



Backgrounder
Glyphosate does not degrade to phosphorous acid
in the environment
July, 2005

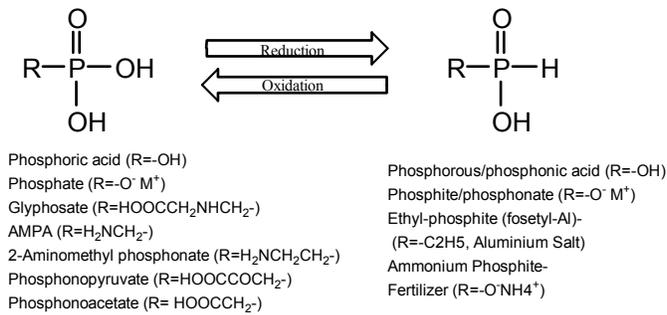
Glyphosate, the active ingredient in Roundup® agricultural herbicides¹, is degraded in the environment to inorganic phosphate/phosphoric acid, and not to phosphite/phosphorous acid as has been erroneously suggested by Whiley *et al.* (1995)².

In a study of the translocation of the systemic fungicide, potassium phosphite (potassium salt of phosphorous acid), in avocado, Whiley *et al.* made an unsubstantiated claim that the background level of phosphorous acid (H_3PO_3) measured in their avocado trees was likely due to glyphosate degradation in soil to produce phosphorous acid which was taken up by the tree (Whiley *et al.*, 1995). This unsupported claim later was misinterpreted into an alleged risk of phosphite contamination in wine when glyphosate-based herbicides are used for weed control in vineyards. The alleged production of phosphorous acid from glyphosate and its primary soil metabolite AMPA, which was apparently supported only by the similarity of their chemical names, can be ruled out based on the following published research.

- It is clear that the authors made an error in classifying glyphosate/AMPA in the same chemical family of phosphorous acid producing fungicides. The misidentification may have occurred because the terms “phosphonic acid” and “phosphonate” have been commonly used in fungicide literature to describe phosphorous acid and its alkali metal salts, respectively. However, “phosphonate” and “phosphonic acid” are also employed for the nomenclature of compounds containing a single carbon-to-phosphorus (C-P) bond such as glyphosate, N-(phosphonomethyl)-glycine and AMPA, aminomethylphosphonic acid, and other naturally occurring phosphonates including 2-aminomethylphosphonic acid, phosphonopyruvate, and phosphonoacetate (Plaxton 1999). As described below, the two families of compounds represent completely different chemistries with profoundly different biological activities.
- In glyphosate, AMPA, other naturally occurring phosphonates, and phosphoric acid/phosphate, the phosphorus atom (P) is at its highest oxidation state of +5. However, phosphorous acid or its salts (phosphite) are reduced phosphorus compounds in which the P atom is at an oxidation state of +3. As shown below, the chemical structure of phosphite differs from phosphate in that a hydroxyl moiety (OH) of phosphate is replaced by a hydrogen atom. This substitution results in different physiochemical behaviors of the two compounds in living organisms (McDonald *et al.*, 2001).

¹ “Roundup agricultural herbicides” refers to Monsanto’s Roundup-branded agricultural herbicides with glyphosate as the sole active ingredient.

² In this Backgrounder, the IUPAC naming system of “phosphite/phosphorous acid” is used, although the term “phosphonate/phosphonic acid” is often used in fungicide literature.



- Phosphate ion, with wholly symmetrical tetrahedron structure, is perfectly suited to interact with plant enzymes. It is transported into plant cells as a source of plant phosphorus nutrition and is an important structural component of macromolecules such as nucleic acids and phospholipids which is involved in virtually all major metabolic processes in plants, including photosynthesis and respiration. Phosphite, on the other hand, functions as an agricultural fungicide as an effective control agent for a number pathogenic fungi. Because of its asymmetric stereochemistry, phosphite does not bind to plant enzymes involved with phosphoryl transfer reactions in the same manner as phosphate. Thus, phosphite cannot be directly used by plants as a source of nutritional phosphorus (McDonald *et al.*, 2001).
- There are several published studies on glyphosate degradation in soil/water suspension (Forlani *et al.*, 1999) and in isolated soil cultures (Pipke and Amrhein 1988) that clearly show glyphosate and AMPA are degraded to phosphoric acid/phosphate and not to phosphorous acid/phosphite. Similarly, other naturally occurring phosphonates, which are in the same family of chemistry as glyphosate/AMPA, also have been reported to degrade by microorganisms to produce phosphate and not phosphite (Kononova and Nesmeyanova 2002).
- Glyphosate and AMPA must be reduced in order to degrade to phosphite which is highly unlikely in an oxidizing environment such as that found in an agricultural soil. To our knowledge there is no evidence published in peer-reviewed scientific journals which documents that glyphosate can be degraded to phosphite/phosphorous acid in the environment. Similarly, evidence that phosphates in the environment are reduced to phosphite is lacking. In fact, it is well documented that in agricultural soil, phosphites are readily oxidized to phosphates rather than the reverse transformation (Adams and Conrad 1953). For this reason, certain commercial fertilizers also contain phosphite for the purpose of possible suppression of plant pathogens as well as supplementing the regular phosphate fertilization program (Mitchell and Adams 2004).
- Glyphosate is initially degraded by microorganisms in soil to give AMPA as the major breakdown product. AMPA further degrades by microbial processes to carbon dioxide and inorganic phosphate, although at a slower rate. Even if glyphosate or AMPA were to degrade to phosphite in soil through some yet unknown reductive processes, the rate of phosphite formation is expected to be much slower than its oxidation to phosphate in soil. Thus, there is no chance of phosphite accumulation in the environment from glyphosate use.

In summary, Whiley *et al.* (1995) erred in classifying glyphosate as a phosphorous acid producing herbicide. There is overwhelming evidence that glyphosate and AMPA are ultimately degraded into naturally-occurring compounds including carbon dioxide and inorganic phosphate, a nutrient important for optimal plant growth and development.

References

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