Food Safety *Review*

A PUBLICATION OF THE CENTER FOR FOOD SAFETY

Going Backwards: Dow's 2,4-D-Resistant Crops and a More Toxic Future

BY BILL FREESE, CFS SCIENCE POLICY ANALYST

Agricultural biotechnology companies such as Monsanto and Dow have recently developed new genetically engineered (GE) crops that are designed to survive dousing with toxic herbicides, including 2,4-dichlorophenoxyacetic acid (2,4-D), a major component of the Vietnam War defoliant, Agent Orange. The U.S. Department of Agriculture (USDA) is currently considering approval of these novel crops. If they are approved, American agriculture will see a massive increase in toxic pesticide use. Many millions of more pounds of 2,4-D and related herbicides will be sprayed, meaning more chemical toxins in our food and more pollution of our waterways and ecosystems. The impacts will be substantial, as hundreds of scientific studies link 2,4-D and its chemical cousins to human health and environmental harms. This massive chemical onslaught will also cause tremendous "collateral damage" to neighboring organic and conventional crops and wild flora because 2,4-D is already the number one culprit in plant-killing herbicide drift episodes. Finally, the herbicides sprayed on these crops will trigger rapid evolution of crop-choking herbicide-resistant weeds, which will be countered with new resistant crops and still greater use of toxic chemicals, leading to still more weed resistance, in a never-ending and ultimately futile chemical arms race with weeds.

WHAT ARE GENETICALLY ENGINEERED CROPS?

Genetic engineering, also called genetic modification, is the direct human manipulation of an organism's DNA using modern biotechnology, developed to overcome the natural limitations—such as the species barrier—of traditional breeding. With this new technology, biotechnology firms have engineered numerous novel creations, such as corn with bacteria genes, "super" salmon with eel genes, rice with human genes, and thousands of other plants, animals and insects. At an alarming rate, these laboratory experiments are now being patented and released into the environment, and our food supply.

The vast majority of GE crops (84% by acreage) are engineered for herbicide resistance.[1] Herbicide-resistant (HR) crops are the chief focus of biotechnology development efforts for two basic reasons. First, all of the major biotech companies are pesticide firms that have acquired seed companies.[2] Biotechnology = pesticides + seeds. Second, herbicides are far and away the most heavily used form of pesticide, comprising two-thirds of agricultural pesticide use in the U.S.[3] HR crops thus create incredibly profitable synergies for Monsanto, Dow and the other pesticide-seed firms, which profit twice by selling both expensive GE seeds and the large quantities of the herbicide(s) used with them.

Dow Chemical Company is presently seeking USDA approval of GE corn resistant to 2,4-D.[4] Dow plans to introduce this corn in a package with 2,4-D in 2013, followed in the next few years by 2,4-D-resistant soybeans and cotton. Dow's crops are certain to dramatically increase use of this toxic herbicide *(Figure 1)*, which was part of the Agent Orange defoliant used in the Vietnam War *(see inset)*. Dow's corn is also resistant to "fops" grass herbicides (e.g. quizalofop), and will be stacked with glyphosate resistance, facilitating greater use of these weed-killers as well.

HUMAN HEALTH CONCERNS

Exposure to 2,4-D has been linked to major health problems[5] that include cancer (especially non-Hodgkin's lymphoma), lowered sperm counts, liver disease[6] and Parkinson's disease.[7] Numerous laboratory studies show that 2,4-D adversely affects the hormonal, reproductive, neurological and immune systems. Further, industry tests reveal that 2,4-D is contaminated with dioxins,[8] a group of highly toxic chemical compounds that bioaccumulate up the food chain, potentially leading to dangerous levels of exposure. A barely visible speck of the dioxin 2,3,7,8-TCDD (less than one-millionth of a gram) is enough to kill an adult guinea pig,[9] the most sensitive mammalian species that has been tested. 2,4-D is the seventh largest source of dioxins in the U.S.[10]

2,4-D-resistant crops may also pose a new food safety risk in the form of 2,4-dichlorophenol (2,4-DCP), a breakdown product of 2,4-D when applied to resistant crops.[11] 2,4-DCP is on the EPA's toxics release inventory, and is the raw material from which 2,4-D is made.[12] According to Dow:[13] 1) Exposure of just 1% of a worker's body (an area the size of the palm of a hand) to molten 2,4-DCP may cause death; 2) 2,4-DCP has adverse effects on blood forming organs (bone marrow & spleen), kidney and liver in animal tests; 3) Some studies suggest 2,4-DCP causes cancer and is a genetic toxin, while others do not; 4) No information was found on potential reproductive effects; and 5) 2,4-DCP is moderately toxic to aquatic organisms.

French scientists concluded that "following 2,4-D treatment, 2,4-D-tolerant plants may not be acceptable for human consumption" due to the breakdown of 2,4-D to 2,4-DCP, and the potential for further transformation of 2,4-DCP residues into highly toxic dioxins and furans in our bodies.[14]

Environmental Impacts

Plants form the base of ecosystems. They provide the primary source of nutrients for most other organisms, and structure habitats. Because many plants are exquisitely sensitive to 2,4-D, drift and runoff are serious threats to the whole community of organisms that depend on plants. In fact, for sensitive species, 2,4-D is over 300 times more toxic to emerging seedlings and nine times more toxic to growing plants than glyphosate.[15] According to the EPA, even existing agricultural uses of 2,4-D are likely to adversely affect the endangered California red-legged frog and Alameda whipsnake via impacts on their habitats and prey.[16] And the National Marine Fisheries Service finds that drift and runoff from agricultural 2,4-D applications can adversely modify critical habitat in the floodplain breeding grounds of Pacific salmon, because it degrades the riparian vegetation that keeps the water clean enough for salmon to breed.[17] Because these impacts were found at current 2,4-D usage levels, they will be greatly exacerbated by the sharp spike with cultivation of 2,4-D crops *(Figure 1)*. Since endangered species act as sentinels for the health of the ecosystems they inhabit, much broader adverse impacts to other organisms are likely.

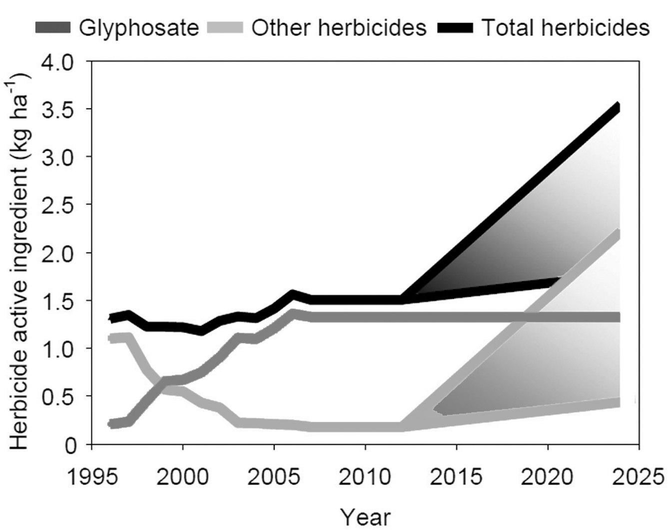

FIGURE 1: Range of projected herbicide use on U.S. soybeans with adoption of soybeans resistant to the herbicides 2,4-D (Dow) and dicamba (Monsanto) (referred to as HR soybeans below), from Mortensen et al (2012).[48] Assumptions: 1) HR soybeans introduced in 2013, with adoption on 91% of soybean acres by 2025, which mirrors the rate of adoption of Roundup Ready crops; 2) Both varieties stacked with glyphosate resistance; 3) Glyphosate use rate remains at present level through 2025; 4) 2,4-D and dicamba (= "other herbicides") applied at annual rate of 0.28 kg/ha (minimum) to 2.24 kg/ha (maximum). The minimum represents typical current usage rates of these herbicides (on conventional corn and wheat), while the maximum corresponds to rates recommended by Dow and Monsanto for use on 2,4-D and dicamba-resistant crops, respectively.

Spray and Vapor Drift

2,4-D is a volatile herbicide that is prone to drift beyond the field of application to damage neighboring crops and wild plants. 2,4-D vapor injures most broadleaf (i.e. non-grass) plants at extremely low levels, as low as three-billionths of a gram per liter of air.[18] Particularly sensitive crops include grapes,[19] soybeans, sunflower, beans, tomatoes, cotton[20] and lettuce, but 2,4-D can injure almost any broadleaf plant. Two surveys of state pesticide regulators establish that 2,4-D drift is responsible for more episodes of crop injury than any other pesticide.[21] 2,4-D ranked above the number two culprit, glyphosate, even during a period (2002 to 2004) when glyphosate use was four times that of 2,4-D.[22] This is explained by 2,4-D's greater volatility and potency versus glyphosate.

Introduction of 2,4-D crops will greatly increase drift injury to crops and wild plants over already high levels for three reasons: 1) Much higher rates of 2,4-D will be applied as a result of high-level 2,4-D resistance conferred by genetic engineering; 2) Much more acreage will be sprayed;[23] and 3) More spraying will take place mid-season, when neighboring crops have leafed out and are thus more susceptible to injury from 2,4-D drift. Field-edge plants that serve as habitat for beneficial insects (e.g. pollinators) will also be impacted.

Chemical Arms Race With Weeds

Dow is falsely hyping 2,4-D crops as the solution to a serious and growing problem generated by Monsanto's first generation herbicide-resistant crops, known as Roundup Ready (RR).[24] Massive post-emergence use of Roundup (i.e. glyphosate) with RR crops has triggered an epidemic of glyphosate-resistant (GR) weeds over the past decade, on the same Darwinian principle by which overused antibiotics foster drug-resistant bacteria.[25] To control GR weeds, farmers are spraying more toxic herbicides (6 to 8 different types in extreme cases),[26] resorting to more soil-eroding tillage operations,[27] and hiring weeding crews to hoe weeds by hand in cotton-growing states.[28] In Illinois, weed scientist Patrick Tranel predicts that waterhemp resistant to as many as four families of herbicide may soon make it impractical to grow soybeans in some Midwestern fields.[29]

AGENT ORANGE: CHEMICAL WARFARE IN VIETNAM

The first planned use of 2,4-D—to destroy Japanese rice fields in WWII—was preempted by the end of the war.[42] Like many wartime biocides, 2,4-D was "repurposed" for domestic use—the war on weeds—only to realize its original mission two decades later in Vietnam. In what has been called the "largest chemical warfare operation in history,"[43] the U.S. military dumped 11 million gallons of Agent Orange (a mixture of 2,4-D and the still more toxic 2,4,5-T) over Vietnam from 1962-1971.[44] The purposes of this chemical warfare were to destroy rice fields and rainforests to deny the Vietnamese food and cover. The Veterans Administration regards Agent Orange exposure as the cause of numerous diseases in Vietnam veterans: diabetes, neuropathy, Parkinson's disease, heart disease, liver dysfunction, chloracne, numerous cancers (e.g. leukemia, lung, prostate, and multiple myeloma), as well as birth defects (e.g. spina bifida) in the children of exposed soldiers.[45] According to one estimate, at least 3 million Vietnamese suffer serious health problems from Agent Orange exposure, including birth defects in children and grandchildren of those exposed.[46] Yet Vietnamese suffering from the toxic legacy of Agent Orange have received little compensation from the U.S. government.[47]

Far from "solving" the GR weed epidemic, studies already suggest that Dow's crops will pour oil on the fire, triggering a still more serious outbreak of weeds resistant to glyphosate, 2,4-D and other herbicides.[30] Dow, Monsanto and other pesticide firms are aware of this, which is why they are focusing the bulk of their R&D on new crops engineered with resistances to ever more herbicides. Monsanto is awaiting approval of soybeans resistant to dicamba (close chemical cousin to 2,4-D) and glyphosate, with triple herbicide-resistant corn and cotton in the pipeline.[31] DuPont envisions a single crop resistant to seven or more different families of herbicide.[32] Altogether, two-thirds of GE crops awaiting approval by USDA are resistant to one to three herbicide groups.[33] RR crops have already triggered a large increase in herbicide use,[34] and 2,4-D crops will further this trend. Increasingly toxic herbicide cocktails will be used on multiple herbicide-resistant (HR) crops, spawning weeds with multiple resistances. The chemical arms race with weeds triggered by these HR crops entails an ever-escalating spiral of pesticide use and pollution, and attendant adverse impacts on public health and the environment. But in the process, these crops will generate substantial profits for pesticide-biotech firms like Dow that sell both HR seed and the associated herbicides. Thus, it is not surprising that Dow scientist John Jachetta reportedly welcomes the chemical arms race in glowing terms as "a new era" and "a very significant opportunity" for chemical companies.[35]

Since the chemical arms race is impossible to win, disengagement from HR crops is the only sensible strategy. Non-chemical practices that facilitate weed control—such as cover crops, judicious tillage, crop rotation, and tight row spacing—must take center stage as part of an integrated approach to weed control that greatly reduces reliance on herbicides and hence evolution of resistant weeds.[36]

Herbicide-Resistant Crops Are NOT Responsible for Conservation Tillage or Related Benefits

Dow falsely claims that Roundup Ready crops have enabled conservation tillage, and so reduced soil erosion, number of herbicide applications, tractor use, fuel consumption, and global warming gas emissions; further, that 2,4-D crops will "preserve" these supposed benefits.[37] Dow is wrong on every count. The big gains in U.S. acreage under conservation tillage occurred from the 1970s to mid-1990s, prior to the 1996 introduction of RR crops. Much of these gains were spurred by strong financial incentives to adopt soil-conserving farming practices contained in the 1985 and subsequent Farm Bills.[38] The success of these policies is reflected in dramatically declining soil erosion over this period, followed by ***a leveling off of soil erosion rates during the decade of Roundup Ready crop adoption, from 1997 to 2007*** *(Figure 2)*. These data—from USDA's soil conservation experts—give the lie to misinformation on this point spread by front groups of the pesticide industry, from the American Soybean Association to PG Economics to ISAAA.

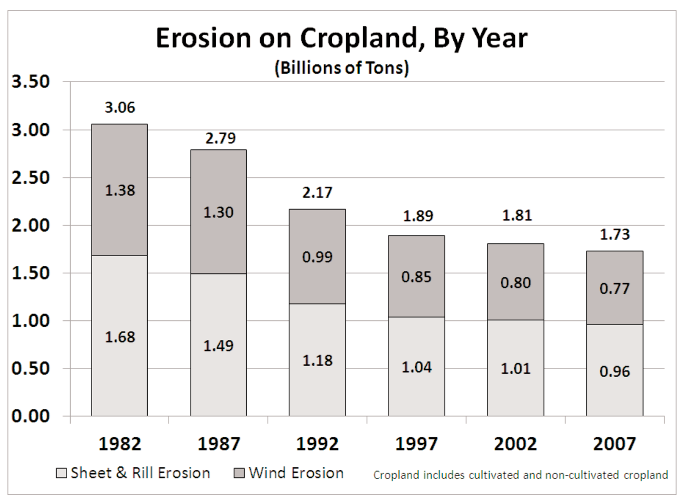

FIGURE 2: Erosion rates based on the National Resources Inventory (NRI), a longitudinal sample survey based upon scientific statistical principles and procedures, conducted by USDA's Natural Resources Conservation Service (NRCS), in cooperation with Iowa State University's Center for Survey Statistics and Methodology. Erosion rates are estimates of average annual (or expected) rates based upon long-term climate data, inherent soil and site characteristics, and cropping and management practices. From: "2007 National Resources Inventory: Soil Erosion on Cropland," USDA NRCS, April 2010. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_012269.pdf.

Since RR crops have not promoted an increase in conservation tillage, they are not responsible for the many benefits attributed to this practice. On the contrary, the epidemic GR weeds fostered by RR crop systems have ***increased soil-eroding tillage.***[39] Since 2,4-D crops will promote still more intractable weed resistance, their ultimate effect will be to further increase soil erosion via greater use of tillage for weed control.

The main reasons farmers adopt herbicide-resistant crops are convenience, and the ability to farm more land with less labor.[40] This latter "benefit" has facilitated the ongoing decline in our farming population, as small and medium-size family farmers disfavored by federal farm policy go out of business and sell off their land to neighbors, who with larger blocks of land to farm are more receptive to labor-saving innovations like herbicide-resistant crops.[41]

Conclusion

American agriculture stands at a crossroads. One path involves ever more intensive use of pesticides, facilitated by genetic engineering, still bigger megafarms, and further depopulation and impoverishment of rural America. This is the path of industrial agriculture. Dow's 2,4-D-resistant crops are the epitome of this unsustainable approach, which sacrifices human and ecosystem health as well as rural communities for cheap food and short-term profits. Fortunately, there is a different path to the future. Organic farming rejects synthetic pesticides and genetic engineering, and utilizes non-toxic, sustainable methods to control pests (including weeds) and enrich the soil. Organic sales are growing by leaps and bounds as more and more people vote with their pocketbooks to support small farmers, rural communities, wholesome foods, and a healthy environment.

---

[1] ISAAA (2009). "Global Status of Commercialized Biotech/GM Crops: 2009 - The first fourteen years, 1996 to 2009." International Service for Acquisition of Agri-biotech Applications, a biotech industry funded organization.

[2] ETC (2008). "Who Owns Nature? Corporate Power and the Final Frontier in the Commodification of Life," ETC Group, November 2008, p. 11. http://www.etcgroup.org/en/materials/publications.html?pub_id=707. Monsanto, DuPont, Syngenta and Bayer are together responsible for 49% of the world's proprietary seed sales, and are also among the leading sellers of agricultural chemicals.

[3] EPA (2011). "Pesticide Industry Sales and Usage: 2006 and 2007 Market Estimates," U.S. Environmental Protection Agency, February 2011, Table 3.4. In 2007, agricultural herbicides (442 million lbs.) represented 65% of overall pesticide use in U.S. agriculture (684 million lbs.)

[4] Philpott, T. (2012). "Dow and Monsanto Team Up on the Mother of All Herbicide Marketing Plans," MotherJones, 1/25/12. http://motherjones.com/tom-philpott/2012/01/dows-new-gmo-seed-puts-us-agriculture-crossroads.

[5] For this section, see generally: NRDC (2008). "Natural Resources Defense Council's Petition to Revoke All Tolerances and Cancel All Registrations for the Pesticide 2,4-D," by Gina Solomon, MD, MPH & Mae Wu, Esp., filed with EPA on 11/6/08, Natural Resources Defense Council; and Cox, C (2006). "2,4-D Herbicide Factsheet," Journal of Pesticide Reform 25(4), updated April 2006. http://www.pesticide.org/get-the-facts/pesticide-fact-sheets/factsheets/24d-factsheet.

[6] Leonard, C, CM Burke, C O'Keefe, JS Doyle (1997). "'Golf ball liver': Agent Orange hepatitis," Gut 40: 687-688; Johnston, S, G McCusker, TJ Tobinson (1998), "'Golf ball liver': a cause of chronic hepatitis?" Gut 42: 143.

[7] Tanner, C.M. et al (2009). "Occupation and risk of Parkinsonism," Archives of Neurology 66: 1106-1113.

[8] EPA (2005). "Reregistration Eligibility Decision for 2,4-D," Environmental Protection Agency, EPA 738-R-05-002, June 2005, p. 82.

[9] Schwetz, BA et al (1973). "Toxicology of chlorinated dibenzo-p-dioxins," Adv. Chem 120: 55-69. A single 0.6 mcg/kg dose killed 50% of male guinea pigs tested; typical weight of male guinea pig = 1 kg.

[10] EPA (2005), op. cit., p. 83.

[11] Wright, TR et al (2010). "Robust crop resistance to broadleaf and grass herbicides provided by aryloxyalkanoate dioxygenase transgenes," PNAS 107(47): 20240-20245.

[12] EPA (1999). Emergency Planning and Community Right-to-Know Section 313: List of Toxic Chemicals within the Chlorophenols Category, Environmental Protection Agency, June 1999 (Technical Update November 2005); on 2,4-DCP as starting material for 2,4-D, http://nzic.org.nz/ChemProcesses/production/1J.pdf.

[13] Dow (2006). 2,4-Dichlorophenol Material Safety Data Sheet, Product Code: 20636, MSDS Number: 000715. Dow AgroSciences LLC, Effective Date: 7-Sept-06.

[14] Laurent, F. et al (2006). "Metabolism of [14C]-2,4-dichlorophenol in edible plants," Pest Management Science 62: 558-564; Wittsiepe, J. et al (2000). "Myeloperoxidase-catalyzed formation of PCDD/F from chlorophenols," Chemosphere 40: 963-968. Note that plants rapidly attach various sugar molecules to 2,4-DCP to form "conjugates," but if food containing these conjugates is consumed, free 2,4-DCP will likely be released in the digestive tract..

[15] Peterson RKD & Hulting ANG (2004). "A comparative ecological risk assessment for herbicides used on spring wheat: the effect of glyphosate when used within a glyphosate-tolerant wheat system," Weed Science 52: 834-844.

[16] EPA (2009). "Risks of 2,4-D Use to the Federally Threatened California Red-legged Frog (Rana aurora draytonii) and Alameda Whipsnake (Masticophis lateralis euryxanthus)," Environmental Protection Agency, Feb. 2009.

[17] NMFS (2011). "Biological Opinion: Endangered Species Act Section 7 Consultation with EPA on Registration of 2,4-D, Triclopyr BEE, Diuron, Linuron, Captan and Chlorothalonil," National Marine Fisheries Services, June 30, 2011.

[18] Breeze, V.G. & West, C.J. (1987). "Effects of 2,4-D butyl vapor on the growth of six crop species," Ann. Appl. Biol. 111: 185-91.

[19] Walker, T. (2011). "Avoiding 2,4-D Injury to Grapevines," Colorado State University Extension, July 2011.

[20] Everitt JD, Keeling JW. 2009. Cotton growth and yield response to simulated 2,4-D and dicamba drift. Weed Technology 23: 503–506.

[21] AAPCO (1999 & 2005). "1999/2005 Pesticide Drift Enforcement Survey," Association of American Pesticide Control Officials, at http://aapco.ceris.purdue.edu/htm/survey.htm. Survey periods 1996-1998 and 2002-2004, respectively.

[22] EPA (2011). "Pesticide Industry Sales and Usage: 2006 and 2007 Market Estimates," Environmental Protection Agency, Feb. 2011, Table 3.6.

[23] Conventional corn is partially tolerant of, but can still be injured by, 2,4-D. Thus, 2,4-D is sprayed on only 9% of U.S. corn at a low average rate of 0.3-0.4 lbs./acre. Based on USDA data for 2010 at http://www.nass.usda.gov/Data_and_Statistics/Pre-Defined_Queries/2010_Corn_Upland_Cotton_Fall_Potatoes/index.asp. By eliminating risk of crop injury at 2,4-D rates 10-fold higher (see Wright et al (2010), op. cit.), 2,4-D corn will trigger a massive increase in both number of acres sprayed and in rates of 2,4-D applied to those acres, worsening the already serious problems associated with drift and runoff. Because 2,4-D is toxic to and thus little used on conventional soybeans and cotton (only prior to planting or crop emergence), 2,4-D-resistant versions of these crops will trigger even greater increases in 2,4-D use.

[24] Kaskey, J (2010). "Dow plans new trait to combat Roundup-resistant weeds," Bloomberg, May 05, 2010, http://www.businessweek.com/news/2010-05-05/dow-plans-new-trait-to-combat-roundup-resistant-weeds-update2-.html

[25] Powles, S.B. (2010). "Gene amplification delivers glyphosate-resistant weed evolution," PNAS 107: 955?56.

[26] Culpepper, AS & Kichler, J. (2009). "University of Georgia Programs for Controlling Glyphosate-Resistant Palmer Amaranth in 2009 Cotton," U of GA Cooperative Extension, April 2009.

[27] NAS (2010). "The Impact of Genetically Engineered Crops on Farm Sustainability in the United States," National Research Council, National Academy of Sciences, 2010 (prepublication copy), p. 2-21; Neuman, W. & A. Pollack (2010). "U.S. farmers cope with Roundup-resistant weeds," New York Times, May 4, 2010. http://www.nytimes.com/2010/05/04/business/energy-environment/04weed.html

[28] Haire, B. (2010). "Pigweed threatens Georgia cotton industry," Southeast Farm Press, July 6, 2010. http://southeastfarmpress.com/cotton/pigweed-threatens-georgia-cotton-industry-0706/.

[29] Tranel, P.J. (2010). "Herbicide resistances in Amaranthus tuberculatus: A call for new options," Journal of Agricultural and Food Chemistry, DOI:10.1021/jf103797n.

[30] Mortensen, DA, Egan, JF, Maxwell, BD, Ryan, MR & Smith, RG (2012). "Navigating a critical juncture for sustainable weed management," Bioscience 62(1): 75-84; Freese, B. (2010). Testimony on Herbicide-Resistant Weeds before the Domestic Policy Subcommittee of the House Oversight and Government Reform Committee, 9/30/10. See "written answers to four followup questions" link at http://www.centerforfoodsafety.org/2010/09/30/center-for-food-safety-testifies-at-congressional-oversight-hearing-on-'super-weeds'-caused-by-biotech-crops/, (question 3, pp. 9-19).

[31] Mortensen et al (2012), op. cit.; http://monsanto.mediaroom.com/index.php?s=43&item=788.

[32] "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent Application Publication, Pub. No. US 2009/0011938 A1, January 8, 2009, paragraph 33.

[33] As of 1/10/12, 13 of 20 "Petitions for Nonregulated Status Pending" are herbicide-resistant GE crops. See http://www.aphis.usda.gov/biotechnology/not_reg.html.

[34] Benbrook, C. (2009). Impacts of Genetically Engineered Crops on Pesticide Use in the United States: The First Thirteen Years," The Organic Center, November 2009.

[35] Kilman, S. (2010). "Superweed outbreak triggers arms race," The Wall Street Journal, June 4, 2010. http://www.gmwatch.org/latest-listing/1-news-items/12263-superweed-outbreak-triggers-arms-race

[36] Mortensen et al (2012), op. cit.

[37] Dow (2011). "Economic and agronomic impacts of the introduction of DAS-40278-9 corn on glyphosate-resistant weeds in the U.S. cropping system," Dow AgroSciences submission to USDA APHIS, May 11, 2011.

[38] Coughenour, DM & S. Chamala (2000). Conservation Tillage and Cropping Innovation: Constructing the New Culture of Agriculture, Iowa State University Press, Ames, Iowa, 2000, pp. 258, 286.

[39] NAS (2010), op. cit., p. 2-21.

[40] Duffy, M. (2001). "Who benefits from biotechnology?" presentation of Dr. Michael Duffy, Iowa State University agricultural economist, to the American Seed Trade Association meeting December 5-7, 2001, Chicago, IL.

[41] That said, in severe cases of weed resistance, labor needs and costs can skyrocket. Cotton farmers afflicted with glyphosate-resistant pigweed employ weeding crews to manually hoe weeds on hundreds of thousands of acres in the South, raising weed control costs threefold or more.

[42] Lilienfeld, DE & Gallo, MA (1989). "2,4-D, 2,4,5-T and 2,3,7,8-TCDD: An Overview," Epidemiologic Reviews 11: 28-58.

[43] Dr. Arthur Galston, Prof. Emeritus at the Yale School of Forestry & Environmental Studies, as quoted in: "Conference to 'put a human face' on the Vietnam War; Yale Bulletin and Calendar 31(1), August 30, 2002

[44] Lilienfeld & Gallo (1989), op. cit.

[45] See http://www.publichealth.va.gov/exposures/agentorange/diseases.asp, last visited 1/23/12.

[46] CRS (2009). "Vietnamese victims of Agent Orange and U.S.-Vietnam Relations," Congressional Research Service, May 28, 2009.

[47] Mason, M. (2010). "$300 million price tag to cope with Agent Orange in Vietnam," Associated Press, June 16, 2010.

[48] Mortensen, DA, Egan, JF, Maxwell, BD, Ryan, MR & Smith, RG (2012). "Navigating a critical juncture for sustainable weed management," Bioscience 62(1): 75-84.