GLYPHOSATE-MANGANESE INTERACTIONS IN ROUNDUP READY SOYBEAN

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Shortly after the introduction of Roundup Ready (RR) soybean questions arose whether these varieties and/or glyphosate applications to them alter manganese (Mn) relations compared to conventional soybean varieties. It is well documented that certain cations, including Mn, can reduce the performance of glyphosate when the cations are present in water used as a carrier. The complexes formed between glyphosate and metal cations are not absorbed as efficiently as free glyphosate alone, resulting in reduced weed control. The primary role of AMS used with glyphosate applications is to minimize formation of the cation-glyphosate complexes. This article will review research that has investigated the interactions between RR soybean and Mn relations, rather than what happens in the spray tank. Although the focus of this article is Mn, glyphosate would interact similarly with other cations (e.g. calcium, iron, magnesium).

Mn efficiency of soybeans with Roundup Ready trait

Some of the first reports of Mn-related problems with RR soybean were reported by researchers at Purdue University in 2001 (Dodds et al. 2001). They found that growth of a RR variety grown on a Mn-limiting soil was inhibited more severely by Mn deficiency than a conventional variety. On a non-limiting soil there was little difference in growth of the two varieties. The research was repeated in 2002 using additional varieties, and some, but not all, RR varieties were found to be more sensitive to Mn-deficieny than conventional varieties (Dodds et al. 2002). Gordon (2007), at Kansas State University, reported that under a high-yield environment a RR variety was responsive to Mn fertilization whereas a conventional variety was not.

Based on this research, it could be concluded that RR varieties are less efficient at Mn absorption/utilization than conventional varieties. However, due to the limited varieties evaluated in the studies, it is just as likely that the difference in response to Mn between the RR and conventional varieties was due to some other difference among the varieties rather than the RR trait. The 2002 Purdue study included several RR varieties and found that not all RR varieties were responsive to Mn, suggesting that the Mn response is not directly linked to the RR trait. Research in California found no evidence that the RR trait affected Mn relations (Rosolem et al. 2009). Research in Brazil found 1 out of 3 RR varieties had lower Mn concentrations in new leaves than the non-RR parental line, but the other two varieties were not affected (Zobiole et al. 2010).

Interactions of glyphosate and Mn within soybean

A second issue with glyphosate and Mn is related to interactions between the two molecules in the plant, rather than the characteristics of RR varieties. An injury response often seen following glyphosate application to RR soybean is chlorosis in newly emerged leaves. The symptoms are similar to those attributable to Mn deficiency, so it has been implied that glyphosate may interfere with Mn relations within the plant. Glyphosate is poorly metabolized by plants and

accumulates in growing points, and can accumulate at concentrations capable of forming complexes with Mn or other metal cations.

Zobiole et al. (2010) reported that glyphosate applications decreased Mn and other nutrient concentrations in RR varieties. They also reported significant reductions in shoot and root biomass due to the glyphosate applications, something that is normally not observed. However, the majority of research has not identified differences in Mn absorption, accumulation and availability between glyphosate-treated and non-treated RR soybean (Bott et al. 2008; Rosolem et al. 2009; Nelson 2009). Rosolem et al. (2009) stated that glyphosate injury symptoms in RR soybean have been misinterpreted as Mn deficiency. Ebelhar and Hart (2006) in Illinois were unable to prevent chlorosis associated with glyphosate by supplementing soybean with additional Mn, nor prevent yield loss associated with high glyphosate rates (2X-4X) with supplemental Mn. While the chlorosis that appears following glyphosate application mimics Mn deficiency, the symptom has been attributed to accumulation of AMPA in new leaves (Reddy et al. 2004). AMPA is a degradation product of glyphosate.

Interactions of glyphosate with Mn in the soil

It has been speculated that glyphosate may interact with Mn relations by reducing availability of Mn in the soil via chelation. It has also been suggested that glyphosate could reduce the availability of soluble Mn by affecting the activity of microorganisms that control the oxidation-reduction status of soil. Glyphosate may enter the soil profile either by direct contact during spraying or through exudation from roots of treated plants. Glyphosate released into the soil has been shown to affect growth of microorganisms in the vicinity of the roots and in the zone of application (Kremer et al. 2005), but there are no published data documenting reduced soil availability of Mn or other nutrients. While it is possible that glyphosate could temporarily tie up essential elements, it would not specifically target Mn, or any other micronutrient, but rather would interact with the most prevalent cations in the vicinity of the roots. In Iowa soils, the majority of glyphosate would likely interact with the highly abundant Ca and Mg rather than Mn, and also organic matter. Furthermore, levels of Mn in Iowa soils probably are sufficient because there have been no reports of Mn crop deficiency symptoms in Iowa. Crop Mn deficiency symptoms occur in some regions, and this is where interactions between glyphosate and Mn nutrition have been reported.

Summary

So the question is whether RR soybean varieties require different Mn management practices than conventional varieties and if this is really a problem under Iowa conditions. Glyphosate is known to form complexes with Mn and other metal cations that may reduce both the availability of the cation and glyphosate activity. However, most interactions

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