Pesticide Briefing

Glyphosate & Roundup®

2009

Summary

Glyphosate is a broad-spectrum herbicide that is widely used to control annual and perennial plants on various crops, orchards, plantations, pastures, lawns, gardens, forestry, roadsides, and for aquatic weed control. Glyphosate is the world's largest selling herbicide. The formulation Roundup was first registered by the US-based corporation Monsanto in 1974. Since its introduction, use of glyphosate has increased rapidly, with a sharp rise since the introduction of genetically modified (GM) glyphosate-tolerant crops. It is non-selective and systemic, thus resulting in residues in food and feed. As the acute toxicity – reflected in the WHO classification - of glyphosate is low, it has long been promoted as safe. However, recent evidence shows substantial adverse health and environmental effects, especially of the formulated products.

Health impacts

The marketed formulations of glyphosate, such as Roundup, contain adjuvants (accessory chemicals), usually 50-60 percent, added to enable the active ingredient to work more effectively. There is mounting evidence that the adjuvants are more toxic than glyphosate and/or potentiate its toxic effects. Publicly available information about the nature of these chemicals is incomplete because adjuvants are treated as proprietary secrets by the manufacturer. One major known agent used e.g. in Roundup is 'POEA'.

Although glyphosate itself shows low *acute toxicity*, serious poising effects such as severe eye irritation and injury, skin and respiratory problems, and damage to lung tissue have been recorded with formulated products - probably due to the presence of POEA. Farm workers exposed to Roundup, e.g. by eye rubbing, has been reported to "have caused swelling of eye and lid, rapid heartbeat and elevated blood pressure. Other reported effects of POEA are: vomiting, diarrhoea, haemolysis (destruction of red blood cells), altered mental status, and pulmonary oedema; ingestion can cause in addition pharyngitis, abdominal pain, liver and renal damage, and erosions of the oesophagus, oropharynx, and stomach.

Recent experiences and studies show a wide range of *long-term adverse health effects*, again mostly related to formulated products, such as leukaemia and other cancers, skin diseases, and birth defects, gastrointestinal problems, and alterations to the central nervous system. Other findings link glyphosate and especially formulations with affecting embryo development, damage cells and DNA, and interrupting the hormone system. In addition, POEA contains dioxin, which causes cancer and damage to the liver and kidneys in humans. A new study found adverse effects of four glyphosate-based herbicides on human embryonic, placental and umbilical cord cells at dilution levels far below agricultural recommendations, corresponding to low levels of residues in food or feed.

Environmental impacts

The environmental effects of glyphosate of greatest concern are those that occur at a subtle level, and can result in significant disruption of aquatic and terrestrial ecosystems, including the agro-ecosystem, and loss of biodiversity.

Agricultural formulations (containing POEA) are toxic to organisms especially in water. Effects include reproductive abnormalities, developmental abnormalities and malformations, DNA damage, immune effects, and oxidative stress, among others. Practically all aquatic organisms are affected, from microorganisms, plankton, algae to crustaceans, molluscs, sea urchins, fish, and amphibians, thus impacting the entire aquatic food chain. POEA was found to be extremely toxic to shrimp/ crustaceans and amphibians.

Glyphosate-based herbicides might be toxic to earthworms, beneficial insects, birds and mammals. Its use may also result in significant population losses of a number of terrestrial species through the destruction of vegetation on which they depend for food and shelter.

Studies suggest several effects of glyphosate on soil organisms, including inhibition of the formation of nitrogen-fixing nodules, nitrogen fixation by bacteria, and influencing the soil fungal community structure, potentially impacting agricultural performance. Furthermore, weeds developing resistance to glyphosate pose a real threat for the farmers as well as the environment. This not only leaves farmers with the problem of dealing with these weeds, but is likely to lead to an increase of use of more toxic herbicides, which results in even greater environmental and health risks.

India/Kerala

The use of herbicides in India is comparatively low, however, the market grew between 15-20 percent over the last few years and is estimated to be more than 5 million litres. For glyphosate formulations, Monsanto India reports that Roundup volumes almost tripled in the last four years, and that in 2007 Roundup entered new segments, including rubber plantations in Kerala and has a 'high penetration' in tea and coffee plantations, and grape orchards. Though overall sales figures are not available, Monsanto reported in March 2008 an annual usage of glyphosate IPA Salt as raw material of 3,074 MT with a value of Rs. 3,071 lakhs, up from 2,122 MT in March 2007.

Given the above mentioned increasing use in plantations, glyphosate-based herbicides constitute a serious threat for Kerala's farmers, consumers, and environment, especially taking into consideration the prevailing conditions of use, the fish and shrimp sector, Kerala's abundant water bodies and its rich biodiversity.

General Information

History

Glyphosate was first registered by the US-based corporation Monsanto in the USA in 1974. Monsanto, the world's fourth largest seller of agrochemicals and the largest seed corporation, is the major manufacturer of glyphosate, selling the product under the trade name Roundup. Since the company's patent expired in September 2000, many other names are used for the herbicide by other companies, and it is produced in many countries, including Argentina, China, India, Italy, Japan, Taiwan, UK, and USA (see box for detailed chemical information and common brand names).

Chemical profile (Glyphosate)

Chemical Group

Organophosphonate, Phosphonoglycine

Chemical name

N-phosphonomethyl glycine (formulated usually in its form of isopropylamine salt)

Related chemicals for glyphosate

Glyphosate, diammonium salt; Glyphosate, dimethylammonium salt; Glyphosate, ethanolamine salt; Glyphosate, isopropylamine salt; Glyphosate, monoammonium salt; Glyphosate, potassium salt; Glyphosate, sodium sesqui salt; Glyphosate-trimesium; N-Acetylglyphosate

CAS numbers

1071-83-6
38641-94-0 (mono(isopropylammonium) salt)

Common name

Glyphosate

Common trade name

Roundup (Monsanto)

Other common trade names (and manufacturers)

in India

COMET (Pesticides India); TRINNASHI (HIL); WEEDALL (Dow – former De'Nocil); GLYCEL, MERA (Excel); CLEANUP (Indofil); ALLOUT, SWEEP (United Phosphorus).

world-wide

AQUAMASTER, FILEDMASTER, HONCHO, RANGER, RASCAL (Monsanto); TOUCHDOWN (Syngenta); GLYPHOS (Cheminova); DURAMAX, DURANGO, GLYPHOMAX, RODEO (Dow); KLEENUP (Bonide), RAZOR PRO (Nufarm)

Other Indian manufacturers and exporters (http://www.tradeindia.com/manufacturers/indianmanufacturers)

GUJARAT: GSP CROP SCIENCE, VIMAL CROP CARE, PESTIMADE GUJARAT, MARUTI PESTICIDES, SIKKO PRODUCTS, JAI RADHE SALES, BHAGERIA DYE-CHEM. **DELHI:** CROP CHEMICALS INDIA LIMITED. **HARYANA:** MAHAMAYA LIFESCIENCES. **UTTAR PRADESH**: PARAMOUNT PESTICIDES.

Mode of Action

Glyphosate is a broad-spectrum, non-selective herbicide that destroys plant tissue by inhibiting photosynthesis, cellular growth, and nucleic acid production. This is done by interfering with the synthesis of three amino acids through inhibition of the enzyme EPSP synthase. It has also been shown to inhibit other plant enzymes.

Glyphosate is a systemic herbicide which means it is getting absorbed by the plant and is then translocated within the plant. It tends to accumulate in plant regions with actively dividing cells (e.g. NPIC 2000, Kegley et al. 2008).

Roundup and other glyphosate formulations

The marketed formulations of glyphosate, such as Roundup, contain adjuvant chemicals, usually 50-60 percent, which are either wetting, sticking, fogging or extending agents. They are added to enable the active ingredient to work more effectively by allowing them to gain entry into plant cells. Often referred to as 'inert ingredients', these are usually not tested for toxicity classification. However, there is mounting evidence that the adjuvants in glyphosate formulations are far from being inert but are more toxic than glyphosate and/or potentiate its toxic effects. Publicly available information about the nature of these chemicals is incomplete because adjuvants are treated as proprietary secrets by the manufacturer. One major known surfactant used e.g. in Roundup is POEA (Polyethoxylated tallow[1] amine), which in recent years was linked to severe adverse health effects. .

Uses, Production and Usage

According to Monsanto, there are more approved uses for glyphosate than for any other herbicide (Monsanto 2005b).

- It is widely used to control annual and perennial plants on various crops, orchards, plantations, pastures, lawns, gardens, forestry, roadsides, and for aquatic weed control. (Watts and Macfarlane 1999).
- Since the commercialisation of crops that were genetically modified (GM) to be glyphosate tolerant, it is used to control weeds during the growing season of these crops (see below).
- Furthermore, glyphosate (among other herbicides) is used by the US government in aerial spraying of coca and poppy fields in South America, especially Colombia, with the aim to hinder the production of cocaine and heroin (e.g. Nivia-Rapalmira 2001, Solomon KR et al. 2007).

Glyphosate is the world's largest selling herbicide. Since its introduction during the mid-seventies, use of glyphosate has increased rapidly, with a sharp rise since the introduction of genetically modified (GM) glyphosate-tolerant crops (see below). Worldwide annual sales in 2005 were estimated at **US$ 5 billion** (Rs. 25000 crore) (Agrow 2005). While Monsanto alone had net sales of glyphosate-based herbicides of US$2.5 billion in 2007, the sales in 2008 amounted to over US$4 billion, mainly due to a sharp price rise. The gross profit amounted to almost US$2 billion (Monsanto 2008).

Global consumption was over **600 thousand tonnes** in 2007. There are more than 30 manufacturers world-wide, with China, besides Monsanto, as one as largest producer of glyphosate, having a production capacity of 30-40% of the global total (CCM International 2008).

[1] beef or mutton fat

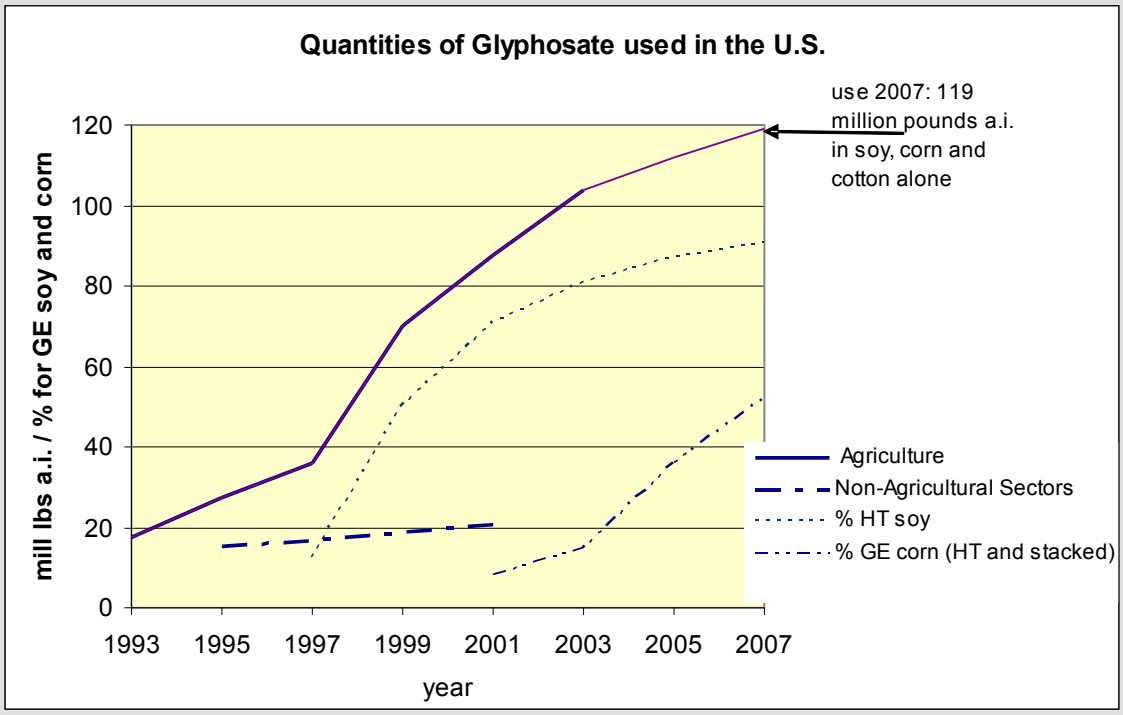
As of March 2007, India had a production capacity of 2640 MT, with an estimated production of 2100 MT in the year 2007-08, up from 308 MT in 2003-04 (Ministry of Chemical & Fertilizers 2008) (for manufacturers, see above).

RR crops/GE

Monsanto's glyphosate-tolerant Roundup Ready (RR) soybean was one of the first genetically modified (GM) crops to be commercialised (Monsanto undated). It was grown commercially for the first time in the USA and Argentina in 1996. Soybean was followed by RR cotton, canola (1997), RR corn (1998) and RR sugar beet (2008), while RR wheat and alfalfa have not been approved for cultivation so far.

In 2008, more than 80 percent of the area under GM crops was planted to crops which were modified to be herbicide tolerant, according to promoters of GM crops (ISAAA 2009a).

While Monsanto claimed that the plants would reduce herbicide application and that Roundup was safe for human health and the environment, the development of glyphosate tolerant crops led to a sharp increase in the use of glyphosate (for the U.S., see figure below). The two other countries with large areas under RR crops are Argentina and Brazil. Argentina, where GM soy covers almost 17 million hectares - around 50 percent of the farmland – uses around 200 million litres of glyphosate per year, mainly applied by aerial spraying (Valente 2009b). In Brazil, 250 million litres were consumed in 2008. The use is closely tied to the GM crops which are said to account for about half of the pesticide market in Brazil (Schobinger 2008 & Agrow 2009).



Sources: American Soybean Association (2008), EPA, USDA a& b

Roundup in India

Though the use of herbicides in India is comparatively low, the market for herbicides in general grew between 15-20 percent over the last few years and is estimated to be more than 5 million

litres. Monsanto India reports that Roundup volumes almost tripled in the last four years, and that in 2007, Roundup entered new segments including rubber plantations in Kerala, and villages in Andhra Pradesh, and has a 'high penetration' in tea and coffee plantations, and grape orchards. Monsanto itself hopes to increase sales with "aggressive sales and marketing strategies". One of these strategies is the "Roundup Tiger Club (RTC)" with its own monthly newsletter for retailers, which rewards members for "outstanding sales volumes and growth (… and) and their contribution in developing markets or entering new markets for Roundup."

Though sales figures are not available, Monsanto reported in March 2008 an annual usage of glyphosate IPA Salt as raw material of 3,074 MT with a value of Rs. 3,071 Lakhs, up from 2,122 MT in March 2007 (Monsanto India 2008).

Furthermore, India is targeted by promoters of GM crops, e.g. the ISAAA just recently started a Hindi edition of its publication "Trust in the Seed" (ISAAA 2009b). Monsanto reportedly wants to bring GM corn (Bt plus RR) to the Indian market and has sought approval for conducting research trials (Damodaran 2008).

Regulatory status

Glyphosate is widely registered, in over 130 countries world-wide. However, in recent years, a few restrictions and bans came into force or under consideration:

- In June 2008, the government of the Canadian state Ontario passed an act that among others prohibits glyphosate for the use on lawns and gardens (www.beyondpesticides.org/dailynewsblog/?p=1351).
- Denmark restricted glyphosate in September 2003 on the ground that it contaminates the drinking water resources (TWN 2003).
- In April 2009, the Environmental Lawyers Association of Argentina filed a law suit before the Supreme Court, seeking a ban on glyphosate, following a study by Argentinean scientists showing malformations in amphibian embryos. Environmental and social organisations have been highlighting health problems of people living near GM soy fields For several years. President Cristina Fernandez ordered the creation of a government committee to investigate the health and environmental impacts of glyphosate (Ho 2009a, Misculin 2009).

Health / Environmental impacts

Short-term (acute) toxicity

Glyphosate is listed in Table V of the World Health Organisation (WHO) classification: 'Unlikely to present an acute hazard in normal use', and the US EPA (1993) ranks glyphosate in toxicity category III (with the label "Caution"). However, some formulations are in category I ("Danger") or II ("Warning") for primary eye irritation or skin irritation.

The oral LD50[2] (rat) is 4320 mg/kg (Peterson &Talcott 2005). Glyphosate causes eye irritation and was slightly irritating to the skin when tested on rabbits (WHO/FAO 1996).

Despite of animal tests showing low acute toxicity of glyphosate, severe poising effects have been recorded with formulated products - probably due to the presence of POEA – causing e.g. severe eye irritation and injury. Formulations containing POEA caused more severe respiratory problems and damage to lung tissue.

Farm workers exposed to Roundup, e.g. by eye rubbing, has been reported to "have caused swelling of eye and lid, rapid heartbeat and elevated blood pressure, or swelling of the face due to residues transferred from hands (…), while drenching caused eczema of hands and arms which lasted two months" (PAN UK 2004). Effects repeatedly reported by farm workers or from

[2] LD50: median lethal dose required to kill 50% of the tested population.

residential areas near fields where glyphosate formulations are sprayed in huge amounts are: skin, eye and respiratory problems, nausea, dizziness and vomiting, as well as accelerated heartbeat, increased blood pressure and allergies (Nivia-Rapalmira 2001).

Roundup - less toxic than table salt?

Monsanto advertises* that Roundup is less toxic than table salt (which has an LD50 of 3000 mg/kg). This is misleading because this LD50 is only a measure for acute oral toxicity. Thus, neither long-term effects nor the reality of exposure (i.e. through skin and inhalation) is taken into account. Furthermore, several cases of Roundup ingestion have been reported which resulted in severe poisoning (see below).

* e.g. Monsanto India (2008).

Sullivan & Krieger (2001) reported as effects of POEA: vomiting, diarrhoea, haemolysis of red blood cells, hypotension, altered mental status, and pulmonary oedema; ingestion can cause in addition pharyngitis, abdominal pain, liver and renal damage, and erosions of the oesophagus, oropharynx, and stomach.

A study in China of people who ingested Roundup showed that people died from doses below 200ml. Ingestion resulted in erosion of the gastrointestinal tract, seen as sore throat, dysphagia, and gastrointestinal haemorrhage (8%). Affected organs were non-specific leucocytosis 65%, lung 23%, liver 19%, cardiovascular 18%, kidney 14%. Deaths following ingestion of 'Roundup' alone were due to a syndrome that involved hypotension, unresponsive to intravenous fluids or vasopressor drugs, and sometimes pulmonary oedema, in the presence of normal central venous pressure (Talbot et al. 1991).

Long-term (chronic) toxicity

The very few official toxicity studies with glyphosate done show treatment-related effects, except those using high doses. In a two-year feeding study (cited in US EPA 1993), rats getting around 1 g/kg/day showed decreased body weight gains, increased incidence of cataracts and lens abnormalities, decreased urinary pH, increased absolute liver weight and increased liver weight/brain weight ratio. The US EPA (und.) lists as possible long-term effects kidney damage, reproductive effects for exposure to drinking water contaminated with glyphosate at levels above the MCL (Maximum Contaminant Level) of 0.7ppm. Glyphosate is not considered to cause cancer or being genotoxic.

However, recent scientific studies as well as experiences and studies of exposed population show a wide range of long-term adverse health effects. These are mostly related to formulated products, i.e. those containing adjuvants like POEA. For example, more and more poising cases are reported from South America where huge amounts of glyphosate formulations are used - on the one hand on GM soy in Argentina and Brazil and on the other hand for the eradication of coca and poppy in Columbia and Peru. Besides short-term effects such as skin and respiratory problems, leukaemia and other cancers, skin diseases, and birth defects have soared for example in Argentina since glyphosate began to be used on the surrounding fields (Villar Belmonte 2006).

RALLT stated that POEA has a much higher toxicity than glyphosate and causes various human health problems including gastrointestinal problems, alterations to the central nervous system, respiratory problems, the destruction of red blood cells and skin irritation. In addition, POEA contains dioxin, which causes cancer and damage to the liver and kidneys in humans (cited in UNEP 2008).

Research findings suggest that glyphosate and especially formulations can cause cancer, affect embryo development, damage cells and DNA, and could interrupt the hormone system.

Selected Studies

- Exposure to glyphosate (and other herbicides) yielded increased risks for Non-Hodgkin Lymphoma, a form of cancer, according to a case-control study in Sweden (Hardell and Eriksson 1999).

- A recent study by Argentinean scientists, which has yet to be published, shows malfunctions in amphibian embryos such as reduced head size, genetic alterations in the central nervous system, an increase in the death of cells that help form the skull, and deformed cartilage. The amphibian embryos were submerged in a glyphosate-water solution 1,500 times weaker than that used on GM soybeans in Argentina. Secondly, embryonic cells were injected with glyphosate diluted with water. The impact was even more negative, indicating that the active ingredient accounts for the toxicity (Valente 2009b).

Toxicity of Roundup / Commercial Formulations

As mentioned above, there is increasing evidence that the adjuvants in glyphosate formulations, so-called 'inert ingredients', are adding to the toxicity or are even more toxic than glyphosate. Several recent studies using Roundup or other formulations found cell and DNA damages, and even endocrine (hormone system) disruption, e.g.:

- When testing 5 different commercial glyphosate formulations, Marc et al. (2004) showed that all induced cell cycle dysfunction, which leads to development of cancers. The study suggests a high risk by inhalation to cause long-term adverse health effects, taking the recommended doses into account.

- A research in Ecuador, collecting data from people exposed to high doses of Roundup Ultra® through aerial spraying for coca eradication, found that it causes DNA damage. A wide range of other signs and symptoms found was noted as well, such as intestinal pain and vomiting, diarrhoea, fever, heart palpitations, headaches, dizziness, numbness, insomnia, burning of eyes, blurred vision, breathing difficulties, skin rashes, blisters (Paz-y-Miño et al. 2007).

- DNA and cell damages, and endocrine (hormone) disruption were found when exposing human liver cells to four different formulations and to glyphosate at sub-agricultural doses with all formulations within 24h. The effects were more dependent on the formulation than on the glyphosate concentration. The recent study therefore considers a real cell impact of glyphosate-based herbicides residues in food, feed or in the environment and discusses their classifications as carcinogens/ mutagens/ reprotoxics (Gasnier et al. 2009).

- Another new study evaluated the toxicity of four glyphosate-based herbicides in Roundup formulations on human embryonic, placental and umbilical cord cells at a dilution level far below agricultural recommendations, corresponding to low levels of residues in food or feed. The formulations have been compared to glyphosate alone, with its main metabolite AMPA (aminomethyl phosphonic acid) or with one known adjuvant, POEA. All formulations cause total cell death within 24 hours. The effects were not proportional to glyphosate concentrations but rather depended on the adjuvants. AMPA and POEA. Their mixtures are generally even more harmful with glyphosate. POEA showed the highest toxicity, either alone or amplified 2-5 times in combination with glyphosate or AMPA. It was concluded that the adjuvants change human cell permeability and amplify toxicity induced already by glyphosate and that the results confirm that the adjuvants in Roundup formulations are not inert and that "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-treated crops (Benachour & Seralini 2009).

Residues

Besides the exposure to glyphosate formulations by application, residues are found in food and feed. The effects on animals fed with GM soy and on people consuming food with glyphosate/ Roundup residues have still to be determined. Interestingly, in 2000, the EU substantially increased the maximum residue level (MRL) for glyphosate in imported (GM) soy 200 times, from 0.1 to 20mg/kg, around the same time GM soy was approved (Dibb 2000). Very few data are available. E.g. in UK, sampling of food for glyphosate residues was done mostly on cereals, bread and flour only. Levels found were below the new MRL, but well above the old one: Out of 27% of bread and flour samples tested

between 2006 and 2008 contained glyphosate residues in the range 0.1-3.8mg/kg, and 6 out of 8 samples of tofu/soya pieces originating from Brazil contained glyphosate, with the highest level being 1.1mg/kg (GM Freeze 2009).

However, trials have shown that AMPA[3], which has a similar toxicological profile compared to glyphosate, can be the main residue (FAO 1998). Kolpin et al. (2005) investigated glyphosate and AMPA levels in treated water sampled from wastewater treatment plants in the U.S. (where glyphosate formulations are also widely used in urban settings). They found that "AMPA was detected much more frequently (67.5%) compared to glyphosate (17.5%)".

ENVIRONMENT

Soil and water

While Monsanto claims that glyphosate is binding to the soil and is rapidly degraded (3-141 days), longer persistence has been found, especially in cold climates. AMPA has been found to be more persistent, with a half life in soil between 119 and 958 days. In pond water, glyphosate persisted 12-60 days, while residues in pond sediment were found 400 days after application. In Sandy soils in Australia, AMPA increased strongly with the soil iron and aluminium content, and the presence of inorganic phosphate (e.g. from fertilisers) inhibits the degradation of glyphosate by some bacteria (cited in Buffin & Jewell 2001).

Aquatic life/ Amphibians

Toxicity depends on the formulation. Agricultural formulations (containing POEA) are toxic to organisms especially in water. The label e.g. in the U.S. therefore must bear the following label statement: *Do not apply directly to water, to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwaters and rinsate.* (US EPA 1993).

POEA is about 30 times more toxic to fish compared to glyphosate, and has also been shown to disrupt respiratory membranes in aquatic organisms. Brausch et al. (2007) found POEA acute toxicity and growth inhibition in Daphnia, and in a similar study it was extremely toxic to shrimp (Brausch & Smith 2007). Tsui & Chu (2003). Showed that POEA was especially toxic to micro algae and crustaceans, and that an increased pH significantly increased toxicity of Roundup to crustaceans.

Roundup is highly toxic to amphibians. For example, when sprayed with Roundup, practically al larval amphibians in a pond died, and 68 to 86 percent of young frogs held in containers were killed (Relyea 2005).

Terrestrial effects /Biodiversity

Glyphosate-based herbicides might be toxic to earthworms, beneficial insects, birds and mammals. Its use may also result in significant population losses of a number of terrestrial species through the destruction of vegetation on which they depend for food and shelter.

Production

Phosphorus is needed for the production of glyphosate. Around 250,000 tonnes of phosphorus trichloride were produced and used for glyphosate production in 2002 which was estimated to grow by 4 to 5 percent per year (Cisse & Mrabet 2004). It recently came to light that Monsanto's phosphate rock mine in Idaho violated water quality laws almost since it opened, sending selenium and other heavy metals into the region's streams. According to the EPA problems at the mine were first documented as early as April 2002 (Miller 2009).

[3] the primary degradation product of glyphosate in plants, soil, and water

Agricultural Impacts

Plant Nutrition

Studies in the 1990s suggest several effects of glyphosate on soil organisms though the impacts on agricultural performance were not established. The effects included the inhibition of the formation of nitrogen-fixing nodules, nitrogen fixation by bacteria, and influencing the soil fungal community structure. One of these studies found reduced strains of nitrogen-fixing species in tea plantation soil in India (Buffin & Jewell 2001).

More recent studies concentrate on soybean. In GM soy, Bellaloui et al. (2008) did find no effect of glyphosate application on nitrogen fixation as measured by acetylene reduction assay, soybean yield, or seed nitrogen content. However, there were significant effects of glyphosate application on nitrogen assimilation. These results suggest that glyphosate application may alter nitrogen and carbon metabolism. Another study with GM soy indicate that nitrogen accumulation was only slightly affected at label use rate, but was consistently reduced at above label use rates of glyphosate and the greatest reductions occurred with soil moisture stress following glyphosate application (Zablotowicz & Reddy 2007). When Bellaloui et al. (2006) studied the effects of glyphosate drift onto non-target (non-GM) soy, the results suggested that nitrate assimilation and nitrogen fixation potential were significantly reduced by glyphosate drift, with the greatest sensitivity early in vegetative growth, though soybean has the ability to recover from the physiological stress caused by glyphosate drift.

Resistance

A real threat, becoming more and more apparent in recent years, are weeds developing resistance to glyphosate. The sheer scale of glyphosate use today, especially as a single herbicide in glyphosate-tolerant GM crops, makes the development of resistances in weeds highly likely. Even industry-sponsored publications point out that “the number of species [of glyphosate-resistant weeds] is increasing at an alarming rate”, and “heavy reliance on glyphosate in (…) Roundup Ready crops in the future will also increase the potential for glyphosate-resistant weeds” (Boerboom and Owen 2006).

The first glyphosate-resistant weed, horseweed (*Conyza canadensis*), was discovered in two US-states (where practically only RR crops were cultivated) in 2000. This plant is especially problematic as its seeds, due to their shape, are spread over very long distances by wind – while in 2000 it appeared only in a few fields, 100,000 to 1 million acres were infested one year later; it had spread to five states by 2002, and 14 in 2006. In the same year, glyphosate-resistant waterhemp (Amaranthus rudis) was found in 3 states of the US corn belt. Worldwide, 9 glyphosate-resistant weeds were reported between 2000 and 2005 (GENET 2003, Boerboom and Owen 2006).

This not only leaves farmers with the problem of dealing with these weeds, but is likely to lead to an increase of use of more toxic herbicides, which results in even greater environmental and health risks. For example, Monsanto itself recommends a mix of Roundup and 2,4-D, while Syngenta suggests a rotation of chemicals (GENET 2003, Marsh et al. 2006).

In 2002, glyphosate-resistant johnsongrass (*Sorghum halepense*) appeared in the north of Argentina and covered at least 10,000 hectares there in 2007 (Binimelis et al. 2009). In March 2008, johnsongrass was announced as the latest glyphosate-resistant weed in Arkansas and Mississippi. It is the first glyphosate-resistant warm-season grass found in the United States (Bennett 2008).

Glyphosate-resistant weeds are clearly on the rise now in RR crop fields, e.g. in the southern U.S. states, driving farmers to use more herbicides, return to conventional crops or even abandon their farms. In Georgia, 100,000 acres are severely infested with pigweed and 29 counties have confirmed resistance to glyphosate. Researchers from Purdue University

declared that glyphosate-resistant giant ragweed can cause up to 100 percent yield loss (cited from GM Watch 2009).

Impact on traditional farming systems

'Weeds' are part of the biodiversity of small farms and are an integral part of the farming system and household in India and many other tropical countries. For example, a study done in Karnataka found a tremendously diverse usage of 'weeds' (von Weizsäcker 1995):

- Food
- Fodder
- Medicine
- Pest control
- Household utensils
- Construction material
- Religious purposes
- Prevention of erosion
- Compost, mulch and green manure

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