



Technical Review - Report on Glyphosate

Title : USDA Scientist Reveals Hazards of Glyphosate
Date : 20 January 2012
Contents: THIRD WORLD NETWORK BIOSAFETY INFORMATION SERVICE

ISIS Report 09/01/12

USDA Scientist Reveals All

Glyphosate Hazards to Crops, Soils, Animals, and Consumers

Don Huber painted a devastating picture of glyphosate and GM crops at UK Parliament.

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A fully illustrated and referenced version of this report is posted on the Institute of Science in Society website (<http://www.i-sis.org.uk>)

In less than an hour, Don Huber, professor emeritus at Purdue University and USDA senior scientist (see Box) delivered to the UK Houses of Parliament a damning indictment of glyphosate agriculture as a most serious threat to the environment, livestock, and human health. [1]

Don Huber

Don Huber, Emeritus Professor at Purdue University and senior scientist on USDA's National Plant Disease Recovery System, has been a plant physiologist and pathologist for over 40 years. His academic career began with 8 years as a cereal pathologist at the University of Idaho, and the next 35 years at Purdue University where he specialised in soil-borne disease control, physiology of disease, and microbial ecology. For the past 20 years, he has conducted extensive research into the effects of glyphosate on crops, in response to the increase in crop diseases on glyphosate-applied fields.

Since his letter to the US Secretary of State Tom Vilsak was leaked in February 2011, there has been a great deal of controversy over what Huber described as a pathogen "new to science" and abundant in glyphosate-tolerant GM crops (see [2] Emergency! Pathogen New to Science Found in Roundup Ready GM Crops?, SiS 50). As he concluded in the letter: "We are now seeing an unprecedented trend of increasing plant and animal diseases and disorders. This pathogen may be instrumental to understanding and solving this problem".

His talk linked glyphosate to reduced nutrient availability in plants, increasing plant diseases, the emergence of a new pathogen, animal illness and possible effects on human health (see [3, 4] Glyphosate Tolerant Crops Bring Death and Disease, Scientists Reveal Glyphosate Poisons Crops and Soil, SiS 47).

Pathogen new to science

The conversion of US agriculture to monochemical herbicide practice has resulted in the extensive use of glyphosate herbicides. Coincidentally, farmers have been witnessing deterioration in the health of corn, soybean, wheat and other crops, and epidemics of diseases in small grain crops. All are associated with the extensive use of glyphosate, which has increased further since the introduction of glyphosate-tolerant, Roundup Ready (RR) crops.



Glyphosate immobilizes nutrients required to maintain plant health and resistance to disease. This weakening of the plants defense could explain the infestation of GM crops with the new pathogen, which has now been observed in horse, sheep, pigs, cows, chicken, multiple animal tissues including reproductive parts (semen, amniotic fluid), manure, soil, eggs, milk, as well as the common fungal pathogen that is currently infesting RR crops, *Fusarium solani* fsp *glycines* mycelium. All are coming into contact with glyphosate either through direct exposure or consumption through animal feed. It is also highly abundant in crops suffering from plant Goss' wilt and sudden death syndrome.

The pathogen can be cultured in the lab, and has been isolated from livestock foetal tissue, replicated in the lab and re-introduced back into the animals. It appears to be very common and may well be interacting with the effects of glyphosate on both plants and animals, exacerbating disease and causing reproductive failure in livestock (see below). Although great expectations have been placed on Huber to publish his findings, he insists that before this can be done, further resources are necessary to be able to characterize the 'entity' and identify what type of species it is, including sequencing of its genome. This is a slow process and once complete, it is his intention to publish the work in a peer-reviewed journal.

Understanding glyphosate's mode of action

Recognizing glyphosate's mechanism of action is the key to understanding how it may exert detrimental effects on the health of crops, animals, and the environment alike. Glyphosate is a broad-spectrum herbicide that interacts with a range of physiological processes in the plant and its environment. Although it is most commonly recognized to work through inhibition of the plant enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) involved in the production of aromatic amino acids in the shikimate pathway, it was actually first patented as a strong metal-chelator that binds to metals including manganese, magnesium, iron, nickel, zinc and calcium, many of which are important micronutrients acting as co-factors for plant enzymes in different physiological processes including the plants' defense system. Indeed, it is actually through chelation of manganese that the EPSPS enzyme is inhibited.

Rendering plants more susceptible to disease through glyphosate's pathogenic activity is actually the way it exerts its herbicidal activity. This is done not just through immobilizing nutrients in the plant but also impacting the agricultural system as a whole. Consistently, if glyphosate does not reach the root of a plant or the plant is grown in a sterile soil, the plant is not killed.

Once in the soil, glyphosate is later immobilised through the chelation of cations, and is therefore very stable and not easily degraded. However, phosphorus (including phosphorus fertilisers) can desorb the herbicide, making it active once again in the soil.

Glyphosate interferes negatively with many components of agriculture Huber stressed that agriculture is an integrated system of many interacting components, which together determine crop health and therefore yield. This concept is undervalued, and the sooner this is recognised, the sooner we will be able to reap the full genetic potential of our crops.

The three main components of an agricultural system are 1) the biotic environment including beneficial organisms for example, nitrogen-fixing microbes and mineralizers; 2) the abiotic environment including nutrients, moisture, pH; and 3), defense against pathogens that damage crops. The genetic potential of a plant can be achieved by minimizing the stress placed on these



components through improving plant nutrition and physiology and prevention of diseases and pests.

We have been repeatedly told that to meet the world's needs for food production we must resort to GM crops and chemical agriculture. However, glyphosate detrimentally interacts with all the agricultural components, so much so that an estimated 50 percent of the potential crop yields are currently being lost (see Figure 1).

As shown in figure 1, glyphosate interacts with a wide range of health determinants, which intensifies stress and reduces crop yields. Not only does it accumulate in the plant tissues (shoot and root tips, reproductive structures and legume nodules), it accumulates in the roots where it then leaks into the soil and harms beneficial microorganisms in the soil including those that act as biological controls of pathogens. The obvious consequence is the increased virulence of soil-borne pathogens that lead to disease. Glyphosate immobilizes nutrients critical for plant defense system and other functions.

One of Huber's important discoveries was the close correlation of all the known conditions affecting the disease 'take-all' with the availability of manganese to the plant and its physiological effect on resistance to this pathogen.

Micronutrients are the activators or inhibitors of many critical physiological functions. Thus, a deficiency or change in availability of these regulatory elements can greatly affect plant growth and resistance to diseases and pests. Those metabolic pathways producing secondary anti-microbial compounds, pathogen-inhibiting amino acids and peptides, hormones involved in cicatrisation (walling off pathogens), callusing, and disease escape mechanisms can all be compromised by glyphosate.

Micronutrients are also necessary for other processes in a plant. Manganese for example is not only involved in co-activating the EPSPS enzyme, with up to 25 other enzymes known to be affected by manganese chelation. Such enzymes are necessary for photosynthesis, in assimilating carbon dioxide in the electron transport chain, along with zinc. It also helps in the synthesis of chlorophyll and in nitrate assimilation.

Numerous enzymes requiring other mineral co-factors are also affected, among them enzymes of the shikimate pathway, to which EPSPS belongs, are responsible for plant responses to stress and the synthesis of defense molecules against pathogens, such as amino acids, lignins, hormones, phytoalexins, flavenoids and phenols.

Consistent with what is known about the role of micronutrients and glyphosate, the levels of key minerals have been measured in transgenic RR soybeans and found to be lower than those in isogenic non-transgenic varieties. Manganese was reduced by as much as 45 %, while iron was reduced by 49 % [5]. Similar deficiencies in mineral content have been found in non-GM varieties, suggesting that the glyphosate, and not the RR transgene, is responsible for reducing mineral availability [6].

Glyphosate reduces photosynthesis, water uptake, amino acid production as well as lignin, a molecule conferring mechanical strength of the plant and crucial for conducting water through plant stems [7, 8].



As Huber stated, the consequences of these nutrient deficiencies is that "crops don't look as good, are not as productive or rigorous, and are slower growing" (see Figure 2). He noted yield drags of 26 % for RR soybeans. Furthermore, with current concerns for global warming, plants that are up to 50 % less water-efficient, such as RR crops, are counter-productive and can only exacerbate problems.

Huber stressed that there is nothing in the glyphosate tolerant crops that operates on the glyphosate applied to them. Consequently, although they have enough resistance to prevent them from dying (conferred by the EPSPS transgene), their overall physiological function is compromised by glyphosate. It therefore affects GM as well as non-GM crops through residual levels of glyphosate in the ground.

In addition to chelating nutrients in the plants, glyphosate can lower mineral content through damaging beneficial soil organisms, including microbes producing indole-acetic acid (a growth-promoting auxin), earthworms, mycorrhizae associations, phosphorus & zinc uptake, microbes such as Pseudomonads, Bacillus that convert insoluble soil oxides to plant-available forms of manganese and iron, nitrogen-fixing bacteria Bradyrhizobium, Rhizobium, and organisms involved in the biological control of soil-borne diseases that reduce root uptake of nutrients.

Figure 2 Effects of long-term glyphosate on crop health; adapted from Huber's presentation

Glyphosate increases incidence and virulence of soil-borne pathogens Thirty-four diseases have been reported in the scientific literature to increase in incidence as a result of glyphosate weed-eradication programs. They affect a wide variety of crops from cereals to bananas, tomatoes, soybean, cotton, canola, melon and grapes [9]. Some of these diseases are considered 'emerging' or 're-emerging' as they had not caused serious economic losses in the past.

This has worrying implications for the agricultural sector with the US now in its fourth year of epidemics of Goss' wilt and sudden death syndrome and eighteenth year of epidemic of Fusarium fungal colonisation resulting in root rot and Fusarium wilt. Not only does glyphosate affect disease susceptibility, there is also evidence of increased disease severity. Examples include 'take-all'; Corynespora root rot in soybean; Fusarium spp diseases, including those caused by Fusarium species that are ordinarily non-pathogenic. Head-scab caused by Fusarium spp of cereals increases following glyphosate application, which is also now prevalent in cooler climates when previously it was limited to warmer climates.

Food and Feed Safety Concerns

Nutrient-deficient, transgenic plants suffering from disease that also harbor herbicide residues, presents an array of possible safety hazards to animals and humans. According to Huber, possible harm include direct toxicity of glyphosate itself, which has been shown to cause endocrine disruption, DNA damage, reproductive and developmental toxicities, neurotoxicity, cancer, and birth defects (see [10]Glyphosate Toxic and Roundup Worse,SiS26; [11]Death by Multiple Poisoning, Glyphosate and Roundup,SiS42; [12]Ban Glyphosate HerbicideNow.SiS43; [13]Lab Study Establishes Glyphosate Link to Birth Defects,SiS48). Furthermore, allergies are on the rise, and animals are showing allergy responses, including inflamed irritated stomachs (Figure 3), discoloration of stomach lining, leakage of intestines as well as behavioral symptoms of irritability and anti-social behavior in cows (abnormal for herd animals). Inflammatory bowel disease in humans has risen 40 percent since 1992, which may be related to consumption of GM foods, although this has not yet been proven.



The increase in infestation of crops with fungal pathogens that produce toxins is an added concern. Mycotoxins, including fusarium toxins as well as aflatoxins released by *Aspergillus* fungi are carcinogenic and have forced imports of wheat into the US due to unsafe levels found in domestic harvests.

Triple whammy of reproductive toxicity caused by glyphosate In 2002, the Cattlemen's Association gave a statement to US Congress on the serious and puzzling rises in reproductive problems. It said: "high numbers of foetuses are aborting for no apparent reason. Other farmers successfully raise what look to be normal young cattle, only to learn when the animals are butchered that their carcasses appear old and, therefore, less valuable...The sporadic problem is so bad both in the United States and abroad that in some herds around 40-50 percent of pregnancies are being lost.. [and] the viability of this important industry is threatened."

Glyphosate appears to be able to induce reproductive failures through three separate mechanisms. The first, mentioned above is the endocrine dysfunction caused by direct toxicity of glyphosate.

The second is the reduced nutrient content having consequential effects on the nutritional status of animals. Manganese in animals, as in plants, is an essential nutrient, and deficiencies have been associated with a variety of diseases as well as reproductive failures, which are becoming increasingly common in livestock. One study performed in Australia following two seasons of high levels of stillbirths in cattle found that all dead calves were manganese deficient [14]. Furthermore, 63 percent of babies with birth defects were also deficient. Manganese is known to be important for mobilizing calcium into bones, correlating with abnormal bone formation in these calves.

Third, the unknown pathogenic 'entity' may be associated with inducing pseudo-pregnancies. As far back as 1998, a suspect agent was found in reproductive tissue of livestock. It has now been isolated in high concentrations from semen, amniotic fluid as well as placental tissue. It has also been found in aborted foetal tissue. Some farms are reporting up to 50 percent fewer conceptions in animals due to increased miscarriages and pseudo-pregnancies. Although evidence of the widespread presence of this new pathogen is clear, Don Huber suggested the need for further research to understand not only what kind of pathogen it is, but importantly, the effects it is having on the health of plants as well as animals.

To conclude

Over 100 peer reviewed papers have been published by Huber and other scientists on the detrimental effects of glyphosate. Glyphosate increases disease in plants (as well as animals), prompting Huber to write to the Secretary of Agriculture. It may be linked to many health problems in animals and humans, which are an added cost to all the failed promises of a new agricultural technology that would feed the world. As Huber concluded, the "public trust has been betrayed."

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Source Website: <http://www.gmwatch.org>



Glyphosate Description (Wikipedia)

Glyphosate (*N*-(phosphonomethyl)glycine) is a broad-spectrum systemic herbicide used to killweeds, especially annual broadleaf weeds and grasses known to compete with crops grown widely across the Midwest of the United States. Initially patented and sold by Monsanto Company in the 1970s under the tradename *Roundup*, its U.S. patent expired in 2000.

Glyphosate is the most used herbicide in the USA.[3] Exact figures are hard to come by because the U.S. Department of Agriculture stopped updating its pesticide use database in 2008. The EPA estimates that in the US during 2007, the agricultural market used 180 to 185 million pounds (82,000 to 84,000 tonnes) of glyphosate, the home and garden market used 5 to 8 million pounds (2,300 to 3,600 tonnes), and industry, commerce and government used 13 to 15 million pounds (5,900 to 6,800 tonnes), according to its Pesticide Industry Sales & Usage Report for 2006-2007 published in February, 2011. While glyphosate has been associated with deformities in a host of laboratory animals, its impact on humans remains unclear.

Glyphosate's mode of action is to inhibit an enzyme involved in the synthesis of the aromaticamino acids: tyrosine, tryptophan and phenylalanine. It is absorbed through foliage and translocated to growing points. Because of this mode of action, it is only effective on actively growing plants; it is not effective as a pre-emergence herbicide.

Some crops have been genetically engineered to be resistant to it (i.e. *Roundup Ready*, also created by Monsanto Company). Such crops allow farmers to use glyphosate as a post-emergence herbicide against both broadleaf and cereal weeds, but the development of similar resistance in some weed species is emerging as a costly problem. Soy was the first *Roundup Ready* crop.

In vitro studies have shown glyphosate affects progesterone production in mammalian cells and can increase the mortality of placental cells. Whether these studies classify glyphosate as an endocrine disruptor is debated.

When glyphosate comes into contact with the soil, it can be rapidly bound to soil particles and be inactivated.[38] Unbound glyphosate can be degraded by bacteria. It has been proposed that glyphosate applications increase the infection rate of wheat by fusarium head blight.

Conclusions (Sierra Club)

Glyphosate is a herbicide that is constantly lauded as benign. These affirmations are based on studies examining the active ingredient only. In the field, our lawns, our communities, however a different result has emerged. Glyphosate has caused a host of acute and chronic effects ranging from red blood cell destruction to increased propensity for miscarriages. The effects on wildlife, from fish to birds and also non-target species have been observed at doses lower than the application rates suggested.