1. Title: **Impact of micronutrient packages on soybean yields in Missouri**

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3. Objectives and Relevance to the Missouri Fertilizer and Lime Industry:
The main objective of this research is to determine the effect of various micronutrient packages offered by the fertilizer industry on soybean yield and seed quality.
The specific objectives are to:

1) quantify the impact of pre-formulated micronutrient packages on yield and seed quality of glyphosate as well as glufosinate resistant soybean cultivars.
2) measure micronutrient uptake by the soybean plants and develop nutrient response curves.
3) determine effects of applications on soil micronutrient status.

The use of micronutrients is increasing as the costs of fungicides and pesticides have many growers and producers focused on balanced plant nutrition to optimize plant health (Brown, 2008). Pre-formulated micronutrient packages are advertised to improve yields and nutritional content of Missouri's crops. Increased yields and grain quality would translate into greater returns for Missouri producers and increased fertilizer sales. Statistics on micronutrient use and yield improvement in Missouri are scant. However, ever-higher crop yields and, with the advent of cellulosic biofuel production, increases in whole plant removal will result in more micronutrients leaving farmers' fields. This increase in micronutrients leaving the field and the potential reduction in soil supply power (associated with reductions in soil organic matter caused by the removal of not only grain yield but also crop residues) emphasize the importance to critically examine the role of micronutrient fertilization in Missouri.

Fertilization with micronutrients recently has been getting more attention in the Ag press. Particularly with regard to what has been described as glyphosate-induced Mn deficiency (GIMD) and Kip Cullers' (soybean world record yield holder) use of a micronutrient package as well as a seed treatment that up-regulates micronutrient-containing enzymes (Stoller products). Press such as the showcasing of Kip Cullers and his use of such products at the 2010 Farm Progress Show and on Stoller's website (www.stollerusa.com), dramatically increases interest in micronutrient packages and similar products.

Dozens of micronutrient formulations are available for the Ag market in general and soybean producers in particular (SoyScience, Pro Bean Mix, Bean Mix, and Crop Mix among others). However, evaluation of product performance by independent researchers is largely lacking, complicating the decision making process for farmers. For producers like Kip Cullers, micronutrient packages are likely a necessary management practice to meet the demands of ever-more productive soybeans. Although most producers do not aspire to achieve world record yields, applications of micronutrients may increase their yields and economic bottom line. Because glyphosate interacts with Mn both in tank mixtures and in the plant (Bernards et al., 2005), products that aim to combat GIMD may be particularly promising. However, because these products are relatively new to the Missouri market, their effect on the "average" soybean grower's yield is uncertain.

The primary difference among most nutrient packages is the chemical form in which the elements are delivered. These materials vary in their ability to retain micronutrient forms that are accessible by plants and may determine the effectiveness of the product (Table 1).

Table 1. Types of micronuntrient delivery chemicals and associated attributes.

Chemical	Type	Stability	Comments
EDTA, DTPA,EDDHA	Chelated	Strong	Stable at high pH and phosphates, crop safe
Phenolics, Lignosulphonates	Sequestered	Moderate	Not good for soil application; foliar OK
Amino Acids, Citrates, Glucoheptonates	Complexed	Weak	Poor stability, but cheaper
Sulphates, Carbonates, Nitrates	Inorganics	Highly water soluble	Soil application ineffective; higher rates needed.

Differences also affect price, with the cheapest materials most often being the least stable and most at risk for loss. In Missouri, few experiments on the effects of these different products on soybean growth and yield have been conducted by independent researchers. Thus, this project will evaluate the different classes of products to better understand their efficacy and suitability for use on soybean in Missouri.

4. Procedures:

This project will be conducted for 3 years at the Bradford Research and Extension Center in Columbia, MO on a Mexico silt loam soil and will include the following treatments:

Micronutrient pkgs
1) United Suppliers' Sovereign (foliar; liquid; EDTA chelate)
2) Agrium's Bean Mix (soil; granular; non-chelated oxides and sulphates)
3) Tetra Micronutrients' Pro Bean Mix (foliar; liquid; citric acid and EDTA chelates)
4) Helena's Tracite Crop Mix (foliar or soil; liquid; Lignosulphonate sequestered)
5) AgExplore's SoyScience (foliar; liquid; non-chelated sulphates)
6) Stoller's X-tra Power (liquid; foliar or soil; MEA chelate)
7) Tetra Micronutrient's ManGro (foliar Mn; specifically for GIMD)
8) untreated control

Soybean Genotypes
1) Conventional variety (Non Roundup ready)
2) Roundup Ready variety
3) Glufosinate resistant variety

Design: Soybean will be no-till planted (15" rows) in different fields each year. Each treatment (8 micro trts x 3 geno) will be replicated 4 times in a randomized complete block design. Plot sizes will be 250 sq ft.

Cultural Practices: The experiment will be initiated in spring 2011. Basic fertility will be applied according to current MU soil test recommendations and micronutrient treatments will be applied at manufacturer recommended times and rates. Weed control will be conducted using conventional herbicides, Roundup, or glufosinate at recommended rates as appropriate for the different soybean genotypes.

Measurements: Plants will be sampled 5 times during the growing season from emergence to last R stage. Tissue samples will be analyzed for nutrient concentrations by ICP-OES. Final yield will be determined with research combine and seed quality will be assessed on a subsample from each plot.
Soil samples will be taken prior to planting, after final harvest, and in the following spring to assess micronutrient changes from applications and residue decomposition.

5. Current Status and Importance of Research Area:

Fertilizer formulators have developed numerous micronutrient packages for soybean. Most of these packages contain similar micronutrients (Fe, Mn, Zn, Cu, B, Mo) and often contain primary (N, P, K) and secondary (Mg, S) macronutrients. The major difference among these products usually is the chemical agent used as carrier (Table 1) for the micronutrients and this may determine the effectiveness of the product. While the effect of these different chemical agents on maintaining micronutrients in available forms are known, the various packages are designed to account for the differences with adjustments in application method and timing unique for each product. The performance of these products at recommended rates needs to be evaluated to determine if they provide micronutrients equally relative to cost.

Yield responses to these types of products published in refereed journals are nearly absent. However, many formulators have published research on their products online. Industry supported research at selected public institutions indicates that some of products can improve yields by an amazing >70 bu/ac, however, 5-7 bu increases are most common. If yield increases of 5-7 bu can be achieved, these products will garner much interest from producers and retailers should be able to sell these products.

The availability of micronutrients is dependent on pH, with decreasing availability under increasing pH and is typically not considered a problem in most Missouri soils (Stevens et al., 2002). However, in continuous

soybean where N fertilizers are not regularly applied, soil pH in the top 20 cm can approach 7.0 (Houx et al., 2010). And, with up to 30% of Missouri soybean being planted following soybean (Wiebold and Belt, 2007), micronutrient deficiency may be problematic and could be ameliorated with these products. Also, in recent years, producers, researchers, and fertilizer formulators have recognized that GIMD can limit soybean yields. Because the vast majority of soybeans grown are glyphosate resistant this could be of major concern for Missouri producers and fertilizer dealers. Several products (e.g. Stoller's X-tra Power and Tetra Micronutrients' ManGro) specifically identify GIMD as the target for their products. With the introduction of glufosinate resistant soybean cultivars, a new alternative to glyphosate tolerant and conventional soybeans has come on the market. The properties of glyphosate, glufosinate and conventional herbicides are different and are also likely to differ relative to their interactions with micronutrients. Thus, examination of the three types of cultivars is important and will be critical to develop cultivar specific recommendations. Another issue is recently discovered low Mg and S in Missouri soils. Tracy (2010) observed that 14 and 93 % of soil samples submitted to MFA Inc. were deficient in Mg and S, respectively. Many micronutrient packages contain S and some also contain Mg. If soils are deficient in S and Mg, micronutrient packages could add these needed elements and address this problem.

The possibility of whole-plant removals for biofuel production suggests that micronutrient deficiencies may increase in Missouri. And, ever-increasing yields will require that more micronutrients be available to crops (Tracy, 2010). This does raise concern because most micronutrients are involved in highly defined physiological processes within the plant including enzyme activation, components of enzymes, protein synthesis, carbohydrate metabolism, membrane integrity, nitrogen transport, lignification, etc. (Marschner, 1995).

This study will allow us to evaluate the influences of several different micronutrient packages representing different types (Table 1) on yield, seed quality and uptake of micronutrients on conventional, glyphosate, and glufosinate resistant soybean cultivars. In addition, soil analyses will allow us to determine levels of micronutrients retained in the soil and mineralized from residue which will nicely complement the data on plant uptake and removal in grain.

6. Expected Economic Impact of the Project

Yield information is lacking on micronutrients in Missouri. However, if 5-7 bu/acre can be added in continuous soybean acreage (estimate 30% of all acreage) then a net of over $82 million will be realized by Missouri producers. However, given the widespread use of glyphosate-tolerant soybean and the improvements in yield from Mn fertilization alone, an increase of 8 bu/acre (Gordon, 2007) over 5.13 million soybean acres would result in $533 million for Missouri producers.

7. Timetable for Proposed Research:

Spring 2010	Soil sampling and analysis, treatment establishment, planting, and general management of soybean.
Summer 2010	Application of treatments and determination of effects on crop growth and development.
Fall 2010	Harvest for yield and seed composition determination; soil sampling.
Spring 2011	Sample 2010 plots for micronutrients in soil. Repeat planting, sampling and analysis as in 2010.
2012	Repeat sampling, planting, and treatments as in 2011.

8. Strategy for Application and Transfer of Knowledge:

Results of this study will be disseminated at appropriate annual field days and workshops (e.g. Missouri Crop Management Conference, Crop Injury and Diagnostics Clinic). The information gained from this project will be presented at annual meetings of professional societies (such as American Society of Agronomy, Crop Science Society, Soil Science Society of America) and will be published in a refereed journal.

9. Proposed Budget:

Category	Year 1	Year 2	Year 3	Total
Personnel				
Graduate Student	$18,000	$18,000	$18,000	$54,000
Undergraduate help	$3,200	$3,200	$3,200	$9,600
Field cost (fertilizers, herbicide, bags, etc.)	$2,000	$2,000	$2,000	$6,000
Tissue and seed analyses	$4,300	$4,300	$4,300	$12,900
Travel	$1,200	$1,200	$1,200	$3,600
Total	**$28,700**	**$28,700**	**$28,700**	**$86,100**

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PUBLICATIONS:

Recent Refereed Journal Articles

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