NUTRIENT UPTAKE AND MANGANESE RESPONSE IN CONVENTIONAL AND GLYPHOSATE-RESISTANT SOYBEAN

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ABSTRACT

Glyphosate-resistant (GR) soybean cultivars are widely accepted in the United States. Glyphosate-resistant technology provides many benefits to production agriculture, yet GR soybeans may require some additional management factors in order to obtain maximum yields. The objectives of this research are to determine (i) nutrient uptake in GR and conventional (CV) soybean isogenetic lines and (ii) response of GR and CV soybean to manganese fertilization. A field study was conducted at 5 locations in Kansas from 2005 to 2007. Manganese soil test levels ranged from 4 to 52 ppm and pH ranged from 5.9 to 8.3. Soybean isolines were planted at each location in a split-block design with 4 replications. Manganese treatments consisted of soil-applied $MnSO_4$ at 0, 2.8, 5.6, and 8.4 kg Mn/ha and foliar applied Mn at 0.22 and 0.45 kg Mn/ha. Leaf tissue and whole plant samples were taken at approximately R1, R3, and R6 growth stages and analyzed for various nutrients such as Mn, N, P, K, Cu, Zn, and Fe. Whole plant samples were separated by leaves, stems, and pods and analyzed. There were no significant differences between varieties for total uptake of any of nutrient. There were no yield differences between GR and CV isogenic lines at low yielding locations (< 3.3 Mg/ha). At high yielding environments, CV soybean yield was greater than GR soybean yield for the 0 kg Mn/ha rate. However, Mn additions increased yield of GR soybean but did not affect CV soybean yield. Our results indicate no response to Mn treatments in CV or GR soybean at low yielding environments and in high yielding environments GR soybean respond positively to Mn treatments and CV soybean yields are not affected.

INTRODUCTION

Soybean (*Glycine max L.*) is an important legume crop throughout the world, occupying over 93 million ha in 2005 and generating over $45 billion in cash receipts (FAO, 2007). Soybean success as a major grain crop is due to the combination of agronomic benefits of soybean production and a diverse market for soybeans. Agronomic benefits of soybean production include greater drought tolerance in comparison to corn, additional weed control options, and N fixation from rhizobium symbiosis. These benefits have prompted significant research in developing new soybean cultivars with improved genetics including soybean with specific tolerance to herbicide or higher genetic yield potentials (Gianessi, 2000).

One of the more notable advances in soybean genetics was the development of glyphosate-resistance. In the United States 91% of soybean ha are estimated to be a glyphosate-resistant (GR) variety (NASS, 2007). Glyphosate-resistant soybeans were developed to simplify soybean production through improved weed control.

Previous research by Elmore et al. (2001a) found that, on average, GR varieties yielded 5% less than their conventional (CV) sister line. In addition, differences were also noted in seed weight and plant height between sister lines. However, Elmore et al. (2001b) found that GR variety yields were not affected by glyphosate rates up to twice as much as the labeled use rate. Also, glyphosate applications during the vegetative and reproductive stages had no effect on yield and the GR gene remained unchanged throughout following generations. Elmore's evidence of yield lags in GR soybean, which are not associated with glyphosate application, illustrates that more investigation needs to be done to determine whether GR soybeans require additional management to maximize yield compared to CV soybean.

The objective of this research is to 1) determine nutrient uptake in GR and CV soybean isogenetic lines, and 2) determine response of GR and CV soybean varieties to manganese fertilization.

MATERIALS AND METHODS

In 2005 a field study was initiated in Scandia, KS. In 2006 and 2007 the study was extended to Ashland Bottoms, Rossville, Britts (Manhattan), and Ottawa, KS (not all locations were used in both years). Soil samples were taken prior to planting and analyzed for N, P, K, pH, organic matter (OM), Mn, and Fe (Table 1).

Table 1. Select soil analysis from field locations for 2006 and 2007.

	Location	pH	om†	Mn	P	K	Fe
2006				———	mg/kg	———	
	Rossville	7.1	1.8	17	20	155	15
	Ashland	6.5	2.2	33	44	388	23
	Ottawa	5.9	2.5	31	56	154	52
	Scandia	6.7	2.7	15	64	438	25
2007							
	Ashland	6.3	2.9	13	16	194	82
	Rossville	6.3	2.3	31	27	319	42
	Scandia	6	2.7	26	8	438	64
	Britts	8.3	0.9	4	68	132	9

† organic matter

A randomized, split block design with variety as the whole plot factor and manganese treatment as the sub plot factor was replicated 4 times at each location. Plots were 3.1 m wide by 10.7 m long, row spacing was 0.8 m. Soybean varieties were KS 4202 and KS 4202RR or KS 4602NR and KS 4602NRRR when soybean cyst nematode was a concern. Manganese treatments included a soil-applied band of $MnSO_4$ at 0, 2.8, 5.6, and 8.4 kg Mn/ha and foliar applications of 0.22 and 0.45 kg Mn/ha.

Leaf tissue samples were taken from every plot at approximate growth stages R1, R3, and R6 from the upper most fully developed trifoliate. Whole plant samples were harvested from 0.9 m^2 (2.3 m total row length over 3 sample periods) of the control plots at approximate growth stages R1, R3, and R6 and separated into pods, stems, and leaves for analysis. Samples were processed with a nitric acid digest and analyzed for N, P, K, Mg, Ca, S, Zn, Mn, Cu, Fe, and B with the ICP. Depending on the location and available equipment, either 4.5 m or 9 m of the center two rows was harvested at maturity for yield determination. Seed samples were analyzed for total nutrient content using methodology described above. Nutrient uptake data is only present for growth stage R6 in 2006 and data for Mn effects on tissue concentration is only presented for the R1 sampling period for both 2006 and 2007.

RESULTS AND DISCUSSION

Nutrient Uptake

Nutrient uptake and removal was recorded for control (0 kg Mn/ha) plots in both varieties in the Mn rate study. The data represented is from growth stage R6 because it is most closely related to plant status at the time of harvest. Significant nutrient uptake differences did occur for the plant components, yet those differences were not consistent across locations, with the exception of K accumulation. Potassium accumulation at growth stage R6 was significantly higher in the leaves of the CV soybean than in the GR variety at both Ashland Bottoms and Ottawa. There were no significant variety differences for seed nutrient accumulation. Also, there were no significant variety differences for total nutrient uptake (Table 2). Although results from 2006 show some significant differences in nutrient uptake between varieties, further analysis including the second year data will be critical for drawing conclusions from the nutrient accumulation study for soybean nutrient management.

Table 2. Nutrient uptake at R3 and removal at harvest for for CV and GR soybean varieties grown at Ashland Bottoms in 2006.

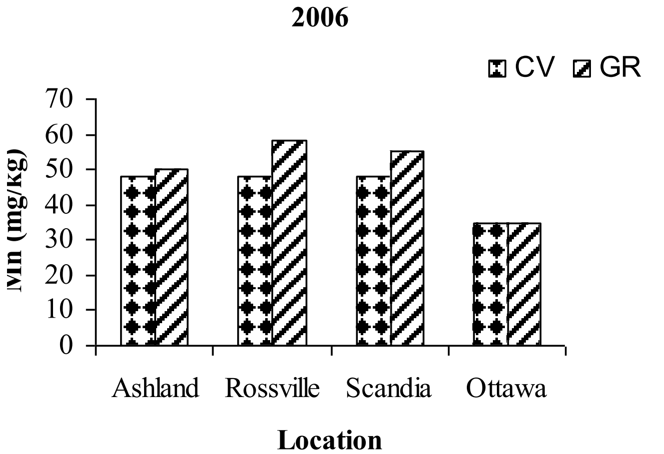
					Nutrients							
Variety	Plant Section	N	P	K	Mg	Ca	S	Zn	Mn	Cu	Fe	B
				kg/ha						g/ha		
Conventional												
	Leaf	17.9*	1.9	15.6*	1.9*	7.8*	1*	17	27	4	156	20*
	Stem	29.4	2.6	13.6	4.5	15.8	2.1	16	52	7	207	29
	Pod	64.3	8.6	87.9	8.6	38.4	4.2	65	116	22	783	119*
	Total	111.6	13	117.1	15	62	7.3	98	194	33	1147	169
	Removal from field											
	Seed	153	17	48	8	12	8	118	96	30	124	120
Glyphosate-resistant												
	Leaf	29.9*	2.4	9.9*	5.7*	14.8*	1.5*	30	29	5	81	40*
	Stem	28	3.5	33.1	4.4	16.5	1.8	22	58	8	589	44
	Pod	63.4	7.5	63.9	7.7	31.8	3.7	55	98	22	819	95*
	Total	121.2	13.4	106.9	17.8	63.1	7	107	185	34	1490	179
	Removal from field											
	Seed	147	16	45	7	10	9	104	88	26	101	106

*significance is between varieties at $p<0.05$

Manganese Response

Manganese tissue concentration with granular applied Mn was significantly affected by variety at growth stage R1 in 2006 at Rossville, Scandia, and Ashland Bottoms locations (p < 0.05), indicating that the GR variety had higher Mn tissue concentrations than the CV sister line (Figure 1). Contrary to results from 2006, there were only significant main effects for variety at

Ashland Bottoms in 2007, indicating greater Mn concentrations in the GR leaf tissue (Figure 1). Manganese rate significantly affected Mn concentrations in leaf tissue at R1 growth stage for Scandia and Ashland Bottoms locations (Table 3). At Ashland Bottoms, Mn tissue concentration increased with increasing rates of soil-applied granular Mn where as at Scandia Mn tissue concentration increased with increasing rates of foliar-applied Mn (data not shown).



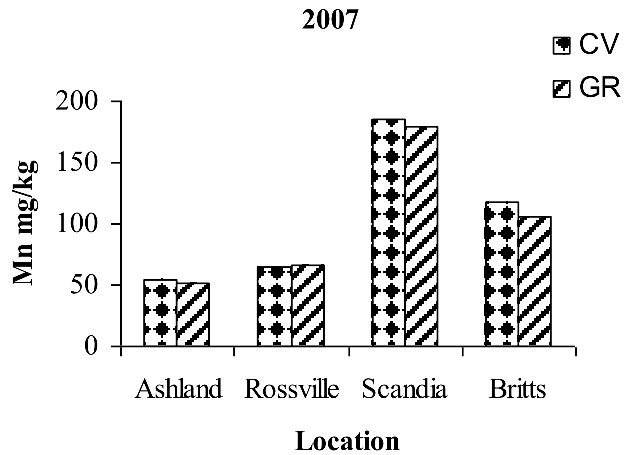


Figure 1. Manganese (Mn) tissue concentrations in leaves of CV (CV) and GR (GR) soybeans at growth stage R1 in 2006 and 2007.

Table 3. F-test *p*-values from ANOVA for variety, Mn rate, and variety by Mn rate effects on soybean leaf tissue concentrations at R1 growth stage for 2006 and 2007.

2006		Ashland	Rossville	Scandia	Ottawa	Britts
	variety	0.050*	0.003**	0.007**	0.783	
	rate	0.886	0.094	0.550	0.909	
	variety*rate	0.989	0.628	0.691	0.0453*	
2007						
	variety	0.003**	0.669	0.735		0.137
	rate	0.002**	0.404	<0.001***		0.900
	variety*rate	0.676	0.923	0.559		0.459

significance indicated at *p<*0.05, **0.01, and ***0.001*

Granular and foliar Mn applications had no significant affect on yield in low yielding environments *(p<0.05)*. Our results show a large amount of variability in yields for low yielding locations (i.e., < 3500 kg/ha). No significant yield response to Mn additions was indicated for CV or GR varieties at Ashland Bottoms (Figure 3). Other low yielding environments, such as Ottawa, Rossville, and Britts showed similar results (data not shown). In contrast, CV soybean yield for control plots was 569 kg/ha greater than the GR soybean at the 2006 Scandia location, or a high yielding location. Furthermore, Mn additions significantly increased GR soybean yield by 570 kg/ha, however, Mn rate did not significantly affect CV soybean yields (Figure 4). Results from Scandia for the 2007 growing season were similar to 2006, where CV soybean yield was 395 kg/ha greater than GR soybean yield at the 0 kg Mn/ha rate, yet GR yields were significantly higher than the CV variety at 5.6 and 8.4 kg Mn/ha rates (Figure 5). Foliar-applied Mn significantly increased yields at Scandia with each additional rate of Mn (data not shown).

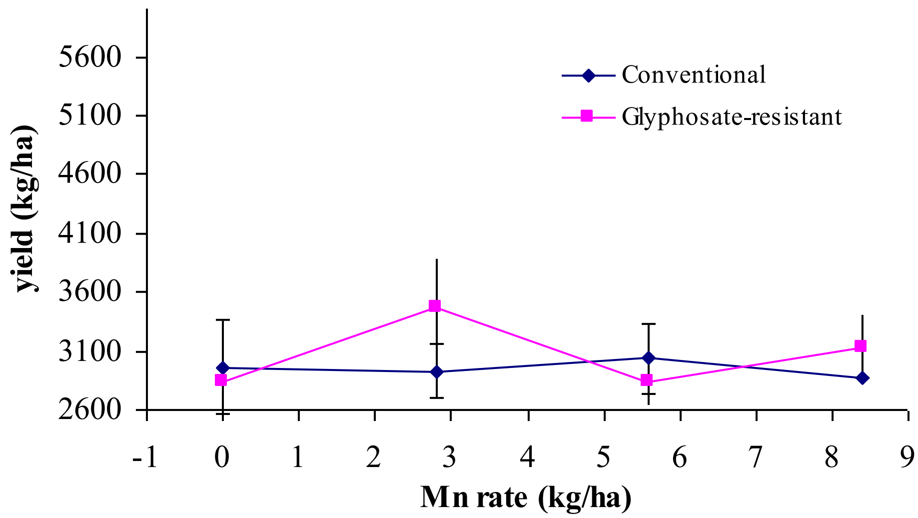


Figure 3. Soybean yield response to soil-applied Mn at Ashland Bottoms for the 2006 growing season.

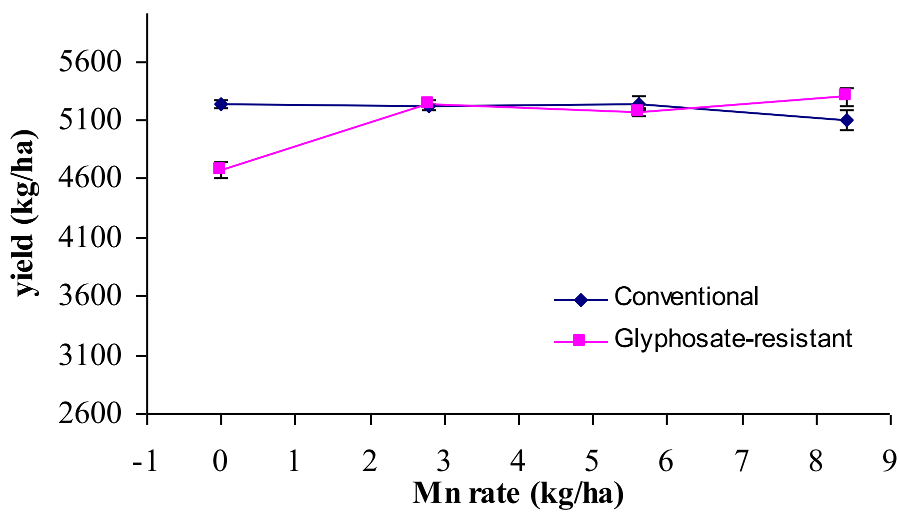


Figure 4. Soybean yield response to soil-applied Mn at Scandia for the 2006 growing season.

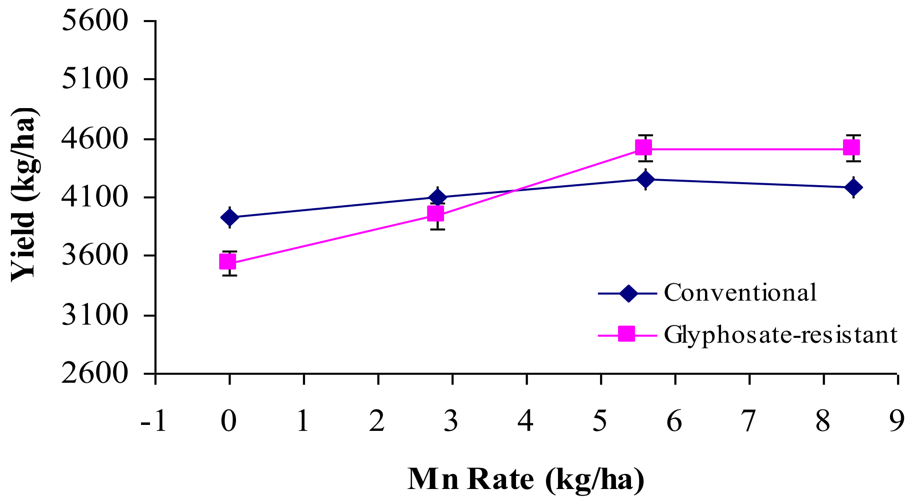


Figure 5. Soybean yield response to soil-applied Mn at Scandia for the 2007 growing season.

CONCLUSIONS

Our results indicate no response to Mn treatments by CV or GR soybean at low yielding environments, indicating that Mn was not the most yield limiting factor. At high yielding environments GR soybean respond positively to soil-applied Mn treatments and CV soybean yields were not significantly affected.

REFRENCES

Elmore, R.W., F.W. Roeth, R.N. Klien, S.Z. Knezevic, A. Martin, L.A. Nelson and C.A. Shapiro. 2001a. GR soybean cultivar response to glyphosate. Agron. J. 93:404-407.

Elmore, R.W., F.W. Roeth, L.A. Nelson, C.A. Shapiro, R.N. Klien, S.Z. Knezevic and A. Martin. 2001b. Glyphosate –resistant soybean cultivar yields compared with sister lines. Agron. J. 93:408-412.

Gianessi, L.P. and J.E. Carpenter. 2000. Agricultural biotechnology: Benefits of transgenic soybeans. National Center for Food and Agricultural Policy1-105.

USDA- National Agricultural Statistics Service. 2007. Acreage. Available at http://usda.mannlib.cornell.edu/usda/current/Acre/Acre-06-29-2007.pdf (accessed 5 January 2008, released 29 June 2007). Pg 25. USDA-NASS Washington, DC.