# ChemicalWatch Factsheet

## GLUFOSINATE-AMMONIUM

### Background Information

Glufosinate-ammonium (glufosinate) is, according to the U.S. Environmental Protection Agency (EPA), an organophosphorus chemical that is primarily a foliar-active herbicide with limited systemic activity,[1] and is linked to a range of human health and environmental effects. Remarkably, in 2013, EPA identified multi-generational hazards in mammals when the chemical is used in accordance with product label instructions, but has not imposed new restrictions to account for this.

**ChemicalWatch Stats**

**CAS Registry Number:** 77182-82-2
**Trade Name:** Basta, Rely, Finale, Ignite, Challenge, Liberty
**Use:** Non-selective foliar herbicide used for pre-plant and post-emergent control of broadleaf weeds
**Signal Word:** Warning!
**Toxicity Rating:** Toxic
**Health Effects:** Known reproductive/developmental effects, neurotoxicant
**Environmental Effects:** Toxic to aquatic organisms and mammals

Glufosinate was first registered in the U.S. for use as an herbicide in 1993 by Hoechst Celanese.[2] Also known as phosphinothricin, this herbicide is commonly marketed under the trade names Basta, Rely, Finale, Ignite, Challenge, and Liberty and is registered for use on golf course turf, residential lawns, ornamentals, and a variety of industrial, residential and public areas, on fruit and nut orchards and vineyards, and as well as a wide range of genetically engineered (GE) crops (since 1995). Glufosinate use is expected to increase dramatically in the coming years as a result of widespread pervasive glyphosate-resistant weeds, and the subsequent incorporation of glufosinate tolerance into new stacked varieties of GE crops as of 2014 that are also resistant to 2,4-D and glyphosate (see box).

### Regulation Status and Current Use

Glufosinate is registered for use on almonds, apples, bananas, berries, canola, corn, cotton, grapes, potatoes, rice, soybeans, tree nuts, and more.[3,4] According to EPA's 2008 Summary Document for glufosinate, the majority of agricultural uses occur in corn (900,000 lb active ingredient (ai)/acre), followed by cotton (300,000 lb ai/A), canola (60,000 lb ai/A), almonds (30,000 lb ai/A), and grapes (20,000 lb ai/A).

Glufosinate-tolerant crops are not approved for use in the European Union (EU).[5] While the EU has a process in place for approving GE crops, and has approved many, France, Germany, Northern Ireland, Scotland, Bulgaria, and many others have banned their cultivation, opting out of the EU approval process.[6]

### Mode of Herbicidal Action

As a phosphinic acid, glufosinate-ammonium is a structural analogue of glutamate and acts in plants via the inhibition of the activity of glutamine synthetase, the enzyme that converts glutamate and ammonia into the amino acid glutamine in both animals and plants, although the extent to which this occurs differs significantly within each type of organism.[7] Through the inhibition of this enzyme, ammonia accumulates within the plant, resulting in cell destruction and the direct inhibition of photosynthesis reactions and eventual death of the plant.[8,9] However, crops genetically engineered to tolerate glufosinate contain a bacterial gene that produces an enzyme that detoxifies the chemical and prevents it from doing damage.[10]

### Human Health Effects

***Acute Toxicity.*** Glufosinate can cause of range of effects from substantial, but temporary eye injury, skin irritation, respiratory failure, to death through dermal absorption or ingestion. Any contact with the substance can result in some sort of deleterious effect. These effects may vary according to glufosinate formulations and in comparison to technical grade glufosinate.[11,12]

Case reports describe symptoms of ingestion that include convulsions, respiratory distress, disturbed and loss of consciousness, tremor, speech impairment, circulatory failure, and loss of short-term memory.[13,14,15,16] Neurotoxicity can result from glufosinate poisoning, although the mechanism in not clear. Glufosinate toxicity appears to come from both the active ingredient and the surfactants in the formulation.[17]

Mild to moderate toxicity includes symptoms of nausea, vomiting, and diarrhea within two hours of ingestion. Within 24 hours, generalized edema and mild leukocytosis commonly develop, along with elevated liver enzymes. Cases of severe toxicity may result in initial gastrointestinal upset followed by severe neurological effects 8 to 32 hours after ingestion. These effects include seizures, coma, nystagmus (uncontrollable eye movements), retrograde and anterograde amnesia, and respiratory failure.[18]

***Chronic Toxicity.*** In laboratory animals, glufosinate has been shown to cause an inhibition of glutamine synthetase activity in different tissues. This inhibition resulted in slight increases of glutamate and ammonia levels at high sublethal and lethal doses. Mammals metabolize glufosinate in a way that allows for the compensation of the inhibition of glutamine synthetase activity by other metabolic pathways.[19] Exposure to glufosinate in mice at 5 and 10 mg/kg over a period of 10 weeks is shown to result in cerebral alterations, specifically mild memory impairments, modification of hippocampal texture, and a significant increase in hippocampal glutamine synthetase activity.[20]

Studies have reported that glufosinate is toxic to mouse embryos *in vitro* (in glass containers) and causes growth retardation and neuroepithelial cell death.[21] Paternal exposure to glufosinate in humans has been found to correlate with a possible risk in congenital malformations.[22]

The herbicide is also being detected in humans. In a 2011 study by Canadian researchers, pregnant women exposed to pesticides associated with genetically engineered food, specifically glyphosate and glufosinate, were examined to investigate whether these toxicants cross the placenta to reach the fetus. Glufosinate's metabolite, 3-MPPA, was detected in 100% of maternal and umbilical blood samples, and in 67% of non-pregnant women's blood samples.[23] Glufosinate is classified as having known reproductive/developmental effects and is a known toxicant, according to the *Pesticide Properties Database*.[24] EPA classifies glufosinate as "Not Likely to be Carcinogenic to Humans."[25]

## Environmental Fate

According to EPA, the half-life of glufosinate in soil ranges from 8.5 to 23.0 days in aerobic (with oxygen) soil, depending on application rate.[26] Other sources document a range of 4 to 10 days in aerobic soil. In anaerobic (absence of oxygen) soil, half-life increases to 37 days. Aerobic water half-lives range from 38 to 87 days. Glufosinate is mobile to highly mobile. Mobility of residues in soil is a function of organic content, meaning that mobility of glufosinate in soil may be less for soils with higher organic content.[27] In one study comparing the persistence of five herbicides, including glyphosate, glufosinate ammonium was found to be the least persistent in sandy loam and clay soil types, with 90% dissipating within 2.5 months.[28] Glufosinate residues resulting from root uptake following soil application have been found in apples, grapevine, potatoes, and cereals (maize and wheat).[29]

A U.S. Geological Survey (USGS) study examining the presence of this herbicide in the environment has found that glufosinate is seldom found in surface water, rainfall, and soil samples.[30] However, due to glufosinate's high mobility, solubility (about 1,370 g/L), and resistance to breakdown by light and water,[31] there is still potential for contamination and risk of harm for aquatic species. Indeed, fish kill incidents have been documented by EPA in association with nearby terrestrial application of glufosinate in surrounding agricultural areas.[32]

## Effects on Non-Target Organisms

***Acute Effects.*** Acute effects in non-target organisms from exposure to both the active ingredient glufosinate ammonium and its formulated products have been documented. Acute glufosinate exposure to the aquatic unicellular alga Chlorella vulgaris was shown to affect the activities of antioxidant enzymes, disrupting the structure of chloroplasts, and reducing transcription of photosynthesis-related genes.[33] Field application rate levels of glufosinate ammonium are found to be highly toxic to nymphs and adults of certain predatory mite species.[34] An investigation of the effects of sublethal concentrations on tadpoles exposed during a period of 48 to 96 hours to the products Liberty® and Ly® found that there is a concentration-dependent increase in micronucleated erythrocytes in blood. Researchers found that the commercial formulation of glufosinate induced micronucleus formation in tadpoles in contrast to the active ingredient, indicating that the inert ingredients of the commercial formulation played an important role in the production of genotoxic damage in the red blood cells of amphibian tadpoles.[35] A similar study examining the effects of sublethal glufosinate ammonium exposure found an inhibition in the activities of both the acetylcholinesterase (ACh) and butyrylcholinesterase (BCh) enzymes, which are important for motor function, in tadpoles, showing a concentration-dependent inhibitory effect. At an exposure of 15 mg glufosinate-ammonium per liter, there is a significant increase (compared to unexposed tadpoles) in swimming speed and the mean distance they are able to swim as well as a significant negative correlation between swimming speed and BCh enzyme activity. These results suggest that this enzyme inhibition is related to an increase in swimming speed, an effect that may have adverse consequences at the population level since neurotransmission and swimming performance are essential for tadpole survival.[36] Fish kill incidents have been reported to EPA in association with terrestrial application of glufosinate in surrounding agricultural areas.[37]

***Chronic Effects.*** In its Environmental Fate and Ecological Risk Assessment for the herbicide, EPA, in 2013, states that glufosinate use "in accordance with registered labels results in chronic risk to mammals that exceeds the Agency's chronic risk Level of Concern (LOC)."[38] Adverse effects to mammals after chronic exposure in laboratory studies includes reductions in growth and in offspring fitness and viability. The agency adds that these "effects are not only seen across generations, but in multiple species as well." Some uses of glufosinate may also result in acute risk to mammals and chronic risks to birds, reptiles, and amphibians due to exposure through diet. The potential for acute risk to birds, reptiles, and amphibians exposed through a terrestrial diet is based on sublethal effects of lethargy and diarrhea. EPA found LOC exceedances for off-site transport of glufosinate to surface water for federally listed threatened and endangered species of aquatic nonvascular plants (e.g. algae) and estuarine/marine invertebrates. As touched on above, formulated glufosinate is generally more toxic to aquatic and terrestrial animals than the technical grade active ingredient.[39] Despite the numerous LOC exceedances outlined in its preliminary ecological risk assessment, EPA has failed to propose mitigation measures, and will not do so possibly until later in 2016.

## Glufosinate and GE Crops

Glufosinate has been approved for use on GE crops since 1995.[40] Currently, there are approved cotton, corn, soy, sugar beet, rice and canola varieties that are genetically engineered (GE) to be glufosinate-tolerant. These crops have been genetically engineered to express phosphinothricin-acetyltransferase (PAT), which allows the plant to metabolize glufosinate ammonium into N-acetylglufosinate.[41] Glufosinate formulations have been marketed as a non-selective chemical control alternative for weeds that have become resistant to glyphosate (Roundup). As such, formulations containing glufosinate are being used on glufosinate-tolerant crops. For example, LibertyLink, a set of genetically-engineered crops developed by Bayer CropScience, is used in conjunction with glufosinate-containing herbicides, like Liberty or Ignite, on GE crops.[42]

## Endnotes


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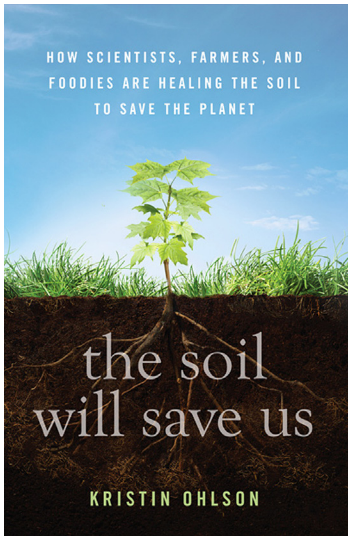
by Jay Feldman

# The Soil Will Save Us

*The Soil Will Save Us, Kristin Ohlson, 2014, 242pp.*

The author takes us through the U.S. and around the world on her journey to understand the value of soil health and the dramatic benefits it provides to the environment and those who inhabit and depend on it for sustenance. Kristin Ohlson's personal interactions with research scientists, farmers, and land managers and the transformative experiences that they relate weave a gripping and informative story that is critical to solving the world's environmental and public health problems. It is the respect, nurturing and management of soil that will determine the livability of the planet, whether we strive to eliminate toxic pesticide use, stop chemical fertilizer runoff into waterways, or reverse global climate change. The story begins with the microbial life in the soil.




Any land manager, whether a farmer or a parks manager, probably knows the structure of the soil being managed, its content of sand, silt and clay, as well as the pH and the soil chemistry. However, typically there is little knowledge about the management of the site's soil biology and the benefits that it delivers. This is not a new problem. In fact, a 1938 publication of the U.S. Department of Agriculture (USDA), *Soils and Men: A Yearbook in Agriculture*, stated, "Do civilizations fail because soils fail or do soils fail because civilizations don't know how to take care of the ground beneath their feet?" Ironically, as the author points out, much of the lack of attention to soil health has been driven by USDA's promotion of chemical farming and industrial scale agriculture that does not incorporate basic soil health practices, as described by Jeff Moyer, long time farm manager and executive director of the Rodale Institute –compost as top dressing, cover crops with atmospheric nitrogen grabbing legumes, and crop rotation, what he calls the three C's.

Here are some numbers conveyed by Ms. Ohlson: the soil may account for up to 95% of our planet's species diversity, and, as many as 75,000 species of bacteria (much of them beneficial) are in a teaspoon of healthy soil, 25,000 species of fungi, 1,000 species of protozoa, and, 200 species of nematodes. These organisms work together and are mutually beneficial as they cycle nutrients that contribute to plant growth, resulting in great environmental benefits. Fungi and bacteria secrete enzymes that liberate minerals from the clay, silt and sand. Microorganisms provide food, protection from predators, and control the underground flow of water, and gases by building soil structure called aggregates –and there are trillions of them. Minimal soil disturbance with no-till practices is beneficial. All of this serves to provide protection during droughts because the soil holds moisture and water and protection against floods because water can move through it instead of running off.

In addition to the fossil fuel intensive production process for chemical fertilizers, Ms. Ohlson writes that their use "interferes with one of nature's great partnerships. By the terms of the partnership, plants are supposed to distribute carbon sugars through their roots to the microorganisms in exchange for nutrients. Fertilizer disrupts this. . ." Quoting Rodale's soil microbiologist, Kristine Nichols, Ph.D. (formerly USDA), "When we add fertilizer, we're putting nutrients right next to the plant roots and the plant doesn't have to give up any carbon to get them. Therefore, the soil organisms can't get enough food."

As the author sums it up, farmers have shown that, "When you understand nature and work with her, farming becomes easier and cheaper, not harder and more costly." Ms. Ohlson, in Burleigh County, North Dakota, talked to farmers who no longer use chemical fertilizers or insecticides and generate 127 bushels of corn per acre (27 bushels more than the county average), spending $1.00 to $1.25 per bushel, compared with the county average of $3.00 to $3.50 a bushel.

The book addresses the value of animals moving through landscapes, quoting Alan Savory, originator of holistic management: "When you graze and then let the plants recover, they pulse carbon and moisture into the soil." Invasive weeds, according to Mr. Savory, are a symptom of the loss of biodiversity in the landscape.

The author notes that parks have successfully converted to organic soil management, from Battery Park in New York City, Harvard Yard, to the Luthy Botanical Garden in Peoria, IL. Finally, on carbon sequestration, the author concludes that, "No other natural process steadily removes such vast amounts of carbon from the atmosphere as photosynthesis." The book concludes with research data from the University of New Mexico's institute for Sustainable Agricultural Research, which finds that enough $CO_2$ (50 tons $CO_2$ per acre) can be captured and retained in healthy soil on less than 11% of the world's cropland to offset all anthropogenic $CO_2$ emission.