Glyphosate: A probable carcinogen

Physicians and Scientists for Global Responsibility

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committed citizens can change the world.
Indeed, it is the only thing that ever has."

Margaret Mead.

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Glyphosate –
A probable carcinogen

N-(phosphonomethyl)glycine the active ingredient in many herbicides

Internationally, there are an increasing number of reports of glyphosate residues in the human food chain and drinking water sources, and in soil, air and rain, and of its role, alone or in tandem with other chemicals, in diseases in humans, animals and crops.

In March 2015, 17 experts from 11 countries met at the International Agency for Research on Cancer (IARC; Lyon, France) to assess the carcinogenicity of the organophosphate pesticides tetrachlorvinphos, parathion, malathion, diazinon, and glyphosate.

Among other effects, the group found:

- Glyphosate has been detected in the blood and urine of agricultural workers, indicating absorption;
- Soil microbes degrade glyphosate to aminomethylphosphoric acid (AMPA);
- Blood AMPA detection after poisonings suggests intestinal microbial metabolism in humans;
- Glyphosate and glyphosate formulations induced DNA and chromosomal damage in mammals, and in human and animal cells in vitro;
- One study reported increases in blood markers of chromosomal damage (micronuclei) in residents of several communities after spraying of glyphosate formulations;
- Glyphosate, glyphosate formulations, and AMPA induced oxidative stress in rodents and in vitro.

The group classified glyphosate as “probably carcinogenic to humans” (Group 2A).

PSGR calls on New Zealand’s central and local government and regulatory authorities to:

- Ban the application of glyphosate-based herbicides;
- Ban processed or unprocessed glyphosate-resistant transgenic crops; and
- Ban imported glyphosate-resistant feed.

Where it falls within their jurisdiction to:

- Establish substantive independent safety studies on all agri-chemicals used in New Zealand, especially glyphosate-based herbicides; and
- Rescind approvals and reject future applications for approval for transgenic foods and food additives containing any measure of glyphosate.

Appendix One presents details of glyphosate-related adverse effects, looking at the human, animal and physical environment. The detailed results and/or findings from studies and first-hand experience far from exhaust the material available. It provides reasons why:

- Central and local government and regulators should place a total ban on the use of glyphosate to protect the New Zealand environment and to ensure it does not enter the human food chain or animal feed, or drinking or other water sources; and

- New Zealand should continue to reject having glyphosate-resistant genetically engineered organisms in the environment.

Appendix Two provides alternatives to the use of glyphosate-based herbicides.

Reviewed by Meriel Watts, PhD; Coordinator Pesticide Action Network Aotearoa NZ

Appendix One

What is glyphosate?

When working as a chemist for Monsanto Company, John E Franz invented glyphosate, a broad-spectrum, post-emergence herbicide. It was first registered for use by the United States Environmental Protection Agency (EPA) in 1974.

Glyphosate is the active ingredient in Monsanto's proprietary herbicide, Roundup®, and an ingredient in proprietary brands marketed by Bayer, Dow, Zeneca and others. Patents continue to be filed for glyphosate and glyphosate-related applications, latterly in respect of genetically engineered glyphosate-resistant crops.

Monsanto's patent on glyphosate outside the US expired in 1991. In the US, the patent on isopropylamine salt, the most widely used salt form for glyphosate, continued until 2000. The first-generation transgenic Roundup Ready® soybean trait patent expires in 2015.

For decades, Monsanto was the largest US producer of glyphosate herbicides. The company introduced transgenic glyphosate-resistant commercial crops in the mid-1990s and by 2007 glyphosate was the most used herbicide in the US agricultural sector. In 2012, the Asia Pacific market accounted for the largest share in terms of volume.

US patent 7771736 B2 (pub. 2010) covers in vivo use for animals or humans of N-phosphonomethyl glycine, i.e. glyphosate, or a salt, ester or other derivative thereof, in combination with a dicarboxylic acid or a derivative thereof, as an antibiotic for the treatment of pathogenic infections, including infections of mammals by apicomplexan parasites.

Regulatory bodies worldwide have approved many applications involving glyphosate, largely on the basis of decisions made by US regulatory authorities. Glyphosate is used in agriculture, horticulture, viticulture, silviculture and forestry, and in industrial and public sites, aquatic environments, gardens, sports facilities and school grounds. Despite being claimed as less toxic than other herbicides, concerns about its effects on human and environmental health continue to be raised and studies pursued to establish substantive evidence. Increasingly, countries are attempting to ban glyphosate: in Brazil, the Prosecutor General's office is a pursuing a ban ; in Sri Lanka, President Mahinda Rajapaksa issued a directive to ban glyphosate ; and in 2013 El Salavador's National Assembly approved a decree to ban glyphosate .

1 - Glyphosate – how it works

Glyphosate is a non-selective herbicide, killing most plants when applied directly to foliage, including grasses, broadleaf, and woody plants. Pre-harvest glyphosate applications are used as a harvest management tool for dry down in addition to or in place of other chemicals for crop desiccation (siccation) to give the appearance of uniform crop maturity. Used in smaller quantities, the sodium salt of glyphosate can act as a plant growth regulator and accelerate fruit ripening.

In actively growing plants, glyphosate-based herbicides are absorbed through foliage and translocated throughout a plant to concentrate in the meristem tissue; the plant tissue whose cells actively divide to form new tissues that cause the plant to grow. Glyphosate inhibits EPSP (5-enolpyruvylshikimate-3-phos-phate), an enzyme involved in the synthesis of the aromatic amino acids tyrosine, tryptophan and phenylalanine which are vital for protein synthesis and plant growth and development, and specific to plants and some micro-organisms. Exposure to glyphosate leads to stunted growth, loss of green colouration, leaf wrinkling or malformation, and tissue death takes from 4 to 20 days, all depending on the application dose.

Plants genetically engineered to be herbicide-resistant - such as Monsanto's Roundup Ready crops - allow farmers to freely apply glyphosate as a post-emergence herbicide. This practice has seen application rates virtually double since the introduction of transgenic crops, and this over-application is seen as a main contributor in weed species becoming glyphosate-resistant.

2 - Glyphosate – the chemistry

Glyphosate is an aminophosphonic analogue of the natural amino acid glycine, and the name is a contraction of gly(cine) phos(phon)ate.1

Glyphosate (N-phosphonomethylglycine) is classified as an organophosphorus herbicide. It and its variants are detailed as herbicides or phytotoxicants. They are materials which control terrestrial and aquatic plants in a given location or selectively control the growth of one or more plant species in the presence of other plants, as with glyphosate-resistant plants.

Formulations of glyphosate include an acid, monoammonium salt, diammonium salt, isopropylamine salt, potassium salt, sodium salt, and trimethylsulfonium or trimesium salt. Generally, references to glyphosate as an herbicide refer to the acid form. The variants can be solids or an amber-coloured liquid. Technical grade glyphosate is used in formulated products, as are the isopropylamine, sodium, and monoammonium salts. Of these, the isopropylamine salt is most commonly-used in formulated products. This is an organic compound obtained, by various processes, from non-renewable fossil fuel resources such as petroleum or natural gas deposits, and to a lesser extent coal.

3 - Glyphosate – registration, additives, interactions and residue levels

To register pesticides in the US, the EPA requires laboratory testing for short-term (acute) and long-term (chronic) health effects. Its website says laboratory animals receive high doses to cause toxic effects to show how overexposure of these chemicals might affect humans, domestic animals, and wildlife. The majority of the tests are carried out by the corporation developing the product.

It is the active ingredient which is safety tested and not usually the other ingredients in a pesticide. These latter, named adjuvants, are often described by the developer as "inert". In a study published in December 2013, researchers give results from testing the toxicity of nine pesticides involving the active ingredient and in addition the the added ingredients. Roundup was shown to be the most toxic of the pesticides tested. The researchers say their results "challenge the relevance of the Acceptable Daily Intake for pesticides because this norm is calculated from the toxicity of the active principle alone. . . . Chronic tests on pesticides may not reflect relevant environmental exposrues if only one ingredient of these mixtures is tested alone."

A study published in January 2014 confirmed the adjuvants, added to glyphosate formulations to increase their effectiveness, may be more toxic than glyphosate itself. For example, studies show that the surfactant polyoxyethyleneamine or polyethoxylated tallow amine used in some glyphosate-based formulations is more toxic by the oral route to animals than glyphosate itself.

The primary purpose of adjuvants is to reduce surface tension and increase penetration. Adjuvants also help the mixing of two or more herbicides in a common spray solution, aid retardants used to decrease the potential for herbicide drift, aid mixing and suspending herbicide formulations in solution, and act as a buffer to change the spray solution acidity. Surfactants (surface active agents) are a type of adjuvant. Their primary purpose is to reduce the surface tension of the spray solution to allow more intimate contact between the spray droplet and the plant surface and thus improve absorption.

3.1 – Glyphosate and chelation

In the 1970s, glyphosate was identified as a chelator of minerals - a compound that combines with other minerals to make them available only under certain conditions. A chelator may be used to extract minerals from ores; e.g. fluoride is used to isolate uranium from the basic rock. Fluoride, found in phosphate fertilizers, chelates calcium and magnesium.

Other recent studies indicate plant uptake systems are susceptible to the chelating effects of glyphosate. For example, short-term experiments showed root uptake and shoot translocation of manganese and iron were severely depressed by glyphosate applications.

A 2014 study hypothesizes that glyphosate, when mixed with hard water, forms a complex with heavy metals like arsenic and cadmium, resulting in the accumulation of the latter in the body. Such metals are naturally present in soil, or may be added through applications of fertilizers. Hard water can contain metals such as calcium, strontium and iron, as well as carbonate, bicarbonate, sulphate and chlorides. The study proposed a link under local conditions between chronic kidney disease and glyphosate. Chronic kidney disease of unknown origin (CKDu) is becoming increasingly common in poor farming communities in some areas of developing countries. The US Centre for Public Integrity found CKDu has killed more people in El Salvador and Nicaragua than diabetes, AIDS and leukaemia combined over the past five years on record. CKDu was identified in the mid-1990s and is now estimated to afflict 15% of working age people in northern Sri Lanka; 400,000 patients with an estimated death toll of 20,000.

Researchers have found copper adsorption decreases in general with increasing concentration of glyphosate in solution, that the concentration of free copper in solution is drastically reduced, and the adsorption of copper in their sample soil lower. Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate-resistant soybean. Decreases in seed concentration of iron, manganese, calcium and magnesium by glyphosate were found to be specific and may affect seed quality.

How such effects affect the nutritional content of a food plant are yet to be determined.

3.2 – Testing for glyphosate residues

In the US, the National Pesticide Information Centre Fact Sheet says glyphosate is not included in compounds tested by its Food and Drug Administration's Pesticide Residue Monitoring Programme. Neither is it in its Department of Agriculture's Pesticide Data Programme. A field test found lettuce, carrots and barley contained glyphosate residues up to one year after the soil was treated with 3.71 pounds of glyphosate per acre. USDA data show that glyphosate-based herbicide use increased 6504% between 1991 and 2010. Following a request from Monsanto Company, acceptable tolerances for residues of glyphosate were recently raised again and posted in the US 'EPA Pesticide Tolerances: Glyphosate' (effective 1 May 2013). These are applied to raw agricultural commodities and hay, oilseed crops, and vegetables, fruits and berries.

4 - Glyphosate in the soil and water

It is claimed that glyphosate residues are immobile and degraded by soil microbes to AMPA and carbon dioxide, and that glyphosate and AMPA (aminomethylphosphonate) are unlikely to move to ground water due to their strong adsorptive characteristics. In fact, glyphosate adsorbs to soil and can potentially contaminate surface waters because it adsorbs to soil particles suspended in runoff.

Glyphosate contamination of surface water is often attributable to urban use. If glyphosate reaches surface water, it is not broken down readily by water or sunlight.

The median half-life of glyphosate in soil ranges from 2 to 197 days, its persistence affected by soil and climate conditions, and can range up to 1699 days under anaerobic conditions in laboratory studies. In water, its median half-life varies from a few days to 91 days. The glyphosate metabolite, aminomethylphosphonic acid, has been shown to have a median-half life of 240-958 days in some soils and persist up to two years in Swedish forest soils.

The French Supreme Court upheld judgements by two previous courts that "Monsanto falsely advertised its herbicide as 'biodegradable' and falsely claimed it 'left the soil clean.'" The French parliament has adopted a law to prohibit private or public non-agricultural use of pesticides in green areas, forests or public space from 1 January 2020. From 1 January 2022, it will be prohibited to place pesticides for non-professional use on the market, to be sold, used or in the possession of someone. This includes glyphosate-based herbicides.

Denmark has banned autumn spraying of glyphosate on sites where leaching is extensive because of heavy rain. Research showed glyphosate had contaminated groundwater from which Denmark obtains drinking water at a rate of five times more than the allowed level for drinking water.

Manuel Tejada (2009) studied the degradation and the effects on biological properties in two soils after the addition of glyphosate, diflufenican and glyphosate+diflufenican and found the application of glyphosate+diflufenican mixture to soil increased the toxic effects of both herbicides in the soil biological activity and the individual soil persistence of each herbicide.

Zabaloya et al (2008) looked at the impacts of post-emergence herbicides on soil microbial communities sampled from agricultural fields with a history of herbicide application in the Argentine Pampas. The herbicides focussed on in the study were glyphosate, metsulfuron-methyl and 2,4-D (2,4-dicholorophenoxyacetic acid). Soil microcosms were treated with one herbicide at a time at a dose 10 times higher than the recommended field application rates causing changes to soil microbial activity, bacterial density and functional richness with the effects of glyphosate most pronounced.

Researchers looking at soil fertility examined the effects of glyphosate with its by-products on growth and viability of microbial models. They found "evidence that Roundup has an inhibitory effect on microbial growth and a microbiocide effect at lower concentrations than those recommended in agriculture."

Also "these results should be considered in the understanding of the loss of micro-biodiversity and microbial concentration observed in raw milk for many years."

Researchers recently quantified the biodegradation of glyphosate using standard "simulation" flask tests with native bacterial populations and coastal seawater from the Great Barrier Reef. The half-life for glyphosate at 25°C in low-light was 47 days, extending to 267 days in the dark at 25°C and 315 days in the dark at 31°C. This is the longest persistence reported for this herbicide. The adjuvant AMPA was detected under all conditions. The conclusion was that "glyphosate is moderately persistent in the marine water under low light conditions and is highly persistent in the dark."

5 – Glyphosate-resistant transgenes in the environment

On the environmental effects of glyphosate, Pesticide Action Network Asia and the Pacific (PANAP) says: ". . . of greatest concern are those that occur at a subtle level, and can result in significant disruption of aquatic and terrestrial eco-systems, including the agro-ecosystem."

Today the loss of genetic diversity in commercially important crops is acknowledged. Despite crops being bred for superior resistance, genetic uniformity and monoculture practices increase the possibility of pests and diseases evolving to overcome the host plants' resistance.

Developers claim transgenic crops will help overcome such problems, but scientists cannot easily quantify the exact effect/s novel organisms will have when released into the environment; each may differ to the next. Genes move naturally within a species, by seed dispersal and pollination. This movement is a basic biological principle of plant evolution and is facilitated by insects, wind, animals, humans and other factors. The ecological risks tied to the release of transgenic plants include non-target effects of the crop and the escape of transgenic DNA into wild populations.

Sufficient knowledge existed prior to release of transgenic organisms to demand applying the precautionary principle and early post-release effects warranted cessation. As early as 1998, a researcher at the US Department of Agriculture (USDA) found a resistance gene transferred by pollen from imidazolinone-resistant wheat to jointed goat grass (Aegilops cylindrica). A Canadian study identified pollen transfer as the main means for the development of canola (Brassica napus) with naturally occurring, multiple-resistance to the herbicides glyphosate, glufosinate, and imazethapyr. Study results have indicated "that the pedigreed canola seed production system in western Canada is cross-contaminated with various herbicide resistance traits at a high level." Cross pollination events are well documented.

A large proportion of the transgenic crop plants developed include glyphosate-resistance: alfalfa, canola/rapeseed, corn/maize, cottonseed, rice, soybeans, sugar beet and wheat. In many locations, transgenic crops have become the dominant crop grown, and pose potential problems as volunteer crops. Glyphosate-resistance and other transgenes have transferred to weeds, and to non-transgenic crops. Called introgression, this is the infiltration of genes from one species into the gene pool of another.

5.1 – Glyphosate-resistant transgenes in weed species

Dr Charles Benbrook, in 'Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years' (2004) said:

"Resistance to glyphosate has emerged as a serious concern across most of the intensively farmed regions of the US. The number of resistant weeds and their rate of spread is not surprising given the degree of selection pressure imposed on weed populations by farmers applying glyphosate herbicides multiple times per year, and sometimes year in and year out on the same field. . . . Resistant weeds typically emerge first on just a few isolated fields, but their pollen, genes, and seeds can travel widely and spread quickly, especially if glyphosate continues to be relied on as heavily has it has been in recent years."

Farmers use Roundup containing glyphosate on Roundup Ready crops, applying it liberally, and have consequently neglected other weed control measures. Historically farmers used multiple herbicides, which slowed the development of resistance, and they tilled growing land. Roundup Ready crops have reduced those practices and increased the use of glyphosate dramatically.

As early as 2000, in Alberta, Canada, chemical and DNA tests found canola volunteers resistant to three herbicides: Monsanto's Roundup (glyphosate), Liberty (glufosinate ammonium) produced by Bayer CropScience and BASF's Pursuit (ammonium salt of imazethapyr). The industry suggested adding the more toxic 2,4-D or similar to a chemical mix to kill these wayward plants.

The more toxic replacement herbicides suggested58 include 2,4-D and HPPD-inhibiting herbicides such as Laudis, Impact and Callisto. Callisto's active ingredient is mesotrione and it has an adjuvant, ethylene glycol. The data sheet of the manufacturer, Syngenta, states Callisto inhibits an enzyme which in turn inhibits carotenoid biosynthesis, that carotenoid pigments protect chlorophyll from decomposition by sunlight and consequently there are restrictions on planting following Callisto applications, from six to 18 months depending on the crop and a withholding period of 70 days from the last application.

Scientists in Nebraska have already found water hemp resistant to 2,4-D and scientists at the University of Illinois have found water hemp resistant to HPPD-inhibiting herbicides. Historically, water hemp is a problematic weed in the US 'Corn Belt' because it is aggressive, fast growing and out-competes corn for light, water and nutrients.

In 2005, the Herbicide Resistance Action Committee identified 13 weeds as glyphosate-resistant and common across the Corn Belt states. There is glyphosate-resistant water hemp in Missouri; ragweed in Arkansas; lambs quarters, horseweed and ragweed in Ohio; horseweed in Kansas. Each year, the list of resistant weeds grows. The International Survey of Herbicide Resistant Weeds lists weeds resistant to EPSP synthase inhibitors (G/9) – i.e.

glyphosate - and to other herbicides. Today, Palmer amaranth, known as pigweed and wild spinach, is traditionally used as a medicinal plant, and is cooked or used as a salad vegetable. Reports say contaminated pigweed is turning fields of transgenic crops into "weed battlefields". A pigweed plant produces around 10,000 seeds at a time, is drought-resistant, and has very diverse genetics. It grows as high as three metres and smothers young cotton plants.

A 2010 report from the Third World Network, says:

"The rapid spread of glyphosate-resistant Palmer pigweed constitutes a major agronomic failure of genetically engineered Roundup Ready seeds. This failure was foreseen by critics but dismissed by Monsanto. The critics were right. The failure is prompting US farmers to revert to agricultural practices used in the 1980s and earlier, such as hand weeding and increased tillage." It continued: "Stricken by a lack of foresight across the conventional agricultural sector, farmers have little choice but to increase use of herbicides, including older chemicals banned in many countries due to their toxicity. These include paraquat and 2,4-D."

A January 2014 Dow AgroSciences Press Release stated new data "indicate an astonishing 86 percent of corn, soybean and cotton growers in the South have herbicide-resistant or hard-to-control weeds on their farms. The number of farmers impacted by tough weeds in the Midwest . . . now tops 61 percent. Growers need new tools now to address this challenge." The "new tools" are their transgenic crops and associated agricultural proprietary chemicals.

Glyphosate-resistant weeds have now been found in 18 countries worldwide, with significant impacts in the US, Brazil, Australia, Argentina and Paraguay. Despite the fact that New Zealand does not grow commercial transgenic crops, glyphosate-resistance has been identified in several locations, the cause given as "over application" of the herbicide.

A study by David Mortensen, a plant ecologist at Pennsylvania State University, University Park, and his team, predicts total herbicide use in the US will rise from around 1.5 kilograms/hectare in 2013 to over 3.5 kilograms/hectare in 2025 as a direct result of growing transgenic crops, and that the new transgenic technologies will also lose their effectiveness.

As stated, to overcome herbicide-resistant weeds Monsanto has suggested applying glyphosate with more toxic chemicals like 2,4-D.

2,4-D is a member of the phenoxy family of herbicides manufactured from chloroacetic acid and from 2,4-dichlorophenol produced by chlorination of phenol. The process creates contaminants; e.g. isomers, monochlorophenol, and other polychlorophenols and their acids.

Developers are now aiming to release transgenic crops resistant to those more toxic herbicides. For example, 2,4-D and dicamba which belong to a chemical class associated with increased rates of diseases, including non-Hodgkins lymphoma. They are highly toxic to broadleaf crops, including many common fruit and vegetable crops, and more prone to air dispersal than glyphosate. Increased use is likely to harm neighbouring farms and uncultivated areas and inevitably result in wider use of these problematic herbicides.

2,4-D is banned in Sweden, Denmark and Norway because it is linked to cancer, reproductive harm and mental impairment. It was an ingredient in Agent Orange, along with 2,4,5-T, the herbicide used in chemical warfare in the Vietnam War. Increased usage will mean increased residues on crops.

In 2013, the USDA's Animal and Plant Health Inspection Service (APHIS) has released a Draft Environmental Impact Statement as part of determining whether to deregulate transgenic corn and soybean plants resistant to several herbicides, including 2,4-D: currently Dow AgriSciences' Enlist™ corn, Enlist soybean and Enlist E3™ soybean traits. At the same time, the US EPA has to conduct a review of the related herbicides.

In a 2012 report, Dr Charles Benbrook said: "Contrary to often-repeated claims that today's genetically-engineered crops have and are reducing pesticide use, the spread of glyphosate-resistant weeds in herbicide-resistant weed management systems has brought about substantial increases in the number and volume of herbicides applied." Approval of transgenic corn and soybeans tolerant to 2,4-D could mean the usage volume of 2,4-D could rise "by another approximate 50%".

5.2 – Glyphosate-resistant transgenes and the dangers to commercial crops

Gene movement does not always stay within a species. It can occur between species that are closely related within the same botanical family. In 2003, Britain's advisory committee on releases to the environment (ACRE) identified wild turnip, hoary mustard, wild radish, brown mustard, and wild cabbage as species from which hybrids could be formed with transgenic canola/oilseed rape. In one field trial plot of transgenic oilseed rape/canola, researchers found 46% of seeds in a wild turnip plant were contaminated with novel DNA. The commercialisation of transgenic rice raises potential for gene flow to wild and weedy rice relatives and to traditional commercial varieties.

Other crops with a high risk of contaminating their weedy relatives include sorghum with shatter cane and Johnson grass, canola with mustards, wheat with jointed goat grass and quack grass, rice with red rice, and sunflower with wild sunflower.

Wild radish, wild turnip, wild cabbage and other wild Brassica species grow in New Zealand. Sorghum is grown in warmer areas for summer feed and although rare Johnson grass has been found growing.

For details of weed species check with Key to Weed Species of New Zealand , Massey University Weed Species Data Base , the Foundation for Arable Research and The Foragers Year , and the New Zealand Department of Conservation website.

Brassica crops related to canola are grown in Australia. Volunteer populations of transgenic herbicide-resistant canola have implications for gene flow into weeds species and vegetable crops, and roadside volunteers have the potential to contaminate adjacent crops. Out-crossing rates can result in a substantial number of out-crossed seed per hectare.

Based on studies elsewhere of gene flow into weed species, we can assume interspecific hybridization will occur in certain species combinations. Introgression of herbicide resistant genes or other transgenic traits from B. Napus to the cultivated species B. Rapa and B. Juncea is possible if the species are in physical proximity.

Since its commercial introduction in the mid-1990s, herbicide-resistant canola has been widely grown by Canadian farmers, principally Liberty Link varieties with glufosinate ammonium as its active ingredient and Roundup varieties containing glyphosate. A Greenpeace report in 2005 stated that by that time it had become virtually impossible for Canadian farmers to grow canola that was not genetically engineered. Evidence of seed contamination is also given in the Union of Concerned Scientists' Report, 'Gone to Seed - Transgenic Contaminants in the Traditional Seed Supply'.

5.3 – Containment of glyphosate-resistant transgenes

Using genetic engineering technology to change one gene does not necessarily change only one function. A variety of changes in transgene expression can occur in a created organism, and each novel DNA sequence is different. The potential for problems starts there.

Glyphosate-resistant and other transgenic crops had been grown commercially for a decade when a Committee under the auspices of the US National Research Council examined the potential consequences of what effect/s transgenes might have on natural or managed ecosystems and human health.

In its report, 'Biological Confinement of Genetically Engineered Organisms' (2004) it states: "It is unlikely that 100% confinement will be achieved by a single method." Studies and reports on transgene transfer are numerous.

5.4 – Glyphosate-resistant transgenes in landraces

Of particular concern is introgression with species known as landraces in areas referred to as 'centres of origin'. A landrace is a local variety of a plant species which has developed over millennia by adaptation to the natural and cultural environment in which it grows. Landraces are the storehouses of humanity's basic stock heirloom varieties.

Such natural genetic diversity and crossbreeding has led to gains in agricultural productivity and quality. For example, following the disastrous Southern Corn Leaf Blight in 1970, new hybrids were bred from Mexico's corn/maize landraces, saving the Southern US states from further significant crop and livelihood losses.

Mexico is the centre of origin of maize/corn and because of potential risks to its landraces cultivation of transgenic corn was banned there from 1998. Despite this precaution, transgenic material has been found in landraces in Mexico's remote regions, with higher concentrations near major transport arteries. Under the North American Free Trade Agreement, Mexico has moved from exporting to importing corn, corn largely trucked from the US, without being milled, along main highways. Many blame seed spillage from this mode of transport for the landrace contamination. In 2013, a judge threw out the appeals of Monsanto and Mexico's Environment and Natural Resources Ministry to overturn a court ruling that continued the ban on planting transgenic maize in Mexico.

5.5 – Glyphosate-resistant transgenes in human gut bacteria

Gene flow has even been recorded in the human gut. Transgenic soy represents 77% of soy production globally. The list on http://www.soyconnection.com/soyfoods/product_overview.php demonstrates how easily most consumers could ingest multiple helpings of soy transgenes via food daily. The single study commissioned by the UK Food Standards Agency on human volunteers and carried out at the University of Newcastle demonstrated that transgenic DNA from soybeans in the form of a burger and a milkshake found its way into the gut bacteria of the human volunteers.

6 – Glyphosate – what farmers face

In 2012, the USDA indicated 88 percent of corn/maize grown in country was transgenic. When a study found glyphosate enhances the growth of aflatoxin-producing fungi, lending an explanation for the substantial increase in fungal toxins now found in corn grown in the US, the potential for affecting large areas is plain.

Canadian, Percy Schmeiser, farms in Bruno, Saskatchewan, breeding and growing canola. In 1997, he found Roundup Ready canola plants growing near his farm. To prove this, he sprayed his nearby field with Roundup and found much of the crop was glyphosate-resistant. He saved this harvest separately, and intentionally planted it in 1998. Monsanto approached him to pay a license fee for using their patented technology without a licence. Schmeiser refused, claiming that the actual seed was his because it was grown on his land. Monsanto sued Schmeiser for patent infringement. The case went through the Canadian courts over several years until a Supreme Court 5-4 ruling found in favour of Monsanto. In 1999, Schmeiser filed a separate lawsuit against Monsanto for ten million dollars for "libel, trespass, and contamination of his fields with Roundup Ready Canola."

Many conventional farmers, on finding transgenic contamination in their fields, have been fined by Monsanto Company, some even losing their livelihood because of financial hardship created by fines and court costs. In Bowman v. Monsanto Company, a US Supreme Court also found in favour of Monsanto and a Reuters article in January 2014 reported that the Supreme Court upheld Monsanto's case against the Organic Seed Growers and Trade Association, organic and conventional family farmers, seed companies and public advocacy interests, who had collectively sought a legal standing to prohibit the company from suing farmers whose fields became inadvertently contaminated with its transgenic crops.

In August 2012, conventional farmer, Bob Mackley, spoke in New Zealand about transgenic crops and their effects in his native Australia. He reported that many Australian farmers have suffered significant losses as a result of transgene contamination of their conventional crops, and that legislation favours seed companies, not farmers. Legally without the means to protect his livelihood, Mackley has been forced to time his plantings to avoid contamination from transgenic crops grown by a neighbour. His is a critical balance between profit or contamination and loss.

Steve Marsh, an organic farmer in Australia, has sued a neighbour growing genetically engineered crops for compensation after claiming the neighbour's crop contaminated 70 percent of his property. He is seeking AUD85,000 in compensation and the decision is expected in April 2014.

Over millennia, farmers learned from experience. Like Percy Schmeiser, who spent his farming life developing his canola seed crop, they selected the best seed for next year's crop to improve yields and quality. Crops were varied and rotated on small acreages, with some land left fallow each year. This method largely solved the potential problems that affect monoculture practices today.

7 - Glyphosate and its effects on human health

With pharmaceuticals a risk benefit judgment needs to be made by a medical professional before any initiation of their use. Pharmaceuticals are clearly distinct and identifiable single agents, whereas food derived using genetic engineering technology contains transgenes, possibly from multiple sources, with unpredictable changes in plant chemistry and often higher levels of accompanying chemical residues. These are multiple, complex and poorly defined alterations compared with those from a food sourced from non-genetically engineered sources.

'Informed consent' is a basic of patient-physician and subject-researcher relationship. It involves making the participant aware of and verifying understanding of the risks, benefits, facts, and the future implications of the procedure or test to which they are going to be subjected.

The definition of informed consent used by US Food and Drug Administration (FDA) is complicated, a virtual "get out of jail free" card. After public outcry, US regulators adopted voluntary labelling of products with transgenic ingredients.100 In contrast, guidelines approved by the Codex Alimentarius Commission allows countries to label transgenic foods and foods containing transgenic ingredients without breaching international free trade laws.100

What is fact is that consumers – particularly citizens in the US where some 40 percent of transgenic crops are grown – have been guinea pigs for close to two decades, given little choice but to ingest multiple unlabelled transgenic foods or food ingredients on a daily basis, day in day out, year round. With about 94% of US soybean farmers and 72% of corn farmers using Roundup Ready crops, common ingredients in a substantial range of food products, a large majority of foods come from glyphosate-resistant crops to some extent. In addition, animals fed glyphosate-resistant crops will bio-accumulate glyphosate and/or glyphosate metabolites, adding to the human end-user's intake.

The safety of glyphosate use on herbicide-resistant crops has not been substantiated by rigorous, independent scientific research. Studies used to legitimize approvals are generally industry studies, often neither published nor peer-reviewed, and taken over a too-short timeframe. Guidelines issued recently by the European Food Safety Authority call for two-year whole food feeding studies to assess the risks of long-term toxicity. This is an improvement on current practices.

7.1 - Glyphosate – exposure for humans

Commonly, people applying glyphosate-based herbicides do not use personal protective equipment and take few other precautions to protect themselves or their families.

Proponents say glyphosate does not easily pass through human skin, that when taken in through the skin or by mouth it is eliminated in less than one day, leaving the body via urine and faeces without changing into another chemical. However, studies with rats showed about one-third of a dose of glyphosate was absorbed by the rats' intestines, and half found in their stomachs and intestines six hours later. All traces were gone within one week.27

Glyphosate residues are found in the Western diet, particularly associated with transgenic food sources. It is estimated 90 percent of transgenic crops grown worldwide are glyphosate resistant and the four main crops are commonly used as food or food ingredients for the human food chain: soy, corn/maize, cottonseed and canola/oilseed rape. They also commonly appear in animal feed.

Pure glyphosate is claimed as low in toxicity, but there is evidence of numerous adverse effects. Additionally, it is formulated with various adjuvants (agents) added to assist efficacy, sold under many trade names , and these adjuvants, while often labelled 'inert', can confer additional toxicity. Negative impacts on the body may manifest slowly over time by damaging cellular systems, including oxidative stress, endocrine disruption as general mechanisms of harm that result in insidious effects.

In 2002, Chemical Research in Toxicology, a publication of the American Chemical Society, published a paper about the effect on cell cycle regulation of glyphosate-containing Roundup. It concluded: "... our results question the safety of glyphosate and Roundup on human health."

Researchers in one study concluded, "The direct effect of glyphosate on early mechanisms of morphogenesis in vertebrate embryos opens concerns about the clinical findings from human offspring in populations exposed to glyphosate-based herbicides in agricultural fields."

A recent study detected glyphosate in 43.9% of human urine samples taken from participants living in urban areas in 18 European countries. It concluded, "the evidence suggests that a significant proportion of the population could have glyphosate in their bodies – and it is not clear where it is coming from."

Another recent study found glyphosate in samples of breast milk in lactating mothers in the US. The levels found were 76 ug/l to 166 ug/l. That is 760 to 1600 times higher than the European Drinking Water Directive allows for individual pesticides, but less than the 700 ug/l maximum contaminant level (MCL) for glyphosate in the US decided upon by the EPA based on the false premise that glyphosate was not bio-accumulative. (N.B. Glyphosate is classified as both a pesticide and herbicide).

Independent work has shown that both glyphosate and its metabolite AMPA were eliminated slowly from plasma and, although bioavailability was only 23.21%, it is likely that glyphosate is distributed throughout the body by the blood's circulation and there may be considerable diffusion of it into tissues to exert systemic effects and where it may accumulate.

Bioaccumulation is a normal process of growth and nurturing of organisms. All animals, including humans, bioaccumulate nutrients, and can bioaccumulate substances in the body to levels that can cause harm. A typical food chain bioaccumulation process is plant uptake from soil or spray, animal eating plant, human eating animal. Each step can result in increased bioaccumulation including toxins where absorption of a substance is at a rate greater than that at which the substance is lost or eliminated.101

Researchers in one study concluded that animals and humans eating transgenic soy "chronically incorporate unknown amounts of this herbicide" and residues of glyphosate in the tissues and organs of food animals that have been fed with transgenic feed are not taken into account in legislation nor studied in detail.

7.2 – Glyphosate – mechanisms of action

In a study published in February 2014, researchers detailed how they evaluated the effect "on hemolysis, hemoglobin oxidation, reactive oxygen species (ROS) formation and changes in morphology of human erythrocytes" (red blood cells) "exposed to different concentrations of glyphosate and its metabolites and impurities (0.01–5 mM) for 1, 4 and 24 h." They concluded their "results clearly show that the changes induced in the erythrocytes can occur only as a result of poisoning with these compounds" and list AChE, acetylcholinesterase, AMPA, aminomethylphosphonic acid, PMIDA, N-(phosphonomethyl)iminodiacetic acid, ROS, reactive oxygen species, H2R123, dihydrorhodamine 123, and NAC, N-acetylcysteine.

In 2009, researchers published the paper 'Glyphosate Formulations Induce Apoptosis and Necrosis in Human Umbilical, Embryonic, and Placental Cells'. Apoptosis is the natural process of programmed cell death that allows human foetuses to develop fingers, toes and other features. Necrosis is the premature death of living cells and living tissues. The study evaluated the toxicity of four different glyphosate-based herbicides in Monsanto's Roundup products range in solutions diluted 100,000 times. This is far below the level at which it is used in agricultural applications and corresponds to levels detected in foods for human consumption and animal feeds.

The researchers tested applications on three distinct human cell types - embryonic, placental, and umbilical – and tested glyphosate alone and the Roundup formula. All of the heavily diluted Roundup formations caused total cell death within twenty-four hours through necrosis, showing Roundup induces apoptosis, causing DNA fragmentation, shrinkage of the nucleus, and fragmentation of the nucleus. It induced complete cell death, whereas glyphosate alone induced only apoptosis. Conclusive evidence proved Roundup adjuvants change the permeability of the three human cells studied, showing they are not inert ingredients as claimed. The researchers concluded: ". . . the proprietary mixtures available on the market could cause cell damage and even death around residual levels to be expected, especially in food and feed derived from (Roundup) formulation-treated crops."

Researchers tested urine samples from a farmer who sprayed a glyphosate-based herbicide on his land. They included his family as two children were born with birth defects that could potentially be allied to pesticides. Glyphosate residues were measured in samples taken a day before, during, and two days after spraying using liquid chromatography-linear ion trap mass spectrometry. Glyphosate presence reached a peak of 9.5 µg/L in the farmer after spraying, and 2 µg/L were found in him and in one child living 1.5 kilometres from the field, two days after the applications. The researchers noted that oral or dermal absorptions could explain the differential pesticide excretions, even in family members at a distance from the fields. Limits of detection and quantification were respectively 1 and 2 ppb.

In 'Impacts of environmental toxicants on male reproductive dysfunction', Wong and Cheng (2011) highlighted the role of endocrine disruptors in embryonic development include epigenetic effects: "Studies in the testis and other organs have illustrated the importance of environmental toxicant-induced oxidative stress in mediating disruption to cell junctions. This, in turn, is regulated by the activation of PI3K/c-Src/FAK and MAPK signalling pathways, with the involvement of polarity proteins. This leads to reproductive dysfunction such as reduced sperm count and reduced quality of semen." Other researchers have also demonstrated endocrine disruption, concluding "a real cell impact of glyphosate-based herbicides residues in food, feed or in the environment has thus to be considered, and their classifications as carcinogens/mutagens/reprotoxics" discussed.

Researchers Anthony Samsel and Stephanie Seneff have proposed that glyphosate may inhibit cytochrome P450 (CYP) enzymes and that this is an overlooked component of its toxicity to mammals. CYP enzymes play a crucial role in detoxifying xenobiotics.

They suggest glyphosate enhances the damaging effects of other food-borne chemical residues and environmental toxins. They also suggest that interference with CYP enzymes acts synergistically with disruption of the biosynthesis of aromatic amino acids by gut bacteria, as well as impairment in serum sulphate transport. They put forward the argument that the consequences are most of the diseases and conditions associated with a Western diet, which include gastrointestinal disorders, obesity, diabetes, heart disease, depression, autism, infertility, cancer and Alzheimer's disease. The journal Anaerobe published a study which confirms the herbicide's ability to adversely affect gut bacteria populations, i.e. generate dysbios, in particular predispose to increased botulism in cattle.44

7.3 - Acute effects

Glyphosate in spray form may cause eye or skin irritation, and/or irritation in the nose and throat. Swallowing it can increase saliva, burn the mouth and throat, cause nausea, vomiting, and diarrhoea, and death; it is used as a suicide agent in some countries. If pets touch or eat plants wet with spray from glyphosate-containing products they may drool, vomit, have diarrhoea, lose their appetite, or seem sleepy.27

Since 2000, a US government backed programme has been funding the Colombian government to aerial spray coca and opium crops. In 2006, 171,613 hectares were sprayed with Roundup-Ultra which is 43.9 percent glyphosate, with adjuvants POEA and Cosmo-Flux 411 F. PANAP says this has resulted in widespread animal deaths and food crop losses.

Human ailments commonly include: vomiting; diarrhoea; abdominal pain; gastrointestinal infections; itchy, burning skin; rashes and infections (particularly in children); blisters; burning or weeping eyes; blurred vision; conjunctivitis; headaches; fever; rapid heartbeat; palpitations; raised blood pressure; dizziness and balance disorders; chest pains; numbness; insomnia; depression; debilitation; breathing difficulties; respiratory infections; dry cough; sore throat; an unpleasant taste in the mouth; reduced cognitive capacity; seizures; impaired vision, smell, hearing; drop in blood pressure; twitches and tics; muscle paralysis; peripheral neuropathy; loss of gross and fine motor skills; excessive sweating; severe fatigue.51

7.4 – Glyphosate – associated allergic reactions

Novel DNA introduced into a plant's genome can result in the production of proteins that may be new to the human diet. The more transgenic plants present in the food chain, the more people will potentially be consuming proteins new to their diet. Allergic reactions to these may not reveal themselves immediately.

Many symptoms identified in a UK study into allergic reactions to transgenic soy may be related to glyphosate exposure; e.g. irritable bowel syndrome, digestion problems, chronic fatigue, headaches, lethargy, skin complaints. Other glyphosate-tolerant crops may potentially present similar results.

7.5 - Glyphosate – reproductive health

Exposure to glyphosate-based herbicides, even at very low doses may result in reproductive and hormonal problems, miscarriages, low birth weights, pre-term deliveries, and birth defects.51

Laboratory studies have shown that very low levels of glyphosate, Roundup, POEA, and the metabolite AMPA all kill human umbilical, embryonic and placental cells. Roundup can reduce sperm numbers, increase abnormal sperm, retard skeletal development, and cause deformities in amphibian embryos.51

Some 95% of Argentina's annual crop of 47 million tonnes of soybean is transgenic Roundup Ready soybean on which 200 million litres of glyphosate are applied annually, mainly by aerial spraying.51 Two years after widespread aerial spraying of Roundup onto transgenic soybean crops bean in 2002, human birth malformations were reported in rural areas.

Professor Andres Carrasco was an embryologist at the University of Buenos Aires Medical School. He and researchers from the UK, US, Brazil and Argentina have shown glyphosate causes malformations in frog and chicken embryos at doses far lower than those used in agricultural spraying and well below maximum residue levels in products presently approved in the European Union (20 mg/kg for soy). The test animals used by Carrasco's group share similar developmental mechanisms with humans.

The researchers concluded their results "raise concerns about the clinical findings from human offspring in populations exposed to Roundup in agricultural fields." Professor Carrasco stated, "The findings in the lab are compatible with malformations observed in humans exposed to glyphosate during pregnancy." He claimed, !The toxicity classification of glyphosate is too low. In some cases this can be a powerful poison."

In 1997, the maximum residue level (MRL) allowed for glyphosate in soy in the EU was raised 200-fold from 0.1 mg/kg to 20 mg/kg. Carrasco found malformations in embryos injected with 2.03 mg/kg glyphosate. Soybeans can typically contain glyphosate residues of up to 17mg/kg. Levels of up to 97 mg/kg have been reported in seven of 11 maize samples in Argentina, tests three months later producing the same results. At that time the MRL was 20 mg/kg. This has since been raised by the US FDA to 40 mg/kg.

7.6 - Glyphosate – genotoxicity and cancer

Exposure to glyphosate-based herbicides, even at very low doses may result in various cancers - especially haematological cancers such as non-Hodgkin's lymphoma, and hormonal cancers such as breast cancer. Several epidemiological studies have linked exposure to glyphosate with non-Hodgkin's lymphoma, hairy cell leukaemia, multiple myeloma, and DNA damage.51

Studies have demonstrated that glyphosate and/or Roundup cause genetic damage in human lymphocytes and liver cells; bovine lymphocytes; mouse bone marrow, liver, and kidney cells; fish gill cells and erythrocytes; caiman erythrocytes; tadpoles; sea urchin embryos; fruit flies; root-tip cells of onions; and in Salmonella bacteria.51

Other studies have shown that it causes oxidative stress, cell-cycle dysfunction, and disruption to RNA transcription, all of which can contribute to carcinogenicity.51

In 2001, 200 cases of cancer were reported in the Argentinean village of Ituzaingo which has 5000 residents. By 2009 there were 300, 41 times the national average. The community has also seen many malformed babies born. After documenting the tragedies, a group took their case to court. In 2006, the provincial Supreme Court ruled to prohibit the use of agrochemicals within 1000 metres of residential areas in the province of Cordoba.

7. 7 - Other health impacts

There is emerging evidence that glyphosate can affect the nervous system, and in particular areas of the brain associated with Parkinson's disease. In one case study glyphosate exposure was linked to 'symmetrical parkinsonian syndrome'. An epidemiological study of children identified a link with Attention-Deficit/ Hyperactivity Disorder (ADHD). Under other effects, a PANAP report says: "Glyphosate damages liver cells and interferes with a number of enzymes important in metabolism."51

Jasper et al (2012) found exposure to Roundup, even at low doses and for a relatively short period of time, can induce serious hepatic and haematological damage. Long-term exposure from contaminated soil or water, even at low concentrations, can lead to serious human health problems, including liver damage, anaemia, and conditions associated with ROS, such as different types of cancer and neurodegenerative diseases.

A 2013 study found the effects of pure glyphosate on estrogen receptors mediated transcriptional activity and their expressions. Results indicated that low and environmentally relevant concentrations of glyphosate possessed estrogenic activity, in particular causing the growth of breast cancer cells, and there was an additive estrogenic effect between glyphosate and genistein, a phytoestrogen in soybeans. Brief exposure to a Brazilian glyphosate formulation caused liver damage in rats the researchers concluded indicated irreversible damage to liver cells.

A 2013 review paper on glyphosate prepared for the Scottish Parliament can be viewed on http://www.gmwatch.org/index.php/news/archive/2013/15047-glyphosate-destructor-of-human-health-and-biodiversity. The findings detail the impact of glyphosate on human health and the environment.

As of April 2014, despite such findings of adverse, or at least questionable, effects, there remains no official monitoring of the consequences to the human population ingesting transgenes or from glyphosate-based herbicides, and consumers have no official notification of risks.

8 - Glyphosate – the conclusion

Glyphosate may be one of the most biologically disruptive chemicals in the human and physical environment, in part because of its wide range of effects at the cellular level and in part because the extraordinary extent of its use and its insertion into our daily diet means constant exposure to it of virtually everyone. The range of diseases now associated with glyphosate-based herbicides should ring alarm bells. Their biological effects are primary. Virtually every bodily system can be adversely affected.

In their study, researchers Anthony Samsel and Stephanie Seneff state122:

"Our systematic search of the literature has led us to the realization that many of the health problems that appear to be associated with a Western diet could be explained by biological disruptions that have already been attributed to glyphosate. These include digestive issues, obesity, autism, Alzheimer's disease, depression, Parkinson's disease, liver diseases, and cancer, among others. While many other environmental toxins obviously also contribute to these diseases and conditions, we believe that glyphosate may be the most significant environmental toxin."

The toxic effects of glyphosate take a considerable time to manifest overtly and no health or regulatory body is officially looking for what effects may have occurred, making it easy to claim glyphosate is not harmful, and allow usage and sales to continue.

There is no need to take risks with glyphosate-resistant transgenic crops when there already exists effective, sustainable solutions to the problems that this novel technology is claimed to address. Conventional plant breeding, in some cases helped by safe modern technologies like gene mapping and marker assisted selection, continues to outperform genetically engineered crops in producing high-yield, drought-tolerant, and pest- and disease-resistant plants that can meet present and future food needs.

Agro-ecological methods of farm management render the use of glyphosate redundant. Numerous methods exist to manage weeds without recourse to chemicals that undermine both human health and ecological stability.

Reviewed by Meriel Watts, PhD; Coordinator Pesticide Action Network Aotearoa NZ

Further material

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GeneWatch UK and Greenpeace International maintain a register of documented releases of transgenic organisms and contaminated foodstuffs on www.gmcontaminationregister.org.

'Who Owns Nature? Corporate Power and the Final Frontier in the Commodification of Life' on

www.etcgroup.org/sites/www.etcgroup.org/files/publication/707/01/etc_won_report_final_color.pdf.

Glyphosate Effects on Crops, Soils, Animals and Consumers, Europe – UK 31 October 2011, Don M Huber, Emeritus Professor of Plant Pathology, Purdue University, Lafayette, IN, http://www.nvlv.nl/downloads/Powerpoint_presentatie_lezing_Don_Huber_25_okt_2011.pdf

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Glyphosate fact sheet - Pesticide Action Network UK http://www.pan-uk.org/pestnews/Actives/glyphosa.htm

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Glyphosate Factsheet - Critical Habitat Project of the Centre for Ethics and Toxics: http://environmentalcommons.org/glyphosate.pdf

World Health Organisation - Chemical hazards in drinking-water - glyphosate and AMPA http://www.who.int/water_sanitation_health/dwq/chemicals/glyphosate/en/

Organic Consumers Association Comments on New Study Showing Glyphosate Found in Mothers' Breast Milk, 7 April 2014, http://www.organicconsumers.org/articles/article_29697.cfm

Food and Agriculture Organization of the UN - GLYPHOSATE N-(phosphonomethyl)glycine http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Specs/glypho01.pdf

Sierra Club Canada – Glyphosate N-(phosphonomethyl)glycine

http://www.sierraclub.ca/national/programs/health-environment/pesticides/glyphosate-fact-sheet.shtml

Glyphosate-tolerant crops in the EU, pub. 30 October 2012, compiled by agricultural economist Dr Charles Benbrook for Greenpeace
http://www.greenpeace.org/international/en/publications/Campaign-reports/Genetic-engineering/Glyphosate-tolerant-crops-in-the-EU/

Appendix Two

Alternative non-chemical weed management

There is a need to develop effective and sustainable methods for weed control that address the needs of territorial authorities and the public.

1 - Alternative methods to conventional herbicide application technologies – major areas

Saturated super-heated steam and hot water are cost effective and environment-friendly. They can be used in practically all weather conditions and are safe to be used in close proximity of children, adults, shops, and wildlife.

They are methods used successfully by a number of New Zealand Councils in urban and rural areas.

A study which looked at thermal weed control compared with the herbicide glyphosate on the efficacy of weed kill found hot water was equally as effective as glyphosate.

In Auckland, hot water control of roadside vegetation costs no more than glyphosate-based herbicides.

Salt - Killing weeds with readily available salt is effective and inexpensive. Salt dehydrates plants, disrupts the internal water balance of plant cells, and makes ground unsuitable for future plant growth.

Dunedin City Council treats weeds on footpaths, kerbs and channels with salt water.

Mowing - turn areas of noxious and invasive plants into mowable areas suitable for re-vegetation

Weeds for erosion and weed control work – some weeds left to grow in gullies can reduce the risk of erosion, exclude other weeds, and act as a nursery for native tree regeneration. .

Non-spray techniques for selective weed control in ecologically sensitive areas or in dense bush canopies where potential for collateral damage with foliar applications of herbicides:

*Simultaneous application of herbicidal gels to cut stems of shrubs and saplings during pruning;
*Rolling herbicidal gels onto crushed plants;

*Injection of herbicidal gels or solutions into rhizomes, bulbs, corms or fibrous tissue;
*Pressure-injection of herbicide solutions or pathogens into trunks of trees.

2 - Alternative methods to conventional herbicide application technologies – small, specialist areas

- Hand weeding in special areas where only unwanted plants need to be removed. It can be done with tools such as weed-eaters and grubbers, or by digging up the weeds by hand. Some weeds can sprout from fragments, so all plant material (including roots) should be removed from the site.

For some species, vegetation should be tied in light-proof bags to rot for 12-18 months before adding to compost, or they can be dried and/or incinerated.

- Weed mats to stop weed germination; either as a blanket cover over an entire area or as one square metre around individual plants. Use natural fibre carpet or woollen weed matting as natural materials help to retain moisture and offer control. Polythene is not biodegradable, has to be removed after the plants have grown, and prevents rain from penetrating the soil.

- Mulch - spread organic material at least 100mm thick around the base of plants to prevent weed invasion and to stop soil drying out. Mulch helps retain moisture and provides long-term weed control. Ideal mulch materials are bark and untreated sawdust. Add fertiliser as the mulch decomposition process takes nitrogen from the soil.

For more information on non-chemical weed control, visit the Weed Management Advisory at https://weedmanagementadvisory.wordpress.com/.

What are New Zealand Councils doing?

The former Auckland and North Shore City Councils had successful non-chemical management of roadside vegetation for many years. Auckland Council has adopted a Weed Management Policy in which herbicides are supposed to be used only as a last resort. Auckland Transport has maintained non-chemical vegetation management in most of those areas in which it was previously used, with a variety of methods, including hot water, steam, plant-based herbicides (pine oil, coconut oil, palm oil), weed eaters; but appears to have ideological problems rolling it out to the rest of the region.

Waiheke Island Local Board and its advisory panel for weed management have called for non-chemical vegetation management on the island.

Waiheke's Eco-village has undertaken massive native bush and wetland restoration over 20 years without any use of herbicide.

Taupo District Council has reduced the use of chemicals by an average of approximately 30 percent per year since 2006. TDC reserves the right, through the Council resolution process, to identify areas under its jurisdiction that are to be "No-Spray" geographical areas.

Falling within Council areas

KiwiRail controls weeds and reduces infestations with guidance from Regional Councils , which may be able to effectively install no-spray policies.

NZ Transport Agency maintains roads only that are part of the state highway network. It undertakes to control plant pests in accordance with regional plant pest management strategies and within its road reserve boundaries. Chemical herbicides used include the active ingredients glyphosate, metsulfuron, terbuthylazine and triclopyr.

The Department of Conservation offers:

Weed Control Advice on http://www.doc.govt.nz/getting-involved/run-a-project/restoration-advice/weed-control/

Control Methods on http://www.doc.govt.nz/getting-involved/run-a-project/restoration-advice/weed-control/control-methods/ and

Biodiversity Inventory and Monitoring Toolbox on http://www.doc.govt.nz/getting-involved/run-a-project/our-procedures-and-sops/biodiversity-inventory-and-monitoring/

Physical control options include: shading; hand weeding; ring barking; grubbing; felling; and mulching. While labour intensive, these methods have the advantage of targeting the weed in question. Decide which control option to use; for example, felling trees may damage seedlings.

Biological control is a longer-term option designed to help native plants compete with weeds.

Chemical use guidelines include:

- Application confined to knapsacks;

- Injection into trees – for example drill and fill methods and cut and stump treat which work well for softwood trees like wattle and woolly nightshade;

- Swabbing stumps using a paintbrush, or by using a herbicide gel;

- Applying early to avoid using a larger amount later;

- Reducing spray drift by not spraying when it is windy, spraying early or late in the day to avoid warm air rising, and increasing particle size by manipulating the trigger to get a stream rather than a mist.