Photo by Tony Downs.

Glyphosate: Not So Benign?

by Matt Hagny

SCIENCE

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Part I: The Science

For the past few decades, everyone *knew* that glyphosate was inert once it hit the soil, and that it had no residual activity. The science of that era taught us that glyphosate was so strongly bound to clay particles that none could be taken up by a newly planted crop, much less a crop planted a year later. However, some studies reported over the years, especially recently, do show that glyphosate applications can cause some serious problems for subsequent crops, whether or not they're glyphosate-resistant as Roundup Ready ('RR') (from the *Aroa* gene insertion event). But it's a hugely complicated issue, and not so easily studied as to what is occurring in the soil, and under which conditions. Let's explore:

First, we find that glyphosate does indeed persist in the soil *in available forms* for many weeks, months, or years, *and can be taken up by roots of newly planted crops*.[1] Much of this derives from the slow decomposition of mulch from plants which took up glyphosate while alive,[2] with glyphosate in plant material persisting 2 to 6 times longer than in bulk field soil.[3]

Photo by Volker Römheld.

Field trial at Hirrlingen, Germany, with winter wheat. All plots were sown on the same day, but glyphosate was applied at two different times ahead of sowing, and at two rates. 2 L/ha = 0.85 quarts/acre of 4-lb/gallon (ai) Roundup Ultra. (Source: Bott et al., 2009b.)

Glyphosate's damage to later vegetation may include poor uptake and impaired translocation of nutrients (especially iron, manganese, zinc, copper, nickel, magnesium, and calcium),[4] reduced drought tolerance, slowing

[1] S. Bott, T. Tesfamariam, A. Kania, B. Eman, N. Aslan, V. Römheld & G. Neumann, 2010a draft, Phytotoxicity of glyphosate soil residues re-mobilised by phosphate fertilisation, unpublished manuscript accepted by *Plant & Soil* in late 2010; S. Bott, B. Eman, N. Aslan, A. Kania, V. Römheld & G. Neumann, 2010b draft, Important factors for rhizosphere transfer of glyphosate: (I.) Role of weed density and soil type for phytotoxic effects in crop plants, unpublished manuscript submitted to *J. Agric. Food Chem*. in late 2010; A. Piccolo, G. Celano, M. Arienzo & A. Mirabella, 1994, Adsorption and desorption of glyphosate in some European soils, *J. Environ. Sci. Health* B29(6): 1105-1115; C.A. Lévesque & J.E. Rahe, 1992a, Review: Herbicide interactions with fungal root pathogens, with special reference to glyphosate, *Annual Rev. Phytopath*. 30: 579-602; M.M. de Andréa, T.B. Peres, L.C. Luchini, S. Bazarin, S. Papini, M.B. Matallo & V.L.T. Savoy, 2003, Influence of repeated applications of glyphosate on its persistence and soil bioactivity, *Pesq. agropec. bras. Brasilia* 38: 1329-1335; S.M. Carlisle & J.T. Trevors, 1988, Review: Glyphosate in the Environment, *Water, Air, Soil Pollution* 39: 409-420 (half-life from a few days to *years*); T. Tesfamariam, S. Bott, I. Cakmak, V. Römheld & G. Neumann, 2009a, Glyphosate in the rhizosphere—Role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants, *Europ. J. Agron*. 31: 126-132; T. Tesfamariam, 2009b, Glyphosate Use in Agro-ecosystems: Identification of key factors for a better risk assessment, Ph.D dissertation (presented 2 Sept. 2009 at Univ. Hohenheim, Germany); O.K. Borggaard & A.L. Gimsing, 2008, Review: Fate of glyphosate in soil and the possibility of leaching to ground and surface waters, *Pest Mgmt. Sci.* 64: 441-456 (glyphosate half-life from 100 to 1,000 days depending on soil type; other studies have found half-life times ranging from a few days to 8 months).

[2] Tesfamariam et al., 2009a; P. Laitinen, S. Rämö & K. Siimes, 2007, Glyphosate translocation from plants to soil—does this constitute a significant proportion of residues in soil?, *Plant & Soil* 300: 51-60.

[3] J. Doublet, L. Mamy & E. Barriuso, 2009, Delayed degradation in soil of foliar herbicides glyphosate and sulcotrione previously absorbed by plants: Consequences on herbicide fate and risk assessment, *Chemosphere* 77: 582-589, and references therein.

[4] Tesfamariam et al., 2009a; Bott et al., 2010a draft (on different soils, different nutrients were affected by soil-applied glyphosate, some of them dramatically reduced and well into deficiency ranges); G. Neumann, S. Kohls, E. Landsberg, K. Stock-Oliveira Souza, T. Yamada, V. Römheld, 2006, Relevance of glyphosate transfer to non-target plants via the rhizosphere, *J. Plant Diseases & Protection* 963-969; S.O. Duke, K.C. Vaughn & R.D. Wauchope, 1985, Effects of glyphosate on uptake, translocation, and intracellular localization of metal cations in soybean (*Glycine max*) seedlings, *Pest. Biochem. Physiol.* 24: 384-394. Glyphosate-induced manganese (Mn) deficiency is often attributed to: the chelating properties of glyphosate itself in either the soil solution, or inside the plant; reduced root growth or other toxic effects of glyphosate & AMPA at the cellular level; and/or the competitive interaction between glyphosate and certain cationic nutrients near or on the root surface. (Tesfamariam et al., 2009a; Bott et al., 2010a & 2010b drafts.) No evidence of immobilization of nutrients within *leaves* has been found for foliar application of glyphosate on RR soybean. (S. Bott, T. Tesfamariam, H. Candan, I. Cakmak, V. Römheld & G. Neumann, 2008, Glyphosate-induced impairment of plant growth and micronutrient status in glyphosate-resistant soybean [*Glycine max* L.], *Plant & Soil* 312: 185-194.) However, research has shown that a complexing of micronutrients within *roots* may explain the depression of root-to-shoot transfer of essential micronutrients. (S. Eker, L. Ozturk, A. Yazici, B. Erenoglu, V. Römheld & I. Cakmak, 2006, Foliar-Applied Glyphosate Substantially Reduced Uptake and Transport of Iron and Manganese in Sunflower [*Helianthus annuus* L.] Plants, *J. Agric. Food Chem.* 54: 10019-10025, and references therein.) Some re-