The Science of Roundup Ready® Technology, Glyphosate, and Micronutrients

Part II - The Fate of Glyphosate: Translocation and Exudation in the Soil

A limited number of research studies have suggested that glyphosate may be transferred from treated plants to non-target living plants via root release in concentrations high enough to cause injury. The behavior and fate of glyphosate in plants and soil have been extensively investigated. The facts about glyphosate adsorption to soil, lack of uptake from soil, translocation through a plant and exudation from roots and will be discussed here, in Part II of the series "The Science of Roundup Ready® Technology, Glyphosate, and Micronutrients."

The behavior of glyphosate in plants and soil defines the ways in which it can be used as an herbicide. In the years following the introduction of Roundup® herbicide, the properties of glyphosate were studied and different uses introduced, as described in several review articles[1,2]. Glyphosate is a systemic herbicide that is absorbed through foliage and is translocated throughout the plant. It does not have activity when applied to the soil.

Glyphosate Adsorption to Soil and Lack of Uptake from Soil into Plants

Glyphosate adsorbs rapidly and binds tightly to most soils[3,4,5,6]. A number of factors affect the adsorption. High clay and mineral content increases adsorption, and pH and phosphate content affect binding. Glyphosate adsorption is reduced in highly sandy soils. After glyphosate is tightly adsorbed to soil, very little can be desorbed into water that is in contact with the soil. Indeed, water is very poor at removing glyphosate from soil, and laboratory extraction methods require harsh conditions (such as extraction with a strong base) in order to release the glyphosate residues that are tightly bound to soil[7]. Because of this tight adsorption and low level of mobility into water, glyphosate is not available for uptake by roots from soil. This is why glyphosate is applied to plants as a foliar spray and is not useful (has no activity) as a soil-applied herbicide.

The lack of uptake of glyphosate into plants due to its strong binding to most soils is clearly demonstrated by its approved and established use patterns. Conventional (non-glyphosate tolerant) crops may be safely planted directly into fields recently treated with a glyphosate herbicide, and glyphosate can be sprayed on weeds adjacent to trees, vines, and other crops. Laboratory studies on the uptake of glyphosate into plants grown both in soil and in hydroponic solution illustrate the effect of soil adsorption on uptake. Corn and soybeans were not affected after being planted in clay loam and muck soil after application of a very high rate of glyphosate (56 kg/ha), although wheat (a sensitive bioassay plant) was affected when grown in quartz sand treated at a standard rate (0.56 kg/ha)[8]. Corn seedlings grown in a hydroponic solution containing glyphosate did take up glyphosate through the roots[9], demonstrating it is the lack of availability of glyphosate in soil rather than the inability of roots to absorb glyphosate that limits its uptake from soil. Under selected circumstances, effects of glyphosate in soil have been seen; tomato seedlings were affected when transplanted into sandy soils shortly after glyphosate application[10]. However, in most agricultural soils, adsorption effectively limits the uptake of glyphosate from soil, allowing crops to be planted in treated soil and applications made adjacent to crops.

Movement of Glyphosate within Plants and Exudation from Roots

In the plant, glyphosate is translocated via the phloem following absorption through the leaf tissues, and moves to actively growing parts of the plant such as meristems and roots[11,12]. Early work with glyphosate provides evidence that minimal amounts of glyphosate in the plant can be exuded from the roots. In an experiment in which couch grass (*Agropyrens repens)* was grown in a hydroponic solution and treated foliarly with ^{14}C-labelled glyphosate, a total of 3.1% of applied ^{14}C was recovered in the hydroponic solution after 8 days[13]. In experiments conducted in soil in test tubes, trace levels of ^{14}C were detected in corn seedlings that were interplanted with glyphosate-treated wheat, and growth effects could be seen in soybean and corn interplanted in soil-containing pots with treated wheat plants, when either high glyphosate rates (6.7 kg/ha) or high wheat densities were used[14].

Recently, additional laboratory studies have been done on glyphosate exudation. Despite having been studied in highly artificial circumstances, these results have been extrapolated to raise concerns regarding use of glyphosate and effects on the rhizosphere. Kremer et al. examined root exudation of

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glyphosate in glyphosate-tolerant soybeans under hydroponic conditions and reported low levels of exudation (200 and 1500 nanograms/plant after 2 days and 16 days, respectively, or an estimated <0.1 and 0.5% of foliar applied glyphosate)[15]. As in earlier work, this represents a minimal level of exudation. In additional experiments conducted in soil in confined spaces (small pots or rhizoboxes, where direct root -contact occurs) and in hydroponic solutions, untreated plants growing intermingled with treated plants showed glyphosate effects[16]. These findings should not be extrapolated to field-use conditions. Under field conditions root-to-root contact is minimal, and the tight binding of glyphosate to agricultural soils effectively prevents significant root uptake by nearby plants.

Extensive and safe use of glyphosate in fields, vineyards, and orchards over the last 30 years, as well as detailed laboratory studies characterizing the behavior of glyphosate in soils and plants, have demonstrated that glyphosate can be used in these various applications without damage to desired vegetation.

In Summary

Collectively, numerous soil and plant studies, extensive and safe use of glyphosate in agricultural applications from preemergence field applications to directed spray orchard applications, and extensive knowledge of the physical and chemical properties of glyphosate all support the conclusion that it is unlikely that significant levels of glyphosate will reach the rhizosphere and be available for uptake. Under actual field conditions, glyphosate application in accordance with labeled uses poses negligible risk to non-target plants.

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