Research

Title: GLYPHOSATE AFFECTS SOYBEAN ROOT EXUDATION AND RHIZOSPHERE MICROORGANISMS

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Interpretive Summary: Soybeans genetically modified (GM) for resistance to the herbicide glyphosate (Roundup®) are planted on more than 85% of the soybean production area in the United States. Although GM soybeans and glyphosate pose little or no human health concerns, their impacts on soil biology and productivity and on the growth and health of the soybean plant itself have received little attention. The important biological processes in the root zone (rhizosphere), including the characteristics of substances released through the soybean root and their subsequent effects on adjacent soil microorganisms, have been largely neglected in environmental assessments of GM soybeans. Our objectives were to determine the amounts and types of substances released by roots of GM soybean after glyphosate treatment and the impact of these root exudates on microorganisms that typically reside in the soybean rhizosphere. We found that some of the glyphosate applied to GM soybean was released through the roots during a 16-day period after glyphosate was applied to the plants. This was similar to the expected leakage of glyphosate from a susceptible, non-GM soybean, which was dead within 14 days after application. Other substances including carbohydrates (i.e., sugars) and amino acids (subunits of proteins) were released in higher quantities compared to plants not treated with glyphosate. Interestingly, the GM soybean released high amounts of carbohydrates and amino acids even when glyphosate was not applied compared to the non-GM soybean, which suggested an inadvertent change in the plant physiology may have occurred during genetic modification of the soybean for herbicide resistance. Bioassays

showed that the combination of glyphosate and elevated amounts of carbohydrates and amino acids in the root exudates of glyphosate-resistant (GR) soybean stimulated growth and development of certain fungi. Fungal growth in root exudates of non-GR soybean was not as extensive as that noted for GR soybean. These results help explain observations in previous studies showing that GR soybean roots were often colonized more heavily by fungi than soybean not treated with glyphosate. The overall results indicate that the glyphosate plus GR soybean production system may alter the microbial composition in the soybean rhizosphere based on changes in substances released from the soybean roots. Follow-up research will be required to assess whether the altered microbial composition is detrimental to growth of the soybean and to subsequent crops grown in the same field. This information has important implications for scientists, extension personnel, and producers because it will be useful in explaining production problems often observed with GR soybeans and in developing improved crop management systems for avoiding potential crop growth reductions that may be related to changes in soil microbial populations resulting from continued use of GR crops.

Technical Abstract: Glyphosate is a nonselective, broad-spectrum herbicide that kills plants by inhibiting the enzyme 5-enolpyruvylshikimic acid-3-phosphate synthase (EPSPS), which is necessary for synthesis of aromatic amino acids. A secondary mode of action involves infection of roots by soilborne microorganisms due to decreased production of plant protection compounds known as phytoalexins. Varieties of several crops, including glyphosate-resistant (GR) or Roundup Ready soybean, are genetically modified to resist the herbicidal effects of glyphosate and provide farmers with an effective weed management tool. After glyphosate is applied to GR soybean, glyphosate that is not bound to glyphosate-resistant EPSPS is translocated throughout the plant and accumulates primarily in meristematic tissues. We previously reported that fungal colonization of GR soybean roots increased significantly after application of glyphosate but not after conventional postemergence herbicides. Because glyphosate may be released into soil from GR roots, we characterized the response of rhizosphere fungi and bacteria to root exudates from GR and non-GR cultivars treated with and without glyphosate at field application rates. Using an immunoassay technique, the flux of glyphosate detected in exudates of hydroponically grown GR soybean was > 1000 ng plant**-1 over the 16-d post-glyphosate application period. Glyphosate also increased carbohydrate and amino acid contents in root exudates in both soybean cultivars. However, GR soybean released higher carbohydrate and amino acid contents in root exudates than W82 soybean without glyphosate treatment. In vitro bioassays showed that glyphosate in the exudates stimulated growth of selected rhizosphere fungi, possibly by providing a selective C and N source combined with the high levels of soluble carbohydrates and amino acids associated with glyphosate treatment of the soybean plants. Increased fungal populations that develop under glyphosate treatment of GR soybean may adversely affect plant growth and biological processes in the soil and rhizosphere.

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