MONSANTO

Backgrounder
Glyphosate and Wildlife
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Monsanto Company

Overview

Before any herbicide can be registered for use in the United States, the active ingredient must undergo a number of required studies to investigate the potential for unreasonable adverse effects to wildlife and other non-target organisms. The required studies are conducted with species representative of various forms of wildlife – small mammals, birds, fish, aquatic invertebrates, algae and aquatic plants, and honey bees. The results from these required studies indicate that glyphosate will not cause unreasonable adverse effects to wildlife when used according to label directions. In 1993, when glyphosate was reregistered in the U.S., the Environmental Protection Agency (EPA) stated: "Based on current data, EPA has determined that the effects of glyphosate on birds, mammals, fish and invertebrates are minimal" (U.S. EPA 1993).

In addition to studies required by the U.S. EPA and other regulatory bodies, many other wildlife-related studies have been conducted with glyphosate products during more than 30 years of use. The weight of evidence from these studies supports the conclusion from regulatory studies that no unreasonable adverse effects are predicted from the normal use of glyphosate herbicides (Sullivan and Sullivan, 2000). Glyphosate herbicides are commonly used as a tool to restore and protect habitat. For example, they have been used in protected habitats such as the Galapagos Islands and the Florida Everglades.

In 2000, three internationally recognized experts in environmental toxicology published an ecotoxicological assessment of glyphosate and the original Roundup[1] herbicide (Giesy et al., 2000). Using very conservative assumptions, the authors established hazard quotient (HQ) values for the various life forms that could be exposed to the formulation and glyphosate in the environment, for both acute and chronic exposures. An HQ lower than 1.0 indicates minimal risk of adverse effects, while HQ values greater than 10 suggest significant risk. The experts found that no terrestrial use of the formulated herbicide produced an HQ of 1.0 or greater. They also found that no aquatic use produced an HQ greater than 1.0, with the exception of glyphosate and surfactant applied directly to very shallow water (6 inches). The highest HQ in such shallow water was only 6.19. The authors point out that in actual use, aquatic vegetation would intercept at least 50 percent of the applied product. As a result, the authors concluded that direct applications of the original Roundup[1] herbicide to water could be carried out with minimal risk to aquatic organisms with consideration of the water depth, vegetation density, and overall rehabilitation goal.[2]

[1] "Roundup" refers to the original single active ingredient Roundup herbicide formulation (also known as MON 2139).
[2] Only specific glyphosate formulations are labeled for aquatic use in certain world areas. Use of a product inconsistent with its label is a violation of law and is strictly prohibited. AquaMaster™ herbicide is labeled for aquatic uses in the United States.

Wild mammals

Glyphosate and Monsanto's glyphosate herbicides have been extensively tested for adverse effects on laboratory mammals, primarily rats, mice, and rabbits. In addition to laboratory studies, the scientific literature contains many field studies in which the effects of glyphosate use on wild mammals have been examined (Sullivan and Sullivan, 2000; Santillo et al. 1989; Hjeljord et al. 1988; Sullivan 1990; Hjeljord 1994; Cumming et al. 1996; Cole et al. 1998). These studies indicate that glyphosate and glyphosate herbicides, when used according to label directions, will not cause unreasonable adverse effects to mammals. An ecotoxicological risk assessment of glyphosate (Giesy et al. 2000) reported estimated exposures that various mammals might encounter from potential use of glyphosate. The authors concluded that mammals, including the tiny meadow vole, would not be expected to encounter harmful levels of glyphosate through multiple possible exposure routes, including food, water and direct contact.

Birds

Glyphosate has been evaluated for toxicity to bobwhite quail and mallard duck in laboratory studies. These species are surrogates for wild avian species that might be exposed to glyphosate through various exposure routes. In dietary studies conducted with bobwhite quail and mallard ducks, in which the birds consume treated diet for 5 days, glyphosate had no effects at the highest dose tested. Reproductive tests indicated that no adverse effects on avian reproduction or hatchling development would be expected from normal use of glyphosate. Exposure of birds to glyphosate in the environment is predicted to occur at much lower levels than the levels evaluated in the laboratory studies. In addition, glyphosate has been shown to rapidly dissipate from treated vegetation, and such vegetation becomes unpalatable within 1 to 3 weeks after treatment. Therefore, the proper use of glyphosate-containing herbicides is not expected to pose a significant risk to birds (U.S. EPA 1993). In addition to the laboratory studies, several comprehensive field studies have examined birds in natural settings where glyphosate products were used. These studies demonstrate that some species favored treated areas, while other species temporarily left treated areas because of changes in the vegetative habitat. No direct toxicity was reported in any of the studies (Giesy et al, 2000). Any form of vegetation removal would be expected to produce similar effects. Studies have shown that avian species abundance returns to pre-treatment levels when plant regrowth occurs (MacKinnon and Freedman, 1993).

A Technical Information Summary titled "Glyphosate and Avian Species" is available upon request from the Monsanto's Public Affairs Director for Agricultural Chemicals at 314-694-3546.

Aquatic animals (fish, shellfish)

Glyphosate and many of Monsanto's glyphosate formulations have been tested for toxicity to numerous aquatic animals, including invertebrate and vertebrate fresh and saltwater species. Results of these studies indicate that glyphosate has very low acute toxicity to aquatic animals (U.S. EPA 1993, WHO 1994) Levels required to produce adverse effects would not be expected from labeled use of glyphosate herbicides. It has also been shown that glyphosate does not bioconcentrate in tissues of aquatic organisms (WHO, 1994).

To work effectively, glyphosate must be mixed with a surfactant (a soap-like substance) that facilitates the uptake of glyphosate by the plant. Surfactants may be more toxic than glyphosate to aquatic organisms in laboratory tests. However, the level of surfactant present in a herbicide application is sufficiently low that no unreasonable adverse effects are expected to result from

the normal use of the products. A conservative aquatic risk assessment indicates that glyphosate and surfactant would not be expected to produce unreasonable adverse effects to aquatic organisms in water 6 feet deep (Giesy et al, 2000). In more shallow water, potential effects predicted by hazard quotients are unlikely to occur in the environment due to interception, sediment binding, and degradation of the herbicide components. The World Health Organization report on glyphosate states: "Fish and aquatic invertebrates would not be affected by glyphosate use" (WHO 1994).

Amphibians

Toxicity studies with amphibians are not included in the standard toxicity tests required for U.S. EPA registration. Toxicity studies with amphibians have shown that amphibians are not more sensitive than fish to herbicides (Mayer and Ellersieck, 1986; Birge et al., 2000). Since fish are included in the mandatory toxicity studies for pesticide active ingredients, amphibians are not. Nevertheless, the toxicity of glyphosate and some glyphosate formulations to several species of amphibians, including frogs, newts and salamanders, have been investigated. A risk assessment based on exposure of amphibians and other aquatic organisms demonstrates that normal use of glyphosate formulations are not expected to cause unreasonable adverse effects to amphibians, including tadpoles (Giesy et al., 2000).

Insects and other terrestrial arthropods

Glyphosate and the original Roundup[1] formulation have been tested for toxicity to honey bees in laboratory tests, using both oral and topical dosing. In these studies, glyphosate and Roundup were found to have no adverse effects to bees at rates much higher than would be present in treated areas. In addition, the original Roundup formulation has been evaluated in laboratory studies with terrestrial arthropods such as the parasitic wasp, predatory mite, carabid beetle, and green lacewing. These laboratory studies use artificial exposure conditions to simulate exposures in the field. When the results of these studies are compared to estimated residues of glyphosate that might occur in and adjacent to treated areas, it can be concluded that the risk of unreasonable adverse effects to terrestrial arthropods ranges from low to moderate. At the maximum use rate, no in-field effects are predicted for the carabid beetle and parasitic wasp, while in-field effects cannot be excluded for the predatory mite and green lacewing. However, no effects to the predatory mite and green lacewing are expected at more typical use rates.

Habitat change resulting from herbicide use (due to the decrease in vegetation) can have a significant influence on leaf-dwelling arthropod populations (e.g. wasp, mite, and lacewing). The primary effect to populations on-site are expected to result from herbicidal effects on vegetation. Therefore, direct effects on arthropod populations that might be observed after herbicide use are expected to be less significant than effects due to habitat change.

The effects of other glyphosate formulations on beneficial arthropods may vary from those observed for the original Roundup formulation. Generally, no effects are observed to beneficial arthropods at rates expected from herbicide drift to nontarget areas. In target areas, habitat change is expected to have the most influence on arthropod populations.

In a screening assay in which 18 different beneficial predators and parasites were exposed to the original Roundup[1] formulation on a synthetic surface, the formulation was found to be “harmless” to 13 species, “slightly harmful” to four species and “moderately harmful” to one species (carabid beetle) (Hassan *et al.* 1988)[a]. The authors did not believe that sufficient toxicity potential existed for the Roundup formulation to warrant semi-field and field tests that

were performed on some of the other compounds tested in the same program. A subsequent semi-field test with a similar glyphosate formulation indicated that even when carabid beetles were directly oversprayed at the maximum use rate, no mortality was observed. One reason for the difference between the laboratory and semi-field study results may be related to the artificial nature of the laboratory glass plate assays (e.g. potential stickiness of the formulation on the glass substrate).

After reviewing extensive research on glyphosate and arthropods, three experts in environmental toxicology wrote (Giesy et al., 2000):

> "In summary, the literature supports the conclusion that non-target arthropods are at minimal risk from glyphosate and its formulations in offsite areas. Within treated areas, applications of the herbicide can produce changes in species diversity and in population size and structure for beneficial insects through modifications of available food sources and habitat."

[a] Categories used by Hassan et al. to report mortality/reduction in beneficial capacity were as follows: "harmless": < 50%; "slightly harmful": 50-79%; "moderately harmful": 80-99%; "harmful": > 99%.

Earthworms

Numerous studies support the conclusion that normal use of glyphosate formulations, such as the original Roundup herbicide[1] and other glyphosate herbicides, will not result in adverse effects to earthworms. A comprehensive review of the effects of agricultural chemicals on earthworms reviewed the effects of glyphosate on earthworms (Edwards and Bohlen 1996). Glyphosate was ranked as zero on a scale of zero (relatively non-toxic) to 4 (extremely toxic). Monsanto and several independent researchers have conducted studies in which no adverse effects were observed when earthworms were exposed to glyphosate residues in soil at rates equal to or greater than labeled rates (Giesy et al., 2000). In field studies, it has been demonstrated that earthworms thrive under conservation-tillage cropping practices, which are facilitated by Roundup UltraMax and other glyphosate herbicides (Giesy et al., 2000).

A Technical Information Summary titled "Glyphosate and Earthworms" is available upon request from the Monsanto's Public Affairs Director for Agricultural Chemicals at 314-694-3546.

Soil microorganisms

Numerous laboratory and field studies have been published by independent researchers investigating the effects of glyphosate on soil microbes. The weight of evidence from these studies conducted using realistic exposure conditions indicates that no significant adverse effects to soil organisms are expected when glyphosate herbicides are applied according to label directions (Giesy et al, 2000). Experiments on glyphosate treated and untreated soil revealed no significant difference in the types or amount of microbes present (Rueppel et al. 1977). Studies also show that glyphosate does not interfere with the ability of microbes to decompose plant material, such as dead leaves, or convert inorganic nitrogen into an organic form needed for plant growth (Grossbard, 1985; Sullivan, 1990).

References

Birge WJ, Westerman AG, Spromberg JA. (2000) Comparative toxicity and risk assessment of amphibians. Chapter 14A in Ecotoxicology of Amphibians and Reptiles. Sparling DW, Linder G, Bishop CA (Eds). Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL. p. 727-791.

Cole EC, McComb WC, Newton M, Leeming JP, Chambers CL (1998) Response of small mammals to clearcutting, burning, and glyphosate application in the Oregon coast range. J Wildl Manage 62(4): 1207-1216.

Cumming HG, Lautenschlager RA, Kelly CP, Thapa S (1996) Effects of conifer release with Vision® (glyphosate) herbicide on moose forage quality (digestible protein). Ontario Forest Research Institute. Forest Research Report 139. Cited In: Sullivan and Sullivan 2000.

Edwards CA, Bohlen PJ (1996) Biology and ecology of earthworms. Ed. 3. Chapman & Hall Ltd. London.

Giesy JP, Dobson S, Solomon KR (2000) Ecotoxicological risk assessment for Roundup herbicide. Reviews of Environmental Contamination and Toxicology 167: 35-120.

Grossbard E, Atkinson D (eds) (1985) The herbicide glyphosate. Butterworths, London.

Hassan SA, Bigler F, Bogenschütz H, Boller E, Brun J, Chiverton P, Edwards P, Mansour F, Naton E, Oomen PA, Overmeer PJ, Polgar L, Rieckmann W, Samsøe-Petersen L, Stäubli A, Sterk G, Tavares K, Tuset JJ, Viggiani G, Vivas AG (1988) Results of the fourth joint pesticide testing programme carried out by the IOBC/WPRS-Working Group "Pesticides and Beneficial Organsisms". J Appl Entomol 105: 321-329.

Hjeljord O, Sahlgaard V, Enge VE, Eggestad E, Gronvold S. (1988) Glyphosate application in forest -- ecological aspects. VII. The effect on mountain hare (*Lepus timidus*) use of a forest plantation. Scandinavian Journal of Forest Research 3: 123-27.

Hjeljord O (1994) Moose (*Alces alces*) and mountain hare (*Lepus timidus*) use of conifer plantations following glyphosate application. Nor J Agric Sci 8(3-4): 181-88 .

Mayer FL, Ellersieck MR. (1986) Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. United States Department of the Interior, Fish and Wildlife Service Resource Publication 160. Washington, DC.

Rueppel ML, Brightwell BB, Schaefer J, Marvel JT (1977) Metabolism and degradation of glyphosate in soil and water. J Agric Food Chem 25(3): 517-528.

Santillo DJ, Leslie DM, Brown PW (1989) Response of small mammals to glyphosate application on clearcuts. J Wildl Manage 53: 164-172.

Sullivan TP (1990) Demographic responses of small mammal populations to a herbicide application in coastal coniferous forest: population density and resiliency. Can J Zool 68: 874-83.

Sullivan DS, Sullivan TP (2000) Non-target impacts of the herbicide glyphosate: A compendium of references and abstracts. 5th Edition. Applied Mammal Research Institute, Summerland, British Columbia, Canada.

U.S. EPA (1993) Reregistration Eligibility Decision: Glyphosate. U.S. Environmental Protection Agency. http://www.epa.gov/oppsrrd1/REDs/old_reds/glyphosate.pdf

WHO (1994) Environmental Health Criteria 159: Glyphosate. World Health Organization. Geneva, Switzerland. http://www.inchem.org/documents/ehc/ehc/ehc159.htm

Williams GM, Kroes R, Munro IC (2000) Safety evaluation and risk assessment of the herbicide Roundup and its active ingredient, glyphosate, for humans. Reg Toxicol Pharmacol 31(2):117-165.