INDUCED MANGANESE DEFICIENCY IN GM SOYBEANS

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Abstract

Glyphosate resistance in soybean and corn reduced manganese uptake and physiological efficiency. Application of glyphosate immobilized manganese applied before, concurrent with, or within 6-8 days after the glyphosate event. Inorganic sources of manganese (Cl, CO_3, SO_4) tank-mixed with glyphosate were antagonistic and reduced herbicidal efficacy; however, antagonism was significantly influenced by glyphosate formulation. Glyphosate root exudates and plant decomposition products can alter the rhizosphere microflora and predispose to soilborne disease. Some of these effects could be compensated for by manganese amendment. The effectiveness of manganese amendment to ameliorate manganese deficiency depended on the cultivar, manganese source, time applied, and glyphosate formulation.

Introduction

Glyphosate weed management programs in field crops have provided highly effective weed control, reduced concern for residual chemicals in the environment, simplified management decisions, and provided cleaner harvested products. This system could also provide a more efficient means of meeting other crop needs such as micronutrients or plant growth promoters by piggy-backing with the herbicide to eliminate a separate trip across the field. About 4.5 million acres of glyphosate-resistant soybeans are planted in Indiana, and eleven Indiana counties have recognized manganese deficiency concerns for soybeans. Since the introduction of glyphosate-resistant soybeans, reports of manganese deficiency have been more common and more wide spread than previously observed. This could result from producers being physically present in fields while spraying when manganese deficiency symptoms occur or the result of induced deficiency from the glyphosate program.

Frequently observed transient foliar chlorosis and reduced response to applied manganese after glyphosate application are consistent with possible effects of glyphosate chelation of micronutrient elements. The essential micronutrient manganese is of especial interest because of its role in photosynthesis, carbon and nitrogen metabolism, and disease resistance. Other researchers have reported reduced nodule efficiency and nitrogen fixation, increased drought stress, earlier maturity, predisposition to disease, and altered rhizosphere microflora with glyphosate weed management programs. Some of these effects are reported to be reduced with supplemental manganese. This research was initiated to evaluate the effect of glyphosate-resistant technology on manganese compatibility and availability as an essential plant nutrient.

Methods and Materials

Randomly replicated field plots (7.5 x 60 ft) were established in a complete block or factorial design on silt loam, sandy loam, and muck soils known to be either low or fully sufficient for manganese availability. Various sources of manganese (inorganic, chelated, complex), methods of application (soil, seed treatment, foliar), times of application relative to glyphosate (prior to, at the same time, or after), glyphosate formulations (UltraMax®, WeatherMax®), and genotypes (conventional, Roundup Ready®, corn, soybeans) were evaluated over the last five years.

Leaf tissue samples (youngest fully expanded leaf) were collected 28 days after treatment, dried, ground, and analyzed by ICP-AA for mineral composition (Midwest Laboratories, Omaha, NE). Growth, color, and manganese deficiency symptom expression were recorded throughout the growing season. Yields were obtained by combine harvesting 50 ft of each plot (37 ft for corn) after end-trimming and adjusting for moisture. Data were analyzed by ANOVA (SuperANOVA®).

Results

There were no differences in growth, color, or yield observed with any of the glyphosate-resistant compared with non-resistant genotypes on the fully manganese sufficient soils even though a 5-12 day transient foliar chlorosis was sometimes observed after glyphosate application to the glyphosate-resistant genotype. This was in sharp contrast to the low manganese soils where manganese inefficient genotypes were shorter, showed more severe manganese deficiency symptoms and had lower yields than more manganese efficient genotypes. Glyphosate-resistant genotypes were less efficient in manganese uptake and had lower manganese tissue content than conventional genotypes. The 4-5 day earlier maturity following application of glyphosate to glyphosate-resistant genotypes was reversed when a foliar application of manganese was applied either 10 or 20 days after the glyphosate.

Application of inorganic manganese salts prior to, at the same time (concurrent or tank-mix), or 4-6 days after the glyphosate event were not translocated to new tissue and were herbicidally antagonistic in combination with glyphosate on soybeans grown on all soils. Normal uptake and translocation was observed with all sources of manganese applied eight days or longer after the glyphosate. Antagonism of manganese with the UltraMax® formulation of glyphosate reduced weed control 50% compared with glyphosate alone (75-90% reduction with Cu, Fe, Mg, or Zn), but only 10% with the WeatherMax® formulation. Manganese complexes had little effect on herbicidal efficacy of either glyphosate formulation even when tank-mixed, but provided less than fully sufficient levels of manganese unless higher than recommended rates were used. Manganese sources were more compatible with the WeatherMax® formulation of glyphosate (Tables 1-4). Yield differences between the various sources of Mn (inorganic, chelate, complex) reflected differences in available Mn and/or immobilization with the glyphosate.

Late application of glyphosate generally resulted in lower yields because of increased weed competition and changes in rhizosphere microflora predisposing to increased root rot (Tables 3-4).

Summary

There is a wide range of differences in manganese efficiency in soybean and corn cultivars. Glyphosate-resistant genotypes tested were less manganese efficient than normal genotypes, and the more manganese efficient glyphosate-resistant cultivars should be selected for low manganese soils or environmental conditions where manganese may be less readily available. Glyphosate-resistant cultivars were less efficient in manganese uptake and the application of glyphosate immobilized manganese in tissues. There was selective immobilization for manganese by glyphosate. Manganese sources were more compatible with the WeatherMax[R] formulation of glyphosate than the UltraMax[R] formulation. Compatibility of manganese with glyphosate depended on the manganese source and glyphosate formulation. Any of the common manganese sources were taken up without antagonism if applied 8 days or longer after the glyphosate. Genetics, micronutrient and method of application produced significant differences in micronutrient concentration in tissues. Like most changes in agricultural practices, implementation of glyphosate-resistant technology changes several non-target factors because of interrelationships in the system. This technology may provide a means of correcting several micronutrient needs if antagonism can be avoided; with the micronutrient(s) off-setting some of the non-target effects of glyphosate.

Table 1. Yield of Soybeans with Mn-complex, Silt Loam Soil, Rainfed, PPAC, 2004.

Treatment[a]			Time foliar Mn applied					
Seed	Foliar	Rate	None	TkMx	Same	+10 day	+20 day	+30 day
None	Yes	1 l/ha	51 a	54.7 abc	55.4 bc	57.6 cde	59.4 de	59.5 de
None	Yes	3 l/ha	-----	56.0 bcd	54.7 abc	57.7 cde	60.8 e	59.5 de
Yes	Yes	1 l/ha	53.0 ab	54.6 abc	-----	55.7 bcd	-----	-----
Yes	Yes	3 l/ha	-----	54.8 abc	-----	57.1 cde	56.9 bcde	-----

[a]150 g Mn/l, 6 l/ton as $MnSO_4$ (20g Mn^{2+}/a as seed treatment);150 g Mn complex/l (23g or 69g Mn^{2+}/a foliar).

Table 2. Yield of Soybeans with Mn sources, Silt Loam Soil, Rainfed, PPAC, 2003.

Treatment[a]			Time foliar Mn applied					
Foliar	Rate	None	-4days	TkMx	Same	+4 day	+13 day	Average
$MnCO_3$	1 l/ha	36 ab	36 ab	34 a	45 c	42 bc	46 c	41
$MnSO_4$	3 l/ha		36 ab	36 ab	45 c	39 bc	44 c	40
Mn cmplx	1 l/ha		36 ab	43 c	43 c	44 c	44 c	42

$MnCO_3$ and $MnSO_4$ had some antagonism with glyphosate and less weed control when tank-mixed.

Table 3. Yield of Soybeans with Mn-complex, Sandy Loam Soil, Irrigated, PPAC, 2004.

Treatment[a]			Time foliar Mn applied					
Seed	Foliar	Rate	None	TkMx	Same	+10 day	+20 day	+30 day
None	Yes	1 l/ha	59.9 abc	58.5 a	60.2 abc	59.9 ab	59.4 ab	57.7 a
None	Yes	3 l/ha	-----	59.4 ab	61.1 abc	58.1 a	59.2 ab	62.4 bc
Yes	Yes	1 l/ha	63.6 c	59.5 ab	-----	59.0 ab	-----	-----
Yes	Yes	3 l/ha	-----	61.3 abc	-----	59.7 ab	61.3 abc	-----

[a]150 g Mn/ha as $MnSO_4$ (seed treatment) or Mn complex (foliar).

Table 4. Yield of Soybeans with Micronutrients Applied 10 Days after Glyphosate, Rainfed, Muck Soil (following soybeans), PPAC, 2004.

Treatment[a]		Source/combination of micronutrient					
Rate	None	Mn Complex	Mn Chelate	Cu(1l/ha)	Cu+Mn	Zn	Cu+Mn+Zn
Early glyphosate:							
3 l/ha	44.6 bcd	50.2 def	59.4 gh	59.9 gh	62.1 h	53.6 efg	58.1 fgh
6 l/ha		56.8 fgh					
Late glyphosate (2-3 ft weeds):							
3 l/ha	38.9 ab	39.1 ab	-----	33.1 a	47.7 cde	38.0 ab	45.0 bcd
6 l/ha		40.8 abc					

Table 5. Yield of Soybeans with Micronutrients Applied 10 days after Glyphosate, Rainfed, Muck Soil (following corn), PPAC, 2004.

Treatment[a]		Source/combination of micronutrient					
Rate	None	Mn Complex	Mn Chelate	Cu(1l/ha)	Cu+Mn	Zn	Cu+Mn+Zn
Early glyphosate:							
3 l/ha	54.9cdef	59.1 f	57.4 ef	50.9 bc	-----	52.1 b-e	57.5 ef
Late glyphosate (2-3 ft weeds):							
3 l/ha	43.0 a	55.8 cdef	51.8 bcde	48.3 ab	52.7 bcde	51.8 bcd	52.8 bcde
6 l/ha		57.3 def	53.3 b-e				

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