
- Human placenta cells are very sensitive to Roundup at levels inferior to those found routinely in agriculture, perhaps explaining the reasons for premature births and abortions in rural areas of the United States.
- Moreover, effects of Roundup on the synthesis of sexual hormones were detected below the level of toxicity, which allows for the classification of this herbicide as a potential endocrine disruptor.
- Finally,the effects from Roundup are always greater than those of glyphosate alone, its active ingredient. (hypothesis: adjuvants)

Roundup and health

Spontaneous abortions

Arbuckle TE, Lin Z, Mery LS. An exploratory analysis of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario farm population. Environ Health Perspec 2001;109:851–857.

Table 2. Spontaneous abortion risk and preconception exposure to various pesticides.

	All gestational ages	< 12 weeks		12–19 weeks	
Pesticide unit	Crude OR (95% CI)	No. of exposed cases[a]	Crude OR (95% CI)	No. of exposed cases[a]	Crude OR (95% CI)
Pesticide active ingredient					
Atrazine	1.2 (0.9–1.7)	24	1.3 (0.8–2.0)	16	1.1 (0.7–1.9)
Captan	1.0 (0.5–1.8)	6	1.0 (0.4–2.1)	5	1.0 (0.4–2.6)
Carbaryl	1.2 (0.9–1.7)	24	1.2 (0.8–1.9)	17	1.2 (0.7–2.0)
Cyanazine	0.7 (0.3–1.7)	4	0.9 (0.3–2.4)	2	0.6 (0.1–2.3)
2,4-D	1.2 (0.8–1.6)	26	1.3 (0.9–2.0)	13	0.9 (0.5–1.6)
2,4-DB	0.8 (0.4–1.5)	10	1.4 (0.7–2.8)	0	0.1 (0.0–1.4)
Dicamba	1.0 (0.7–1.7)	11	1.0 (0.5–1.8)	9	1.1 (0.6–2.2)
Glyphosate	1.4 (1.0–2.1)	16	1.1 (0.7–1.9)	17	1.7 (1.0–2.9)
MCPA	0.8 (0.5–1.3)	17	1.1 (0.6–1.8)	7	0.6 (0.3–1.2)
Chemical families					
Phenoxy acetic acid	1.2 (0.9–1.5)	48	1.5 (1.1–2.1)	21	0.8 (0.5–1.9)
Triazine	1.3 (1.0–1.8)	35	1.4 (1.0–2.0)	22	1.1 (0.7–1.8)
Organophosphate	1.0 (0.7–1.4)	24	1.0 (0.6–1.6)	18	1.0 (0.6–1.7)
Thiocarbamate	1.5 (1.0–2.1)	16	1.1 (0.7–1.9)	18	1.8 (1.1–3.0)
Use classes					
Herbicide	1.3 (1.0–1.6)	78	1.4 (1.1–1.9)	51	1.1 (0.8–1.6)
Insecticide	1.1 (0.9–1.4)	68	1.2 (0.9–1.5)	49	1.1 (0.8–1.5)
Fungicide	1.4 (1.1–1.8)	36	1.3 (0.9–1.9)	28	1.4 (0.9–2.1)
Miscellaneous	1.5 (1.1–2.0)	25	1.3 (0.8–2.1)	21	1.5 (1.0–2.4)

[a]The total number of cases of spontaneous abortion is 395, with 226 and 169 early and late abortions, respectively.

Roundup and health

GMOs and food residues

Vecchio, L., Cisterna, C., Malatesta, M., Martin, T.E., Biggiogera. 2004. «Ultrastructural analysis of testes form mice fed on genetically modified soybean». *European Journal of Histochemistry*, vol. 48, no.4 (Oct.-Déc.), p. 449-454.

- Ultrastructural analysis of testes from mice fed on GM soya tolerant to glyphosate found differences with the control group.
- The alterations suggest a reduction in transcription among mice fed on GM soya
- Hypothesis: these alterations, which correspond to the effet from glyphosate reported in other studies, can be related to to residues of glyphosate present in the GM soya (Vecchio et al., 2004).

For more on the effects of GM soya see also[i]:

- **Malatesta et al. 2002.** «Ultrastructural Morphometrical and Immunocytochemical analyses of Hepatocyte Nuclei from Mice Fed on Gentically Modified Soybean», Cell Structure and Function, vol. 27, p. 173-180.
- **Malatesta et al., 2003**. «Fine structural analysis of pancratic acinar cells from mice fed on genetically modified soybean». European Journal of Histochemistry, vol. 47, no.4 (pct.-déc), p. 385-388.

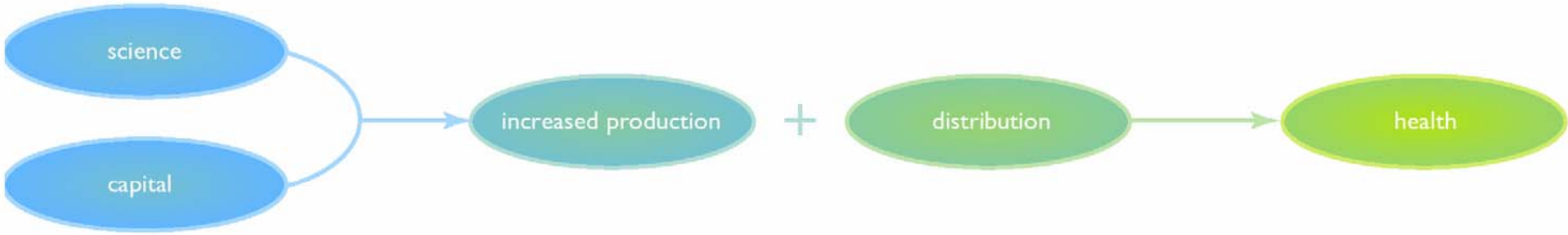
Subterfuge ?

« Nombreux sont ceux qui en faisant le commerce de supercheries et de miracles simulés, duperaient la multitude insensée; et si personne ne dénonçait leurs subterfuges, ils en imposeraient à tous. »

Léonard De Vinci

Source: MacCurdy, E. 1942. Les Carnets de Léonard De Vinci. Tome 2, Paris, Édition Gallimard, 570 p.

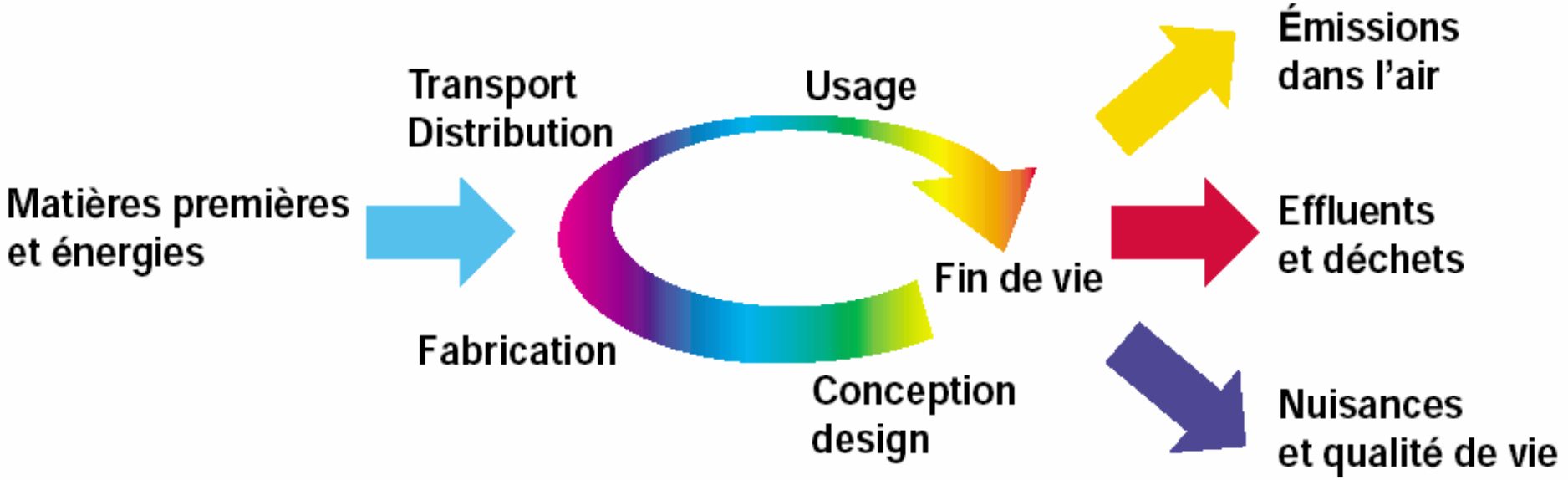
A linear conception



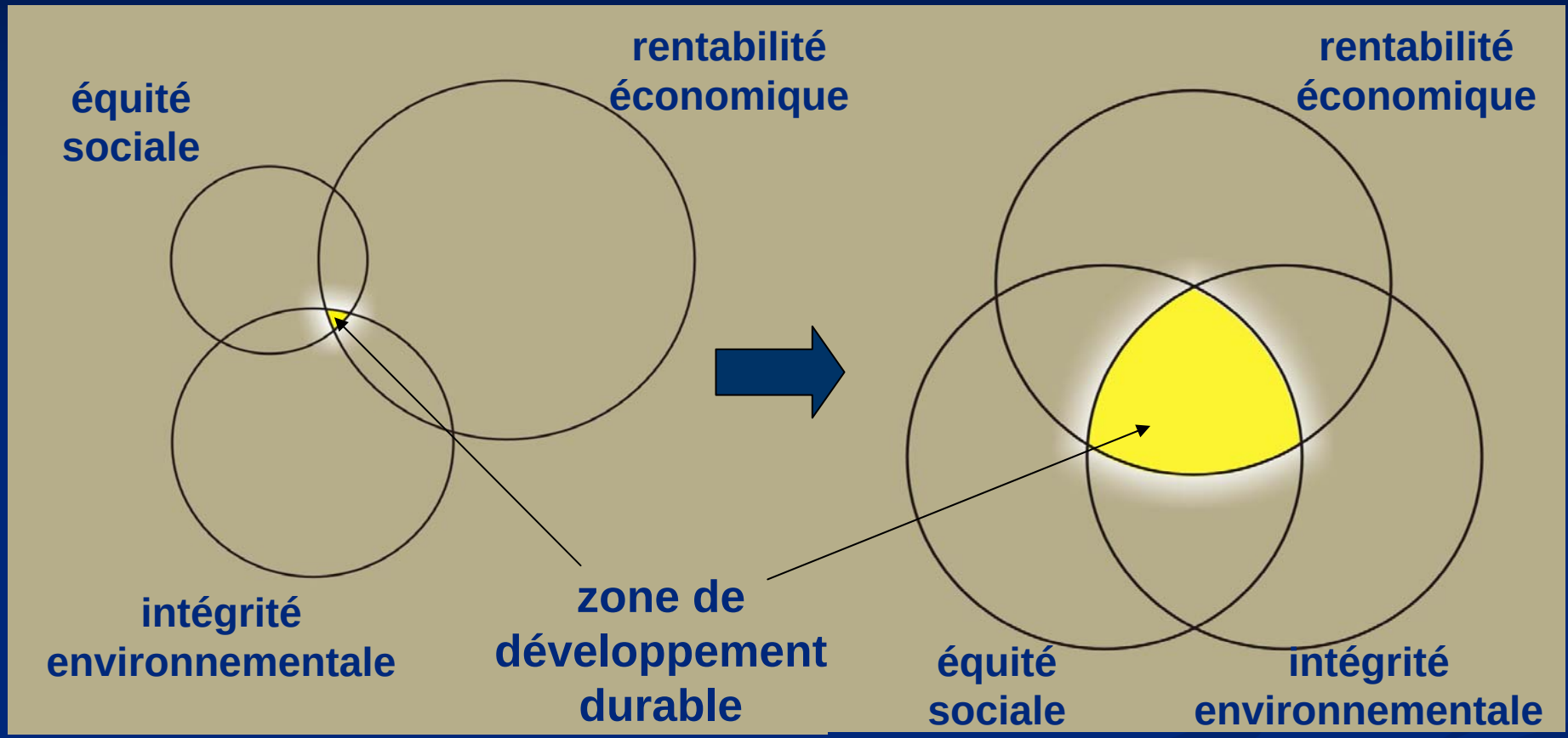
GLOBAL CHANGE & HUMAN HEALTH, VOLUME 1, NO. 2 (2000)

Versus…

Le concept de cycle de vie d'un produit



The challenge for sustainable development in agriculture



Actual situation

Desired situation

D.Boutin, agronomist and rural economist, M.Sc.Dir. des politiques en milieu terrestre, M.Environnement, Qc, juin 2004

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- Hanson, K.G. et M.R. Fernandez. 2003. «Glyphosate herbicides affect plant pathogenic fungi» *Canadian Journal of Plant Pathology*, vol. 25, p.120.

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- Thank you for your attention…

GMOs and pesticides

Pesticide sales in canada increase by 41% from 1994 to 2000

- In 2001, Round Up patent expires
- By 2005: 69% of global pesticide market expected to be to generics **(Kuyek2002)**
- « Regulatory cost » for bringin a pesticide to market = 40-100 M$ and for a new plant variety = $1 million **(Kuyek2002)**

GM seeds offer triple protection:

- Intellectual property right
- Possible introduction of genetic use restriction technologies (GURTS) to prevent the reporduction of the plant or important genetic characteristics.

(Benbrook, 2004)