Manganese Nutrition of Glyphosate-Resistant and Conventional Soybeans

By Barney Gordon

This study was conducted to determine if glyphosate-resistant (GR) soybeans respond differently to Mn fertilizer than conventional soybean varieties in an irrigated high-yield environment, and if so to develop fertilization strategies that will prevent or correct deficiencies. Yield of the GR variety was less than the conventional variety without Mn fertilizer. However, Mn application (banded at planting) to the GR variety closed the yield gap. The conventional soybean variety was not responsive to Mn fertilization. Conversely, yield was reduced at the highest rate of Mn. A second phase of the study showed that a combination of Mn applied as starter and foliar application provided maximum yield response.

Glyphosate-resistant soybean variety planting dwarfs that of conventional varieties in the U.S. by a factor of about 9 to 1. Nevertheless, GR soybean yield may still lag behind that of conventional soybeans, as many farmers have noticed that yields are not as high as expected, even under optimal conditions. In Kansas, average yield seldom exceeds 60 to 65 bu/A even when soybeans are grown with adequate rainfall and/or supplemental irrigation water.

There is evidence to suggest that glyphosate may interfere with Mn metabolism and also adversely affect populations of soil micro-organisms responsible for reduction of Mn to a plant-available form. Manganese availablity is also strongly influenced by soil pH. As soil pH increases, plant-available Mn decreases. It is unlikely that Mn deficiencies will occur on acid soils. It stands to reason that the addition of supplemental Mn at the proper time may correct deficiencies and result in greater GR soybean yields.

In higher plants, photosynthesis in general and photosynthetic O_2 evolution in Photosystem II (Hill Reaction), in particular, are the processes most sensitive to Mn deficiency. Manganese deficiency-induced changes in O_2 evolution are correlated with changes in the ultrastructure of thylakoid membranes (internal chlorophyll containing membranes of the chloroplast where light absorption and the chemical reactions of photosynthesis take place). When Mn deficiency becomes severe, the chlorophyll content decreases and the ultrastructure of the thylakoids is drastically changed.

Manganese acts as a cofactor, activating about 35 different enzymes. Manganese activates several enzymes leading to the biosynthesis of aromatic amino acids such as tyrosine and secondary products such as lignin and flavonoids. Flavonoids in root extracts of legumes stimulate *nod* (nodulation) gene expression. Lower concentrations of lignin and flavonoids in Mn-deficient tissue is also responsible for a decrease in disease resistance of Mn-deficient plants. In nodulated legumes such as soybean which transport N in the form of allantoin and allantoate to the shoot, the degradation of these ureides in the leaves and in the seed coat is catalyzed by an enzyme that has an absolute requirement of Mn. Ureides account for the majority of N transported in the xylem sap to the aerial portions of soybean. Tissue Mn deficiency and drought stress can increase shoot ureide concentration. In research done in Arkansas, it was found that foliar Mn applications reduced soybean shoot ureide concentrations and prolonged N_2 fixation. Information is needed to determine if field-grown GR soybean responds to applied Mn in a different manner than conventional soybean and, if so, what fertilization practices are best to correct the problem. Currently there is little information on Mn fertilization of soybean in Kansas.

Research in Kansas found that a GR soybean variety did not accumulate Mn in the same manner as a conventional variety in the high-yield environment of the study.

The objective of this research was to determine if GR soybeans respond differently to applied Mn than conventional soybeans and, if so, to develop fertilization strategies that will prevent or correct deficiencies leading to improved yield for soybean producers.

Methods

Two separate sprinkler irrigated experiments were conducted on a Crete silt loam soil (fine, smectitic, mesic Pachic Argiustolls) with a pH of 7.0 at the North Central Kansas Experiment Field, located near Scandia, Kansas. Experiment I compared response of the GR soybean variety KS 4202 RR and its conventional near-isoline to granular Mn sulfate applied at planting in a band beside the row to give rates of 2.5, 5, and 7.5 lb Mn/A. A zero Mn check plot also was included. Soybeans were planted without tillage in early May in 2005 and 2006. The experimental design was a randomized complete block with a split-plot arrangement. Whole plots were herbicide resistant and conventional soybean varieties and split plots were Mn rates and sources.

Experiment II evaluated liquid chelated Mn applied to soybean as a starter at planting and as a foliar treatment at three growth stages (V4, V8, and R2). Manganese was applied to the GR soybean variety, KS 4202RR, to give a rate of 0.33

Abbreviations and notes for this article: Mn = manganese; N = nitrogen; O_2 = oxygen; ppm = parts per million.

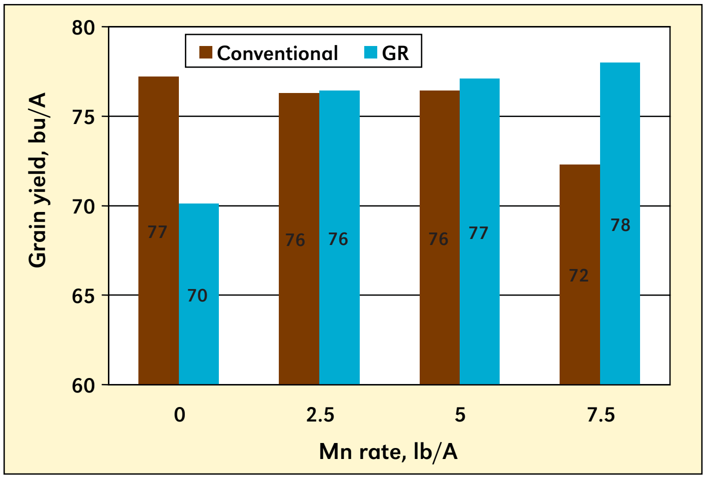

Figure 1. Soybean yield response to applied Mn, 2005-2006.

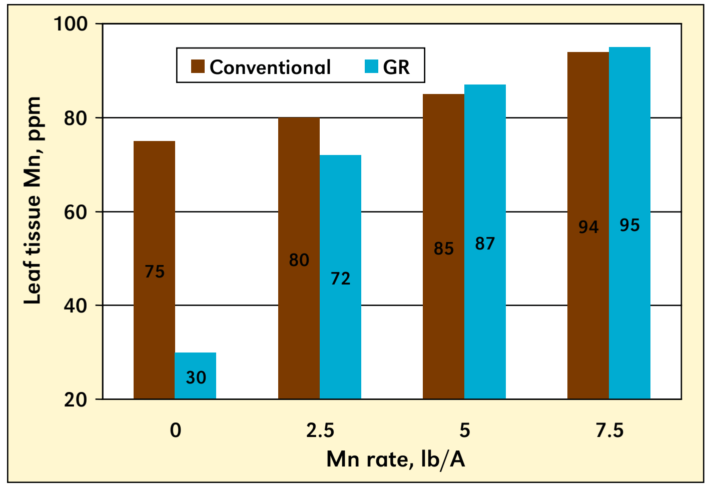

Figure 2. Soybean leaf tissue Mn concentration (uppermost expanded trifoliate at full bloom) 2005-2006.

Table 1. Foliar applied Mn effects on soybean yield, 2006.

Stage of growth	Yield, bu/A
Starter (0.33 lb)	66
Starter (0.66 lb)	70
Starter (0.33 lb) + V4 (0.33 lb)	74
V4 (0.33 lb)	66
V4 + V8 (0.33 +0.33 lb)	72
V4+V8 +R2 (0.33+0.33+0.33 lb)	74
Untreated check	66
LSD (0.05)	3

lb/A Mn at each application.

Results

In Experiment I, yield of the GR variety (KS 4202 RR) was 7 bu/A lower than its conventional near-isoline when no Mn was applied (**Figure 1**). The application of 2.5 lb Mn/A improved yield of the GR variety equal to that of the conventional near-isoline. Yield of the conventional near-isoline was depressed at the high rate of Mn. Tissue Mn concentration (upper most expanded trifoliate at full bloom) in the herbicide resistant near-isoline was less than half of the conventional variety when no Mn was applied (**Figure 2**). However, Mn fertilizer application closed the gap in tissue Mn concentration between the GR and conventional varieties.

In Experiment II, yield of the glyphosate–resistant soybean variety KS 4202 RR was maximized by a combination of Mn applied as a starter 2 in. to the side and 2 in. below the seed at planting, plus a foliar application at the same rate applied at the 4 leaf stage (**Table 1**). A starter alone application at either 0.33 or 0.66 lb Mn/A did not give results equaling the combination of starter and foliar treatment. Application of foliar-applied Mn at 0.33 lb Mn/A at the V4, V8, and R2 stages of growth gave yields equal to the starter plus one foliar application at the V4 stage. One or two foliar applications were not as effective as the starter plus foliar or the three foliar applications. Higher rates of starter-applied Mn and single foliar applications will be investigated next year in order to determine if timing is critical or if higher rates applied earlier in the growing season may be as effective as lower rates applied more frequently.

This research provides evidence that the GR soybean variety used in this study did not accumulate Mn in the same manner as the conventional variety, and did respond to application of Mn in this high-yield environment. BC

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