Manganese Nutrition of Glyphosate-Resistant and Conventional Soybeans

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Abstract

There is evidence to suggest that glyphosate may interfere with manganese metabolism and also adversely affect populations of soil micro-organisms responsible for reduction of manganese. This study was conducted in order to determine if glyphosate-resistant soybeans respond differently to applied Mn than conventional soybeans and if so to develop liquid fertilization strategies that will prevent or correct deficiencies. Two separate experiments were conducted. In experiment I, the conventional soybean variety KS 4202 and its glyphosate-resistant isoline KS 4202RR were grown on a Crete silt loam soil with a pH of 7.0 at the North Central Kansas Experiment Field, located near Scandia, KS. Granular manganese sulfate was applied at planting in a band beside the row to give rates of 2.5, 5 and 7.5 lb Mn/a. A no Mn check plot also was included. Soybeans were planted without tillage in early May in 2005 and 2006. Experiment II consisted of combinations of starter and foliar applied chelated liquid manganese treatments. The experiments were both sprinkler irrigated. Averaged over the 2-year period in Experiment I, yield of the conventional soybean variety was 7 bu/a greater than its glyphosate-tolerant isoline when no Mn was applied. Addition of Mn improved yield of the glyphosate-resistant variety but the yield of the conventional isoline decrease at the highest Mn rate. Leaf tissue Mn at full-bloom in the glyposate-resistant variety was less than half of the conventional variety when no additional Mn was applied. Application of foliar applied liquid Mn also proved to be effective in improving yield of glyphosate-resistant soybean. Yield of soybean was maximized with a combination of .3 lb Mn/acre applied as a starter and another .3 lb/acre applied at the four leaf stage or foliar application of 0.3 lb Mn/acre at the 4 leaf, 8-leaf, and full-bloom stage. These two treatments both improved yield by 12 bu/acre over the untreated check. Full yield benefit was not achieved with starter only application even at a higher rate of Mn.

Introduction

Many farmers have noticed that soybean yields on high pH soil, even under optimal conditions are not as high as expected. In Kansas, average yield seldom exceeds 60-65 bu/acre even when soybeans are grown with adequate rainfall and/or supplemental irrigation water. Application of glyphosate may retard manganese metabolism in the plant. Glyposhate may also have an adverse effect on populations of soil micro-organisms that are responsible for the reduction of Mn to a form that is plant available. Manganese availability is strongly influenced by soil pH. As soil pH increases, plant available manganese decreases. It is unlikely that manganese deficiencies will occur on acid soils. Addition of supplemental manganese at the proper time may correct deficiency symptoms and result in greater soybean yields on soils with pH's at 7.0 or above.

In higher plants photosynthesis in general and photosynthetic O_2 evolution in Photosystem II (Hill Reaction), in particular, are the processes which respond most sensitively to manganese 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 manganese 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 manganese deficient tissue is also responsible for a decrease in disease resistance of Mn-deficient plants. In nodulated legumes such as soybean which transport nitrogen 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 manganese. Ureides account for the majority of N transported in the zylem sap to the aerial portions of soybean. Tissue manganese deficiency and drought stress can increase shoot ureide concentration. Foliar manganese applications have shown to be effective in prolonging N_2 fixation. Information is needed to determine if field-grown gyphosphate-resistant soybean responds to applied manganese 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 manganese fertilization of soybean in Kansas.

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

Methods

The glyphosate-resistant soybean variety KS 4202 RR and its conventional isoline were grown on a Crete silt loam soil with sprinkler irrigation. The soil pH in the top 6 inches of soil at the site was 7.0. Manganese (Mn) fertilizer treatment was pre-plant banded soil applications of manganese sulfate at rates of 2.5, 5, and 7.5 lb/a. A no Mn check treatment also was included. The experimental design was a randomized complete block with a split-plot arrangement. Whole plots were herbicide resistant and conventional soybean varieties (isolines of KS 4202) and split plots were Mn rates and sources. An additional experiment 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 the glyphosate-resistant soybean variety, KS 4202RR, to give a rate of 0.3 lb/acre Mn at each application.

Results

In Experiment I, yield of the glyphosate-resistant variety KS 4202 RR was 7 bu/acre lower than the conventional variety when no Mn was applied (Figure 1). The application of 2.5 lb Mn/acre improved yield and equaled that of the conventional isoline. Yield of the conventional variety was depressed at the high rate of Mn. Tissue Mn concentration (upper most expanded trifoliate at full bloom) in the herbicide resistant variety was less than half of the conventional variety when no Mn was applied (Figure 2).

In Experiment II, yield of the glphosate–resistant soybean variety KS 4202 RR was maximized by a combination of Mn applied as a starter to inches to the side and two inches below the seed at planting at a rate of 0.33 lb Mn/acre and a foliar application at the same rate applied at the 4 leaf stage (Table 1). A starter alone application at either 0.3 or 0.6 lb Mn/acre did not give results equaling the combination of starter and foliar treatment. Application of foliar applied Mn at 0.33 lb Mn/acre 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 affective 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 glyphosate-resistant soybean variety used in this experiment did not accumulate Mn in the same manner as the conventional variety and did respond to application of Mn in this high-yield environment.

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

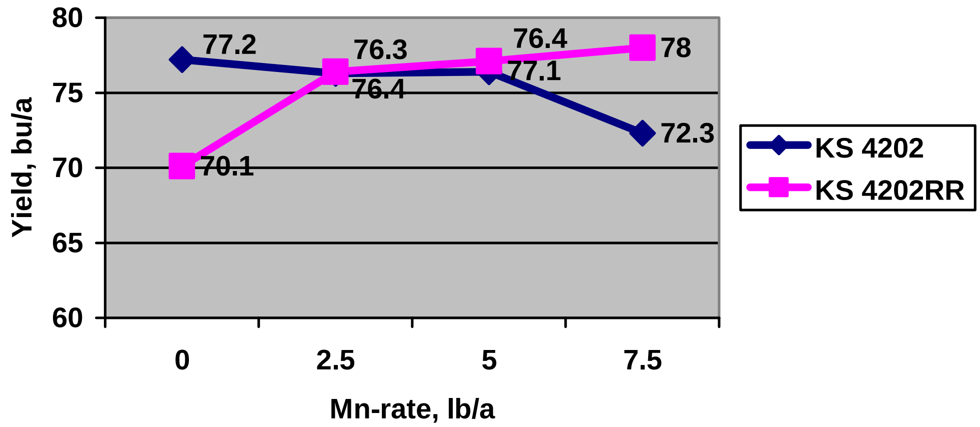

Figure 2. Soybean leaf tissue Mn concentration (uppermost expanded trifoliate at full bloom) 2005-2006.

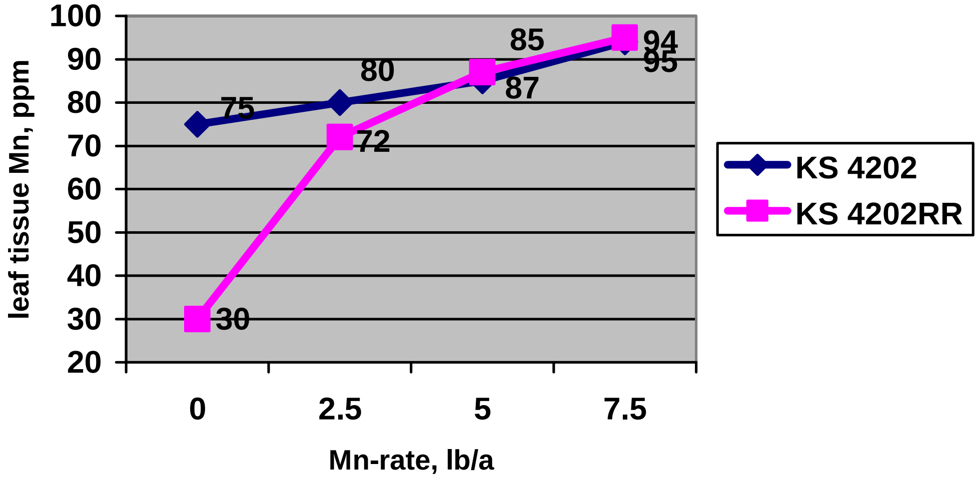

Table 1. Foliar applied manganese effects on soybean yield, 2005-2007.

Stage of Growth	Yield, bu/a
Starter (0.33 lb)	65
Starter (0.66 lb)	70
Starter (0.33 lb) + V4 (0.33 lb)	76
V4 (0.33 lb)	67
V4 + V8 (0.33 +0.3 lb)	73
V4+V8 +R2 (0.33+0.33+0.33 lb)	76
Untreated Check	64
LSD (0.05)	3