EVALUATING THE INTERACTION BETWEEN CHELATED FE SOURCE AND PLACEMENT ON PHOSPHORUS AVAILABILITY IN SOYBEAN

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Abstract

In agriculture, chelating agents are used to supplement micronutrients, such as iron (Fe). However, little research has been conducted on a field scale to evaluate chelating agent effects on phosphorus (P) uptake. The objectives of this study were to evaluate four commercially available chelated Fe sources on early soybean growth and nitrogen (N), P, and potassium (K) uptake. The study was conducted at two locations, and the experimental design was a randomized complete block with four replications in a factorial treatment arrangement. The two factors included fertilizer source and fertilizer placement. The fertilizer sources were P only, EDTA-Fe, HEDTA-Fe, and two glucoheptanate products with two fertilizer placements, in furrow with seed contact and surface band at planting. Results show that there was a significant interaction between fertilizer source and placement for plant population, biomass, N, P, manganese (Mn), and zinc (Zn) uptake, at the V-4 growth stage. Trifoliate Fe and Zn nutrient concentrations at growth stage R3 were also found to have a significant interaction between fertilizer sources and placement, similar significant interaction were found for the Rossville location for grain yield.

Introduction

Increasing yield with the application of chelated micronutrients has been studied extensively since the 1920's. Chelating agents are used extensively in the Great Plains and North Central regions due to widespread Fe deficiencies in soybean (Good and Johnson, 2000). The chances of increasing soybean yields with the application of micronutrients is highest with Fe (Liesch et al., 2011) and Mn (Loecker et al., 2010) when compared to other nutrients. Soil application of chelated Fe has shown to decrease Mn uptake (Ghasemi-Fasaei et al., 2003) as soybeans are affected more by Fe/Mn antagonism (Ghasemi-Fasaei et al., 2003).

In addition to the effects of chelated Fe on other metals, there is potential for an effect on plant available phosphorus. A soil incubation study observing the effects of chelates on plant available P resulted in increased P with the application of EDTA and HEDTA (Edwards et al., 2013). Increasing chelating agent application rate was also found to increase soil test P for EDTA and HEDTA ($r2$=0.86 and 0.95) in a soil with high P adsorption capacity. This increase in P was attributed to EDTA binding Fe within soil colloids and decreasing the P adsorption capacity of the soil (van der Zee and van Riemsdijk, 1988).

Farmers often question the most effective application method of chelated micronutrient and their effects on other nutrients. Little research has been conducted on a field scale to evaluate the effect of chelates on phosphorus and other nutrients. The objectives of this study were to evaluate four commercially available chelated Fe sources on early soybean growth and N, P, and

K uptake comparing two common application methods.

Materials and methods

The study was conducted at two locations, Rossville and Scania, Kansas, in 2014. The experimental design was a complete randomized block design with four replications. Plots were 10ft wide by 30ft long (4 rows of soybeans). A total of 11 treatments were included at each location and are described in table 1. The treatment structure includes an absolute control with a factorial arrangement of placement and fertilizer source. In-furrow and surface band fertilizer placements were compared in combination with 4 chelate products and a control (P only) for each placement. Phosphorus fertilizer was applied at 20lb P_2O_5 acre^{-1} and chelates were applied in furrow and surface banded at 3 and 6 gal acre^{-1}, respectively. The chelating agents used were commercially available products. Both EDTA and HEDTA were solutions of 4.5% Fe. Both the CeeQuest N5Fe-758 (CQ N5Fe- 758) and specialty product 4-15-15 + micronutrients contains 5% Fe chelated with a glucoheptanate.

Initial soil samples were collected in spring 2014 by collecting one composite sample at 6 inches deep per plot. Samples were analyzed for pH, Mehlich-3 P, ammonium acetate K, and organic matter (Table 2). Plant tissue samples were collected at specific growth stages for soybeans and seed grain were analyzed after harvest. The center two rows of soybeans were used for sampling and harvest. Ten whole plant samples were collected at growth stage V-4 and thirty soybean trifoliate (uppermost fully developed trifoliate without the petiole) tissue samples were collected at R3 growth stage (Pedersen, 2009). All plant tissue samples were dried in a forced air oven at 60 degree Celsius for a minimum of 4 days. After drying, plant samples were ground with a Wiley Mill grinder to pass a 2 mm screen and digested using a sulfuric acid and hydrogen peroxide digest (Thomas et al., 1967). Phosphorus and Fe concentration was then determined by inductively coupled plasma atomic emission spectroscopy (ICP-AES).

The center two rows of soybeans were machine harvested for the total length of the plot (30ft). Grain weight were recorded at the end of the growing season and adjusted for 130 g kg^{-1} moisture. Soybean seed grain moisture and test weight were determined using the Dickey-john. The seed grain was then ground using a coffee grinder and analyzed for P and Fe concentration (Thomas et al., 1967).

Data was analyzed by location, and across locations using location as a random variable for analysis. Soybean parameters were analyzed using *proc Glimmix* SAS 9.1 (SAS, 2010) to determine if there was a significant ($P=0.10$) response to fertilizer source, placement, and the interaction between fertilizer and placement. Main effects of fertilizer and placement and the interaction on least square means of soybean parameters were tested.

Summary

The Scandia location can be considered high yielding and categorized at “very low” on STP level (Table 2) (Liekam et al., 2003). Therefore the Scandia location should be expected to show response to P fertilization. The Rossville location had an average STP of 16.8 ppm but ranged from 8 to 39 ppm.

Soybean biomass at V-4 growth stage was found to be significantly affected by the source of fertilizer applied and the placement method used (Table 3). Early soybean uptake of N, P, Mn, and Zn were also found to be significantly affected by fertilizer and placement. Phosphorus, Mn, and Zn tissue concentrations were found to be significantly affected by fertilizer source. Across locations, Zn concentration in whole plant tissue was found to be significantly affected by fertilizer and placement. Nitrogen, P, and Fe early uptake were affected by placement. Only Mn uptake was affected by fertilizer source.

Population counts show that germination was also significantly affected by fertilizer and placement at both locations and when averaged across locations. Soybean yield in Rossville was found to be significantly affected by fertilizer source and placement. The Scandia location has not been harvested at this time. Chelating agents EDTA-Fe and HEDTA-Fe applied in furrow were found to have significantly higher yields when compared to the other chelates and surface band placement.

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Table 1. Description of treatments.

Placement	Fertilizer†
Control	none
In-furrow	P Only
In-furrow	CQ N5Fe 758 (Glucoheptanate)
In-furrow	EDTA-Fe
In-furrow	HEDTA-Fe
In-furrow	4-15-15 + micros (Glucoheptanate)
Surface Band	P Only
Surface Band	CQ N5Fe 758 (Glucoheptanate)
Surface Band	EDTA-Fe
Surface Band	HEDTA-Fe
Surface Band	4-15-15 + micros (Glucoheptanate)

† Fertilizer application rate was 20 lb P_2O_5 $acre^{-1}$ for all treatments

Table 2. Initial soil samples collected as one composite per plot at 0-6 inches and averaged by location.

Location	pH	Phosphorus	Potassium	Organic Matter
		- - - - - - -mg kg^{-1} - - - - - - -		%
Rossville	7.07	16.8	218	2.07
Scandia	6.21	6.0	508	2.83

Table 3. Significance of soybean parameters for both locations.

Sample	Rossville			Scandia			Across Locations		
	Fertilizer (F)	Placement (P)	F x P	Fertilizer (F)	Placement (P)	F x P	Fertilizer (F)	Placement (P)	F x P
	- P < F -								
Population	*0.001	*0.001	*0.008	0.344	0.729	*0.014	*0.005	*0.002	0.154
Yield	*0.006	0.578	*0.019	---	---	---	---	---	---
	Biomass and nutrient concentration at the V-4 growth stage								
Biomass	*0.033	0.383	*0.014	*0.104	0.311	0.221	0.212	0.171	0.727
N	0.605	0.112	0.352	0.922	0.905	0.634	0.791	0.538	0.928
P	*0.006	*0.095	0.202	0.490	0.236	0.731	0.422	*0.002	0.593
K	0.223	0.387	0.610	0.300	0.457	0.875	0.429	0.716	0.880
Fe	0.577	0.434	0.165	0.372	0.489	0.853	0.286	*0.059	0.862
Mn	*0.001	0.504	0.605	*0.001	0.958	0.961	*0.001	0.563	0.987
Zn	*0.001	0.523	0.253	*0.146	*0.002	0.628	*0.002	0.824	*0.080
	Nutrient uptake at the V-4 growth stage								
N	*0.056	0.231	*0.017	0.533	*0.085	0.388	0.468	0.110	0.665
P	*0.037	*0.093	*0.008	0.387	*0.039	0.483	0.279	*0.018	0.599
K	0.840	0.755	0.246	*0.076	0.404	0.251	0.289	0.118	0.747
Fe	0.874	0.285	0.293	0.789	0.216	0.987	0.423	*0.044	0.986
Mn	*0.010	0.334	*0.070	*0.001	0.364	0.406	*0.001	0.283	0.917
Zn	*0.017	*0.041	*0.046	0.169	0.926	0.339	0.480	0.358	0.262

* Significance at 0.10 alpha level.

Table 4. Average soybean yields and population as affected by fertilizer source and placement.

Placement	Fertilizer	Yield†	Population‡
		bu $acre^{-1}$	plants $acre^{-1}$ x 1,000
In-furrow	P Only	51.4cd	111.1a
In-furrow	CQ-758 N5Fe	46.3d	99.1ab
In-furrow	EDTA-Fe	54.6abc	94.3b
In-furrow	HEDTA-Fe	59.8a	74.0c
In-furrow	4-15-15	52.1cd	106.3ab
Surface Band	P Only	58.7ab	113.2a
Surface Band	CQ-758 N5Fe	51.6cd	113.2a
Surface Band	EDTA-Fe	53.3bc	108.1ab
Surface Band	HEDTA-Fe	49.6cd	104.5ab
Surface Band	4-15-15	46.4d	109.6a

† Yields presented here are for the Rossville location only, Scandia has not yet been harvested.

‡ Populations were averaged over locations, Rossville planted at 160,000 and Scandia at 180,000 plants $acre^{-1}$

Table 5. Average soybean biomass and nutrient concentration at the V-4 growth stage across locations.

Placement	Fertilizer	Biomass	N	P	K	Fe	Mn	Zn
		%						
In-furrow	P Only	3.33	4.14	0.32abc	2.80	479abc	67.9a	29.9c
In-furrow	CQ-758 N5Fe	3.06	4.08	0.32abc	2.81	505abc	66.7a	30.5bc
In-furrow	EDTA-Fe	2.88	4.18	0.33a	2.73	545ab	51.2cd	33.5a
In-furrow	HEDTA-Fe	3.35	4.12	0.33ab	2.71	569ab	57.6b	32.7ab
In-furrow	4-15-15	3.08	4.05	0.32bc	2.73	591a	67.0a	34.3a
Surface Band	P Only	3.10	4.00	0.32c	2.74	469bc	68.7a	30.1c
Surface Band	CQ-758 N5Fe	3.12	4.07	0.32bc	2.78	428bc	64.9a	34.1a
Surface Band	EDTA-Fe	2.82	4.15	0.31c	2.78	476c	49.5d	34.1a
Surface Band	HEDTA-Fe	2.97	4.09	0.31c	2.68	539abc	56.0bc	34.0a
Surface Band	4-15-15	3.00	4.07	0.31c	2.74	485abc	66.3a	32.5ab

Table 6. Average soybean nutrient uptake at the V-4 growth stage across locations

Placement	Fertilizer	N	P	K	Fe	Mn	Zn
		mg plant^{-1}			g plant^{-1}		
In-furrow	P Only	139	10.6ab	95.2	16.3abc	2.27a	1.09
In-furrow	CQ-758 N5Fe	125	9.8abc	88.4	15.6abc	2.04ab	0.93
In-furrow	EDTA-Fe	121	9.5bc	81.1	15.9abc	1.44d	0.95
In-furrow	HEDTA-Fe	139	11.0a	93.4	19.4a	1.92bc	1.16
In-furrow	4-15-15	127	9.8abc	87.8	18.5ab	2.06ab	1.05
Surface Band	P Only	125	9.6bc	86.0	14.5bc	2.13ab	0.93
Surface Band	CQ-758 N5Fe	129	9.8abc	90.4	13.8c	2.04ab	1.08
Surface Band	EDTA-Fe	117	8.7c	77.4	13.4c	1.42d	0.92
Surface Band	HEDTA-Fe	121	9.3c	81.1	16.4abc	1.66cd	1.01
Surface Band	4-15-15	121	9.1c	83.2	14.7abc	1.97abc	1.00

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