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

Part III - Glyphosate and Soil Microbes

A number of research studies have investigated whether soil microorganisms are affected by glyphosate. The importance of soil microbes and the effects of Roundup® brand agricultural herbicides on soil microbes and nitrogen fixation will be discussed here in Part III of the series "The Science of Roundup Ready® Technology, Glyphosate, and Micronutrients."

Microbial Processes and Agricultural Practices

Soil microbes and their associated biochemical processes are critical to maintaining soil health and quality. Soil microbial communities are highly complex and are often characterized by high microbial diversity[1]. The occurrence and abundance of soil microorganisms are affected by: 1) soil characteristics like tilth, organic matter, nutrient content, and moisture capacity, 2) typical physico-chemical factors such as temperature and pH, and 3) soil management practices. Agricultural practices such as fertilization and cultivation may also have major effects on soil microbial populations, species present, species establishment, and associated biochemical processes[2,3]. As a result, significant variability in microbial populations is expected in agricultural fields. Minor changes in a single microbial species or group are difficult to measure in such an ever-changing system. In fact, the effects of such a change may be better assessed by measuring changes in soil fertility and other soil processes such as nitrogen metabolism. Research on the effects of agricultural practices on soil microbial communities should consider the complex interactions of all soil life and soil characteristics to aid in proper interpretation of study results.

Effects of Roundup Agricultural Herbicides on Soil Microbes

The effects of glyphosate and glyphosate-based products on soil microorganisms have been extensively investigated[4,5]. Results of formal glyphosate testing performed for submission to regulatory agencies indicate no long-term effects on microorganisms in soil even at rates up to five times maximum use (label) rates. In addition, independent researchers have reviewed numerous laboratory and field studies, investigating the effects of glyphosate on soil bacteria and fungi and concluded that there was minimal risk to these organisms[6,7]. For example, in a recent greenhouse investigation, the effects of multiple glyphosate applications on the root-zone (rhizosphere) bacterial community associated with glyphosate-tolerant soybean were evaluated[8]. While slight, short-lived shifts in community structure were noted after glyphosate applications, an ability to recover and no reduction in bacterial diversity were observed for the bacterial community associated with roots of glyphosate-treated versus unsprayed glyphosate-tolerant soybean.

The exact design of studies looking for glyphosate effects on microbial communities is very important. Although some laboratory tests have shown effects on nitrogen-fixing bacteria (see next section)[9,10] and soil fungi[11,12], effects are typically observed only under artificial laboratory conditions and at glyphosate concentrations well above normal field application rates. This has caused several researchers to conclude that it is difficult to extrapolate results from the laboratory to the natural soil environment[11,13,12].

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Many investigations of the effects of glyphosate or glyphosate-based products have been performed in the field or with soil collected from the field to better reflect conditions in the soil environment. Investigations of glyphosate applications over glyphosate-tolerant crops indicate that glyphosate is degraded over time by soil microbes, even at high application rates, without adversely impacting the soil microbial community[14,15]. In addition, field studies evaluating the fungal component of the soil microbial community indicate that glyphosate treatment has no harmful effects on beneficial soil fungi[16,17,12,18,19]. In a 4-year field study, researchers assessed effects of glyphosate applications on soil microorganism interactions and crop debris decomposition in a glyphosate-tolerant soybean and corn rotation[20]. They concluded that: "Permanent responses in soil [organisms] were not observed, suggesting a high level of resilience in soil [organisms] and a lack of a persistent effect resulting from the genetically modified (GM) cropping system." Further, soil microbial and nematode communities were similar when glyphosate or conventional herbicides (soy- chloransulam/metolachlor, corn-acetochlor/atrazine) were applied to crop rotations of glyphosate-tolerant soybean and corn cultivars[21]. Moreover, the history of safe use and yield data obtained from nearly 15 years of glyphosate-tolerant crop production reinforce the findings that soil microbes and microbially influenced processes are not adversely impacted by field-rate applications of glyphosate.

Glyphosate-based Herbicides and Nitrogen Fixation in Roundup Ready® Soybeans

Nitrogen fixation is the process by which atmospheric nitrogen is "fixed" or converted into organic nitrogen (ammonia) necessary for plant growth

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by members of the bacterial families *Rhizobiaceae* and *Bradyrhizobiaceae*. The *Rhizobium*-legume relationship results in the formation of root nodules, which are an integral part of the soybean root system. The process of nitrogen fixation is subject to subtle variations depending on soil type and environmental conditions. While some laboratory investigations have indicated that glyphosate may inhibit pure cultures of nitrogen fixing bacteria[9,10], effects were only observed at glyphosate concentrations well above normal field application rates. The laboratory studies also utilized nutrient-rich growth media and bacterial cultures acclimated to artificial laboratory conditions; leading several researchers to conclude that it is difficult to extrapolate these results to the natural soil environment[11,13].

Several field studies have assessed potential effects of glyphosate-based herbicides on symbiotic nitrogen fixation in glyphosate-tolerant soybeans. One study reported that application of Roundup Ultra® herbicide delayed nitrogen fixation and decreased nitrogen accumulation in some glyphosate-tolerant soybean cultivars[22]. However, effects were only observed under drought conditions and at application rates of glyphosate above the recommended label rates. The soybean yield was not affected. Researchers have also reported some reduction in nodulation in Roundup Ready® soybeans, but noted that effects were of minimal consequence due to the soybean's ability to compensate[23]. In a study that included four soybean varieties and four field sites, there was no indication Roundup Ultra herbicide inhibited nitrogen fixation apart from a small reduction in ureide (a nitrogen-rich compound) content in one soybean variety at one site[24]. It was also recently found that under field conditions, nitrogen fixation was only slightly affected at the labeled use rate for glyphosate, and the label use rate did not affect yield[25]. Finally, it has been observed that glyphosate applied at recommended field rates has no effect on *Bradyrhizobium japonicum* colonization of roots of glyphosate-tolerant soybean[26].

For purposes of regulatory approval, numerous tests were conducted on the composition and yield of Roundup Ready soybeans compared to conventional soybean varieties. Results have confirmed that the yield of Roundup Ready soybeans is equal to or greater than that of conventional soybean varieties. Moreover, nitrogen levels in seeds and plant material were not significantly different between Roundup Ready soybeans and conventional varieties, indicating no major changes in nitrogen uptake or metabolism. At recommended use rates of Roundup® brand agricultural herbicides, the Roundup Ready soybean production system is not expected to negatively affect soil fertility, nodulation, or nitrogen fixation.

Glyphosate applied at recommended field rates has no effect on nitrogen-fixing bacteria colonization of roots of glyphosate-tolerant soybean[26].

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