1. Title: How Does Kip Grow 150+ bu/acre Soybeans? Is K^+ a Key?

2. Investigator: Tim Reinbott, Felix Fritschi, Dale Blevins, Univ. of Missouri-Columbia

3. Objectives and Relevance to the Missouri Fertilizer and Lime Industry:

Soybean yield ceilings have been a discussed for many years. With his world record setting yields in 2006 (139 bu/a) and 2007 (154.7 bu/a), Kip Cullers of Purdy, MO., has raised the yield beyond levels many thought possible and stimulated the discussion anew. These yields stunned many producers and scientists and raised tremendous interest in the production practices he employed while others doubt the authenticity of these yields. Key management aspects include fertilization and irrigation strategies to avoid any potential limitations due to abiotic stress, and protection of the plants to minimize yield depression as a result of biotic stress.

The management practices involved in achieving these yields are of great interest not only regarding the records per se, but also because these yields illustrate the huge gap between average yields (41.3 bu/a in US in 2007) and soybean yield potential with currently available genotypes. Certainly, there are many lessons to be learned from Kip Cullers production practices that can be transferred to improve soybean yields on average. However, the first step in this process is to study the influence of key management practices with regard to the production of record soybean yield.

The overall objective of this proposal is to evaluate the importance of key management practices in achieving record yields and lessons learned can be adapted to standard production practices.

Specifically, we will

1) determine if application of N, P, and K as mineral fertilizers have the same effect on yield as manure applications conducted by Kip Cullers (equivalent amounts of N, P, and K applied).
2) quantify the influence of supplemental application of foliar K on yield and leaf tissue K concentrations.
3) measure the effect of foliar micronutrient application on yield
4) establish the influence of daily irrigation as compared to standard irrigation practice.

4. Procedures:

Fertilization Treatments:

Main:

1) Base Fertilizer treatment: match the nutrients (N, P, K) applied by 9 tons/a of poultry manure
2) Base Fertilizer plus 36 lb K /a foliar applied (9 lb K /a each time) at late V, R1, R2, and R3.
3) Base Fertilizer plus 36 lb K /a soil applied at the time the first foliar K will be applied
4) Fertilizer Control: standard fertilization practices based on maintenance soil test
5) Base Manure treatment: 9 tons/a poultry manure
6) Base Manure plus 36 lb K /a foliar applied (9 lb K /a each time) at late V, R1, R2, and R3.
7) Base Manure plus 36 lb K /a soil applied at the time the first foliar K will be applied
8) Manure Control: match fertilizer application of treatment 4.

Split Treatments:

1) Plus micronutrients: Source: Nutrition Plus™ for Beans (0.2%B, 0.3%FE, 3.2% Mn, 0.01% Mg, 2.1% Zn) will be applied shortly before the first foliar K application (late V stage).
2) Zero micronutrients: Surfactant control applied at the same time

Irrigation Treatments:

1) Standard irrigation practices
2) Daily irrigation

Because of the large quantities, the base fertilizer (N, P, and K) treatment and the base manure treatment will be established by three separate applications each. Fertilizer and manure will be incorporated into the soil after each application. The nutrient composition of poultry litter is influenced by many factors and varies considerably. A ball park figure expected would be 40-50-40 lb/ton N-P-K on an as-received basis. The nutrient composition and dry matter content of the poultry litter will be determined prior to application. The amount of base fertilizer will be matched as closely as possible with the nutrients applied in form of manure.
Foliar applications of both K and micronutrients will be conducted using a backpack sprayer. Plots not receiving foliar fertilizers will be sprayed with surfactant control. Foliar K will be applied as KNO_3 and equivalent amounts of NO_3 will be applied as $NaNO_3$ in the other treatments to balance the N application among treatments.

Cultural practices: The study will be conducted at the Bradford Research and Extension Center near Columbia, MO. Large applications of fertilizer and manure will be incorporated prior to planting season in three separate passes. A group IV soybean variety will be planted in 15" rows at a population of 220,000 seeds/acre. Weeds will be controlled by a pre-emergence herbicide followed by glyphosate if necessary. To eliminate biotic stress factors a fungicide and insecticide treatments will be applied as needed.

Design: Each treatment will be replicated four times in a split-split plot design. Whole blocks will be 40 x 160 ft of either daily irrigated soybeans or irrigated according to the Woodruff Chart. Split plots will be 20 x 40 treatments of one of the 8 treatments above. Split-Split plots will be the 20 x 20 micronutrient application plots. Irrigation and base fertilizer treatments will be separated by buffers of ~20ft.

Measurements: Soybean yield will be determined from the two center rows of each plot (5 x 20 ft). Yield components (two 2-ft sections from each 20 x 20 ft plot) will be determined just prior to machine harvest. Crop growth and development will be observed over the course of the season using plant mapping. Plant samples will be collected, dried, and ground to determine biomass production and tissue nutrient concentrations.

5. Current Status and Importance of Research Area:

The soybean "Boxwood" model (Figure 1) shows the leaf, developing pod, roots, a root nodule, xylem and phloem transport during mid-summer. In this model, and based on much literature, both xylem and phloem transport processes are strongly linked to K^+ supply. The K^+ balances negative charges on allantoate or nitrate (NO_3^-) in the xylem and malate^{2-} in the phloem and it is vital for transport in both organs. It is important to point out that pods are primarily fed by phloem, and phloem transport depends on K^+. The K^+ is vital for transport into the developing pods and seeds, again for charge balance, but also to support protein synthesis. The protein synthesis apparatus must be bathed in ~100 mM K^+ in order to function.

When everything is operating at a maximum under the high yield conditions without water stress, the model indicates that leaves of these soybean plants might become low in K^+ in mid-summer. That is exactly what was found this summer (2007) when Pioneer scientists analyzed leaf samples from Kip's soybeans. Leaves were apparently low in K^+ concentrations!

Although Kip applies a lot of poultry litter, the strain on root uptake of K^+ maybe too great to keep up with the demand for K^+ by developing pods, seeds, leaves and nodules. Therefore, we propose to apply foliar K in a similar high-yield, irrigated environment in order to overcome this problem.

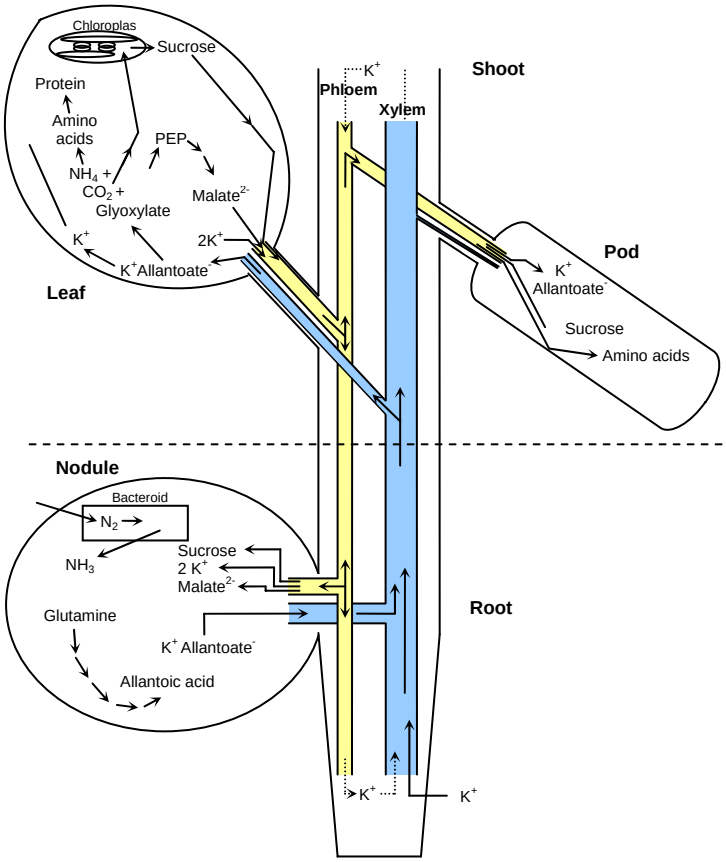

Figure 1. The "Boxwood" model for high-yielding soybean.

6. Expected Economic Impact of the Project:

Soybean is the most important row crop in Missouri (4.5 million acres planted in 2007). Soybean yields have increased steadily over the past decades, but, average yields are more than 100 bu/a lower than the world record soybean yield. Fertilization strategies are considered critical to achieving world record soybean yield and it is anticipated that lessons learned will impact soybean farmers and the fertilizer industry as they are translated into optimized management strategies.

7. Timetable for Proposed Research:

January-March 2008	Soil sampling, fertilizer and manure applications
April – October 2008	Planting and general crop management; application of foliar K fertilization treatments; irrigation; plant tissue sampling and growth monitoring;
October – November 2008	Grinding and analysis of tissue samples; harvest; Analyze field results; Collection of soil for GH study from field site
December 2008	Preparation and submission of progress report
2009 and 2010	Same as 2008

8. Strategy for Application and Transfer of Knowledge:

Results of this study will be disseminated at appropriate annual field days and workshops. The information gained from this project will be presented at annual meetings of professional societies (such as American Society of Agronomy) and will be published in a refereed journal.

9. Proposed Budget:

Category	Year 1	Year 2	Year 3	Total
Personnel				
Graduate Research Assistant (50%)	$14,000	$14,500	$15,000	$43,500
Benefits	$1,960	$2,030	$2,100	$6,090
Laboratory analyses (soil and plant spls)	$3,840	$3,840	$3,840	$11,520
Field Supplies*	$3,500	$3,500	$3,500	$10,500
Travel (professional meeting)	$1,200	$1,200	$1,200	$3,600
Total	**$24,500**	**$25,070**	**$25,640**	**$75,210**

*fertilizer, irrigation expenses (fuel and riser repair), seed, pesticides, machinery repair

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Education:
BS-Agronomy, University of Missouri, 1984
MS-Agronomy, University of Missouri, 1986
Thesis Title: Intercropping soybeans into standing green wheat
Advisor: Dr. Zane Helsel

Employment History:
October 2000-present:Superintendent Bradford Research & Extension Center
January 2000-October 2000: Interim Superintendent Agronomy Research Center
Supervisor-Dr. John Gardner-Associate Director of Agriculture Experiment Station
September 15, 1987-January 2000: Research Associate at the University of Missouri, Agronomy Department.
Supervisor-Dr. Dale Blevins-Professor of Agronomy

Refereed Journal Articles:

Reinbott, T.M., Z.R. Helsel, D.G. Helsel, M.R. Gebhardt, and H.C. Minor. 1987. Intercropping soybeans into standing green wheat. Agron. J. 79:886-891.

Reinbott, T. M. and D. G. Blevins. 1991. Phosphate interaction with uptake and leaf composition of magnesium, calcium, and potassium in winter wheat seedlings. Agron. J. 83:1043-1046.

Morris, R.O., Blevins, D.G., Dietrich, J.T., Durley, R.C., Gelvin, S.B., Gray, J., Hommes, N.G., Kaminek, M., Matthews, L.J., Meilan, R., Reinbott, T.M. and Sayavedrasoto, L. 1993. Cytokinins in plant pathogenic bacteria and developing cereal grains. Aust. J. Plant Physiol. 20: 621-637.

Reinbott, T.M. and D.G. Blevins. 1994. Phosphorus and temperature effects on magnesium, calcium and potassium in wheat and tall fescue leaves. Agron. J. 86: 523-529.

Reinbott, T.M. and D.G. Blevins. 1995. Response of soybean to foliar-applied boron and magnesium and soil-applied boron. J. Plant Nutrition 18: 179-200.

Reinbott, T. M. and D. G. Blevins. 1995. Multi-year use of killed-strips for forage and grain sorghum production in a tall fescue pasture. J. Production Agriculture 8: 354-359.

Dietrich, J.T., M. Kaminek, M., D.G. Blevins, T.M. Reinbott and R.O. Morris. 1995. Changes in cytokinins and cytokinin oxidase in developing maize kernels and the effects of exogenous cytokinin on kernel development. Plant Physiol. Biochem. 33: 327-336.

Blevins, D.G., C.L. Scrivner, T.M. Reinbott and M. K. Schon. 1996. Foliar boron increases berry number and yield of two highbush blueberry cultivars in Missouri. J. Plant Nutrition 19: 99-113.

Reinbott, T.M. and D.G. Blevins. 1997. Phosphorus and magnesium fertilization interaction with soil phosphorus level: Tall fescue yield and mineral element content. J. Production Agriculture 10:260-265.

Reinbott, T.M., D.G. Blevins and M.K. Schon. 1997. Content of boron and other elements in main stem and branch leaves and seed of soybean. J. Plant Nutrition 20:831-843.

Blevins, D.G. and T.M. Reinbott. 1998. Impact of phosphorus nutrition on magnesium, calcium, and water status of plants. *In* Pennsylvania State Root Biology Proceedings. J. Lynch (ed). Pp. 197-206

Reinbott T. M. and D.G. Blevins. 1999. Phosphorus nutritional effects on root hydraulic conductance, xylem water flow and flux of magnesium and calcium in squash plants. Plant and Soil 209:263-273.

Lock, T.R., Kallenbach, R.L., Blevins, D.G., Reinbott, T.M., Bishop-Hurley, G.J., Crawford, R.J., Massie, M.D., and Tyler, J.W. 2002. Adequate soil phosphorus decreases the grass tetany potential of tall fescue pasture. Online. Crop Management. Doi:10.1094/CM-2002-0809-01RS.

Lock, T.R., Kallenbach, R.L., Blevins, D.G., Reinbott, T.M., Crawford, R.J., Massie, M.D., and Bishop-Hurley, G.J. 2004. Phosphorus Fertilization of Tall Fescue Pastures May Protect Beef Cows from Hypomagnesaemia and Improve Gain in Nursing Calves. Online. Crop Management. Doi:10.1094/CM-2004-0608-01RS.

Reinbott, T.M., Conley, S.P., and Blevins, D.G. 2004. No-Tillage Corn and Grain Sorghum Response to Cover Crop and Nitrogen Fertilization. Agronomy Journal:96:1158-1163.

Extension/Popular Articles:

Reinbott, T. M. and D. G. Blevins. 1989. Winter Annual Cover Crops for Missouri. UMC Agronomy Technical Report, Vol. 7, No. 10. December. Pp. 5-7.

Reinbott, T. M. and D. G. Blevins. 1991. A Strip Kill Forage Production System for Fescue Pastures. UMC Agronomy Technical Report, Vol. 9, No. 2. February. Pp. 2-4.

Blevins, D. G. and T. M. Reinbott. 1991. Foliar Fertilization of Soybeans in Missouri. Proc. North Central Ext.-Indust. Soil Fert. Conf., Vol. 7:97-106.

Scrivner, C. L., D. G. Blevins, M. K. Schon and T. M. Reinbott. 1991. Effects of foliar boron applications on yield of Collins and Blueray blueberries. In: P. L. Byers, ed., Missouri Small Fruits Conf. Proc., State Fruit Exp. Stn., Mountain Grove, Vol. 11, pp. 51-64.

Blevins, D. G., M. LeNoble, K. Lukaszewski, T. Reinbott and R. Miles. 1992. Physiological aspects of alfalfa root growth. In: Alfalfa Production in Missouri. A manual, Ed. Craig Roberts.

Blevins, D.G., Reinbott, T.M. and Boyce, P.J. 1993. Foliar fertilization of soybeans with boron and magnesium: Plant physiology. PPI/FAR Technical Bulletin 1993-1, Potash & Phosphate Inst. and Foundation for Agronomic Research Publ., Norcross, GA, p.1-6.

Reinbott, T, Mattas, R., and Blevins, D. 1997. Low phosphorus soils cause major problems with forage and livestock production. Better Crops with Plant Food 81:14-15.

Lock, T.R., Kallenbach, R.L., Blevins, D.G., Reinbott, T.M., Crawford Jr., R.J., Massie, M.D., and Bishop-Hurley, G.J. 2001. Soil Phosphorus may be important to beef herd health and performance. Better Crops with Plant Food 85:4-5.

Current Grants:

2006-2008: Improve Propagation Techniques, Conduct Research and Increase Landowner Outreach and Agricultural Applications of Select Native Plant Species- $150,000 Missouri Department of Conservation

2006-2009: Demonstration of farm profitability utilizing management techniques that promote soil and water conservation practices and improve pastures.-$236,151 USDA-NRCS

2007-2009: Evaluating Native Grasses and Forbs for Suitability in the Ozarks-$5,000 Wurdack Endowment

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Education:
Ph.D., Plant Biology, 2002. Univ. of California, Davis.
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Assistant Professor, Univ. of Missouri, 2007 – present.
Post-doctoral Research Associate, USDA-ARS. 2002 – 2006

Membership in Professional Societies:
American Society of Agronomy
Crop Science Society of America
Soil Science Society of America
Gamma Sigma Delta Agricultural Honor Society
Alpha Zeta Honor Society.

Publications:
Refereed Journal Articles: 14; Proceedings and Abstracts: 40

Selected Refereed Publications:

Fritschi, F.B., and J.D. Ray. 2007. Genotypic variation in soybean chlorophyll content, a/b ratio and leaf N. Photosynthetica 45:92-98.

Ray, J.D., **F.B. Fritschi**, and L.G. Heatherly. 2006. Large early season fertilizer N application affects protein and oil concentration in soybean seed. Field Crops Res. 99:67-74.

Ray, J.D., L.G. Heatherly, and **F.B. Fritschi**. 2006. Influence of large amounts of nitrogen on nonirrigated and irrigated soybean. Crop Science 46:52-60.

Fritschi, F.B., B.A. Roberts, D.W. Rains, and R.L. Travis. 2005. Nitrogen recovery from 15N-labeled incorporated cotton residues and recovery of residual fertilizer N by Acala and Pima cotton. Soil Science Society of America Journal 69:718-728.

Fritschi, F.B., B.A. Roberts, D.W. Rains, R.L. Travis, and R.B. Hutmacher. 2004. Fate of nitrogen-15 applied to irrigated Acala and Pima cotton. Agronomy Journal 96:646-655.

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Fritschi, F.B., K.J. Boote, L.E. Sollenberger, and L.H. Allen, Jr. 1999. Carbon dioxide and temperature effects on forage establishment: Tissue composition and nutritive value. Global Change Biology 5:743-753.

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Education

B.S. in Chemistry, Southwest Missouri State University, 1965
M.S. in Soils (Plant Nutrition), University of Missouri, 1967
Ph.D. in Plant Physiology, University of Kentucky, 1972

Experience

1985 - present, Professor, Agronomy Department, U. Missouri, Columbia
1980 – 1985 Associate Professor, Agronomy Department, U. Missouri, Columbia
1978 - 1980 Assistant Professor, Agronomy Department, U. Missouri, Columbia
1974 - 1977 Assistant Professor, Botany Dept., U. Maryland, College Park
1972 - 1974 Postdoctoral Research Associate, Department of Botany and Plant Pathology, Oregon State University, Corvallis

Awards

1982 Gamma Sigma Delta Superior Research Award for Junior Faculty in Agriculture
1983 Amer. Soybean Assoc./ ICI International Soybean Researchers Recognition Award
1983 Gamma Sigma Delta Superior Graduate Teaching Award
1992 Fellow of the American Society of Agronomy
1992 Fellow of the Crop Science of America
1992 Distinguished Faculty Award, UMC Alumni
1993 Kemper Teaching Award, UMC
2006 Outstanding Graduate Advisor, CAFNR, UMC
2006 Teaching Academy, CAFNR, UMC

Selected Publications

Reinbott, T.M. and D.G. Blevins. 1997. Phosphorus and magnesium fertilization interaction with soil phosphorus level: Tall fescue yield and mineral element content. J. Production Agriculture 10:260-265.

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Markwell, J. and D.G. Blevins. 1999. The Minolta Spad-502 leaf chlorophyll meter: An exciting new tool for education in the plant sciences. The American Biology Teacher 61:672-676.

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Smith, G.J., W.J. Wiebold, T.L. Niblack, P.C. Scharf and D.G. Blevins. 2000. Yield components of soybean plants infected with soybean cyst nematode and sprayed with foliar applications of boron and magnesium. J. Plant Nutrition 23:827-834.

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Waters, B.M., D.G. Blevins and D.J. Eide. 2002. Characterization of FRO1, a pea (*Pisum sativum*) ferric-chelate reductase involved in root Fe uptake and tissue Fe distribution. Plant Physiol. 129:1-10.

Lock, T.R., R.L. Kallenbach, D.G. Blevins, T.M. Reinbott and G.J. Bishop-Hurley. 2002. Adequate soil phosphorus decreases the grass tetany potential of tall fescue pasture. Online. Crop Management doi:10.1094/CM-2002-0809-01-RS.

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Reinbott, T.M., S. P. Conley, and D. G. Blevins. 2004. No-Tillage Corn and Grain Sorghum Response to Cover Crop and Nitrogen Fertilization
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Blevins, D.G., M. Massie and W. McClain. 2004. Phosphorus fertilization improves quality of stockpiled tall fescue. Better Crops with Plant Food 88:7-9.

Bolanos, L., K. Lukaszewski, I. Bonilla and D. Blevins. 2004. Why boron? A Reviw. Plant Physiology and Biochemistry 42:907-912.

Todd, C.D., P.A. Tipton, D.G. Blevins, P. Piedras, M. Pineda and J.C. Polacco. 2006. Update on ureide degradation in legumes. J. Exp. Botany 57:5-12.

McClain II, W.E. and D.G. Blevins. 2007. Phosphorus fertilization increased macronutrient concentrations in leaves of stockpiled tall fescue. Online. Forage and Grazinglands doi:10.1094/FG-2007-0302-01-RS.