Benefits of Lime Placement on Grain Yield Response and Remediation of Acid Subsoils

Investigators:
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Objective and Relevance:

An extensive root system is essential for crop plants to tolerate short- and long-term periods of drought that often occur during the growing season in Missouri. Acid subsoils reduce root growth and grain yield. Stratification of pH values is common in claypan soils in Missouri. In soil survey publications, surface soil samples of claypan soils may have optimum pH values; however, the subsoil from 8 to 20 in. may decrease to pH values as low as 3.6, 4.5, and 4.5 for soils such as Putnam, Mexico, and Armstrong, respectively (Ferguson, 1995). In three-paired watershed research, seventy five soil samples from the Ap, AB, and Bt1 horizons had average pH values of 6.6 ($\pm$1.7), 6.3 ($\pm$0.6), and 4.9 ($\pm$1.2), respectively (Udawatta, unpublished). Drainage research plots had subsoil (8-18 in.) pH values from 4.7 to 5.2 (Nelson, unpublished) while other research indicated average subsoil pH values from 29 claypan soils at the 0-6 in., 6-12 in., 12-24 in., and 24-36 in. depths were 6.2, 6.0, 5.0, and 5.1 (Scharf, unpublished). Over 60% of the 29 fields had pH values less than 5 at the 12-24 in. depth. The lowest pH value at any site was 4.4. Acidic subsoils (at or below the 12 in. depth) may be a greater barrier to root growth than physical restrictions in many soils in Missouri.

Research on cotton (Adcock et al., 1999) and alfalfa (Rechcigl et al., 1991) has demonstrated the benefit of deep lime placement. Methods that incorporated lime increased corn grain yields greater than conventional liming techniques using surface applications (Farina and Channon, 1988). In this research, corn grain yields increased 20 bu/a in a dry year while in a wet year grain yield increased 6 bu/a (Farina and Channon, 1988). Low soil pH, 5 to 5.5, is an agronomic and environmental concern. Macronutrient and microbial activity is restricted and phytotoxic levels of exchangeable Al and Mn are common at low soil pH values. In addition, nitrification may be limited in an acidic environment. Nitrogen applications from ammonium-based N fertilizers acidify soils and require agriculture lime applications to neutralize the impact on soil pH. N sources may require 1.8 to 5.4 lb $CaCO_3$ to neutralize acidity depending on the N source. Anhydrous ammonia applications are commonly used throughout the region and may contribute to a decrease in subsoil pH while the surface soil pH is acceptable. A deep lime application may also reduce the impact of low soil pH on root growth and development.

Acid-subsoil amelioration has been studied with long-term impacts on soil pH levels (Toma et al., 1999; Farina et al., 2000b). Grain and forage yields increased 29 to 50% even 16 yr. after application (Toma et al., 1999) with increased returns (Farina et al., 2000a). Deep placement of dry lime at 1500 lbs/acre over two years increased soybean grain yields over 4 bu/a and increased profitability $94/acre compared to deep tillage only (Tupper et al. 1987). Farmers have utilized no-till and conventional tillage systems to attain specific production goals. Incorporation of lime may be necessary to realize an immediate (Toma et al. 1999) increase in grain yield. Deep placement of lime utilizing conservation-type knives could accomplish an immediate increase in grain yield, provide zone-tillage, increase subsoil pH, and maintain surface residue. Concerns regarding the practicality and economics of deep incorporation have been expressed; however, numerous producers continue to subsoil claypan soils.

- Situations in which farmers may consider deep placement of lime:
  - ✓ Subsoil pH is low.
  - ✓ The practice is cost-effective.
  - ✓ A yield benefit can be demonstrated and there is increased root development.
  - ✓ Improved drought tolerance is evident.
  - ✓ The farmer already utilizes a conservation subsoiler.
- This research would initiate a long-term evaluation of the impact of addressing subsoil pH correction in no-till and reduced tillage cropping systems.

The objective of this research is to evaluate yield response of corn and soybean to lime placement and the impact on subsoil pH.

Procedures:

- A field trial will be established at the University of Missouri Greenley Research Center on a Putnam silt loam that has been in continuous no-till production for over seven years with an acid subsoil. Surface and subsurface pH, neutralizable acidity and other soil characteristics will be determined in each plot prior to the initiation of treatments. A factorial arrangement of treatments will include placement, crop, and lime rate to evaluate the response of corn or soybeans within a given year.
  - ✓ Tillage: No-till surface application and a Conservation subsoiler–deep injection at 4 levels throughout the soil profile. The principal investigator of this proposal custom built the knives for the subsoiler and delivery will be accomplished using a commercial Montag dry fertilizer applicator that is currently on-site. A local cooperator's conservation ripper will be utilized in the experiment. The knives will be switched for this experiment.
  - ✓ Crops: Corn and Soybean
  - ✓ Lime rates: Average subsoil recommendation, top 6 inches of soil recommendation, and a non-treated control. A site with a low surface pH will be utilized in the experiment.
- This research will evaluate soil pH and neutralizable acidity at four depths (0-5, 6-10, 11-15, and 16-20 inches) similar to other research (Farina et al. 2000a, 2000b; Tupper et al., 1987), grain yield, and crop growth characteristics. Soil samples will be processed through the University of Missouri Soil Testing Laboratory. Soil sampling depth will correspond to the different distribution drop tubes on the applicator shank.
- Grain samples will be collected and analyzed for protein and oil (soybean), and starch, protein, oil (corn) using near-infrared spectroscopy (Foss Infratec 1241 Grain Analyzer, Eden Prairie, MN).

Current Status and Importance of Research:

- Acid subsoils reduce root growth and grain yield. Root injury may be observed at pH 5 and lower. Lateral root growth may be suppressed and resemble nematode damage; therefore, rooting depth and degree of branching may be limited. Poor plant growth may be due to exchangeable Al^{3+}, H^{+}, or Mn^{2+} toxicity.
- Lime is very insoluble; therefore, mixing into the subsoil may be necessary to hasten the impact of the treatment in the subsoil.
- Previous MU research has evaluated pH management of the top 6-8 inches of soil; however, no research has evaluated deep lime applications or the impact on subsoil properties.

- Little is known about the yield effects of subsurface lime applications on crop performance and drought tolerance. Increased root penetration of the claypan could reduce the impact of drought on crop performance.
- An increase in subsurface soil pH could provide additional nutrients to the crop. Lower rates of P may be required when exchangeable Al is neutralized. Nitrification is reduced at low pH values which could limit the availability of N to corn.
- Understanding the impact of ameliorating subsoil acid levels would help farmers make informed decisions on subsoil pH changes and tillage systems.

Expected Economic Impact of the Project:

If increased yields from deep lime applications could increase corn yields 6-20 bu/acre and soybean yields 4 bu/acre with a 10% rate of adoption, This increase in yields could add up to $39 million to the economy of Missouri.

Timetable:

2012	
February-April	Prepare equipment, sample soil, and apply lime treatments
April-September	Manage plots and demonstrate at local field day
September	Harvest and resample soil
Oct-Dec	Analyze results
2013	Repeat 2012 procedures rotating corn to soybean and soybean to corn, establish an additional site that will be carried out for 2 years.
2014	Repeat 2013 procedures rotating corn to soybean and soybean to corn, complete results of the additional site.

Strategy for Application/Transfer of Knowledge:

Results of this research will be utilized to demonstrate the beneficial effects of lime placement on crop production. Dissemination of knowledge will be accomplished through field day events, field day reports, and written and broadcast media outlets. Transfer of knowledge will be mainly via written and oral educational programs, including press releases, newsletter articles, radio interviews, television interviews, and conferences. Furthermore, on-site field days will provide a forum for farmers and agriculture professionals to learn about on-going research activities and current findings.

References:

Adcock, C.W., A.O. Abaye, and M.M. Alley. 1999. Subsurface liming effects on cotton development and root growth: a greenhouse study. Communications in soil science and plant analysis 30:316-327.

Farina, M.P.W. and P. Channon. 1988. Acid-subsoil amelioration. I. A comparison of several mechanical procedures. Soil Sci. Soc. Am. J. 52:169-175.

Farina, M.P.W, P. Channon, and G.R. Thibaud. 2000a. A comparison of strategies for ameliorating subsoil acidity: I. Long-term growth effects. Soil Sci. Soc. Am. J. 64:646-651.

Farina, M.P.W, P. Channon, and G.R. Thibaud. 2000b. A comparison of strategies for ameliorating subsoil acidity: II. Long-term soil effects. Soil Sci. Soc. Am. J. 64:652-658.

Ferguson, H.J. 1995. Soil Survey of Macon County, Missouri. USDA, SCS. pp. 158.

Rechcigl, J.E., R.B. Reneau, Jr., D.E. Starner. 1991. Alfalfa yields and quality as influenced by subsurface application of phosphorus, potassium, and limestone. Developments in plant and soil sciences 45:485-490.

Toma, M., M.E. Sumner, G. Weeks, and M. Saigusa. 1999. Long-term effects of gypsum on crop yield and subsoil chemical properties. Soil Sci. Soc. Am. J. 39:891-895.

Tupper, G.R., H.C. Pringle, III, M.W. Ebelhar, and J.G. Hamill. 1987. Soybean yield and economic response to broadcast incorporated and deep band placement of lime on low pH soils. Mississippi Agri. & Forestry Ext. Station Bulletin 950. pp. 7.

Proposed Budget:

CATEGORIES	Year 2012	Year 2013	Year 2014	Total
A. Salaries Research Specialist or M.S. Graduate Research Assistant (50%)	$13,823	$14,382	$14,670	$42,875
B. Fringe Benefits Fringe for graduate student	$2,402	$2,474	$2,548	$7,424
TOTAL SALARIES AND FRINGE BENEFITS	$16,225	$16,856	$17,218	$50,299
C. Travel Travel to field site To present research findings at National Meetings	$0 $0	$0 $1,200	$0 $1,200	$0 $2,400
TOTAL TRAVEL COSTS	$0	$1,200	$1,200	$2,400
D. Equipment	$0	$0	$0	$0
TOTAL EQUIPMENT use and maintenance COSTS	$0	$0	$0	$0
E. Other Direct Costs Soil analysis Grain analysis Publication cost Misc.	 $2,750 $1,500 $0 $3,500	 $5,500 $2,500 $750 $3,500	 $5,500 $2,500 $750 $3,500	 $13,750 $6,500 $1,500 $10,500
TOTAL OTHER DIRECT COSTS	$7,750	$12,250	$12,250	$32,250
TOTAL REQUEST	**$23,975**	**$30,306**	**$30,668**	**$84,949**

Budget narrative:
Salaries and fringe benefits: Funds are requested for partial support of technical support or a M.S. student.
Presentations, publications, and documentation: This will help defray cost of publication and documentation of results and conclusions as well as assist travel and board for presentation of results
Other Direct Costs: Covers cost of analysis, sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, soil processing, and other field supplies and operations.

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EDUCATION AND TRAINING

- Ph.D. Crop and Soil Sciences, Dep. of Crop and Soil Sci., Michigan State Univ. (2000)
- M.S. Crop and Soil Sciences, Dep. of Crop and Soil Sci., Michigan State Univ. (1997)
- B.S. Plant Science, Dep. of Agronomy, Univ. of Missouri (1995)

APPOINTMENTS

- Research Agronomist & Associate Professor, Univ. of Missouri, Novelty, MO (2007-present)
- Research Agronomist & Assistant Professor, Univ. of Missouri, Novelty, MO (2000-2006)
- Graduate Research Assistant, Michigan State Univ., East Lansing, MI (1995-2000)
- Teaching Assistant, Michigan State Univ., East Lansing, MI (1996)

OTHER EXPERIENCE

- Research Technician, Ciba Crop Protection, Lee's Summit, MO (1994)
- Integrated Pest Management, Gypsy Moth Technician, Univ. of Missouri, Columbia, MO (1992)
- Crop and Livestock Production Assistant, Nelson Farms, Skidmore, MO (1980-1995)

HONORS AND AWARDS

- Citation of Merit, Mizzou Alumni Association of the University of Missouri (2010)
- ASABE Blue Ribbon Award, Circular Publication, Questions and answers about drainage water management for the Midwest, American Society of Agricultural and Biological Engineers (2007)
- Junior Faculty Award, Gamma Sigma Delta, Honor Society of Agriculture (2005)

SCHOLARLY SOCIETIES

- Sigma Xi
- Gamma Sigma Delta
- Honor Society of Phi Kappa Phi
- Golden Key National Honor Society
- Phi Eta Sigma Honor Society

PROFESSIONAL ORGANIZATIONS

- American Society of Agronomy
- Crop Science Society of America
- Weed Science Society of America
- North Central Weed Science Society of America

SERVICE

- North Central Regional Drainage Committee (NCR-217) (2003-present); Secretary 2008-2009; Chair 2009-2010
- Missouri Agriculture Leaders of Tomorrow Class XIII (ALOT) (2008-2010)
- Missouri Livestock Symposium Committee (2001-present)
- Manuscript reviewer for eight peer-reviewed journals (2000-present)
- North Central Weed Science Society (1996-present); Membership Committee Chair (2006-2008)
- Weed Science Society of America (1996-present); Extension Committee(2001-2003)
- Missouri Wind Resources (2006-present)

SELECTED PUBLICATIONS:

Nash, P.R., K.A. Nelson, and P.P. Motavalli. 2012. Polymer-coated urea application ratios and timings affect wheat and double-crop soybean yields. Agron. J. *In review*.

Nash, P.R., P.P. Motavalli, and K.A. Nelson. 2012. Nitrous oxide emissions from claypan soils due to nitrogen fertilizer source and tillage/fertilizer. Soil Sci. Soc. Am. J. *In review*.

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Noellsch, A.J., P.P. Motavalli, K.A. Nelson, and N.R. Kitchen. 2009. Corn response to conventional and slow-release nitrogen fertilizer across a claypan landscape. Agron. J. 101:607-614.

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EDUCATION:

Ph.D., 1989, Soil Fertility and Plant Nutrition	Cornell University, Ithaca, NY
M.S., 1984, Soil Fertility and Plant Nutrition	University of Wisconsin, Madison, WI
B.S., 1982, Agronomy	University of Wisconsin, Madison, WI
B.S.F.S., 1978, Foreign Service	Georgetown University, Washington, DC

RESEARCH, EXTENSION AND TEACHING EXPERIENCE:

University of Missouri, Columbia, MO (Mar., 1999 – present). Professor of Soil Nutrient Management in the Dept. of Soil, Environmental and Atmospheric Sci.

University of Guam, Mangilao, GU (Aug., 1994 – Mar., 1999). Associate Professor of Soil Science in the Agricultural Experiment Station, College of Agriculture and Life Sciences.

Colorado State University, Ft. Collins, CO and North Carolina State University, Raleigh, NC (Feb., 1992 - Jul., 1994). Post-doctoral fellow at the Natural Resource Ecology Laboratory at Colorado State University and Department of Soil Science at North Carolina State University.

SELECTED PUBLICATIONS

Veum, K.S., K.W. Goyne, S.H. Holan' and P.P. Motavalli. 2011. Assessment of soil organic carbon and total nitrogen under conservation management practices in the Central Claypan Region, Missouri, USA. Geoderma. 167:188-196.

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Jung, W.K., N. R. Kitchen, K. A. Sudduth, R. J. Kremer, and P. P. Motavalli. 2005. Relationship of apparent soil electrical conductivity to claypan soil properties. Soil Sci. Soc. Am. J. 69:883-892.

Stevens, W.E., T. Gladbach, P.P. Motavalli and D. Dunn. 2005. Soil calcium-magnesium ratios and lime recommendations for cotton. J. Cotton Sci. 9:65-71.

Udawatta, R.P., P.P. Motavalli, and H.E. Garrett. 2004. Phosphorus loss and runoff characteristics in three adjacent agricultural watersheds with claypan soils. J. Environ. Qual. 33:1709-1719.

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Motavalli, P.P., S.H. Anderson, P. Pengthamkeerati, and C.J. Gantzer. 2003. Use of soil cone penetrometers to detect the effects of compaction and organic amendments in claypan soils. Soil Tillage Res. 74:103-114.

Motavalli, P. P. and R. J. Miles. 2002. Soil phosphorus fractions after 111 years of animal manure and fertilizer applications. Biol Fertil Soils 36: 35-42.

PROFESSIONAL ORGANIZATIONS:
Soil Science Society of America
American Society of Agronomy

SELECTED AWARDS AND FELLOWSHIPS:
2000 - present Adjunct Assistant Professor, Division of Plant Sciences, Univ. of Missouri
2001 - 2006 Member of Editorial Board, Journal of Plant Nutrition
2002 - 2003 New Faculty Teaching Scholar, University of Missouri
2003 Junior Faculty Research Award, Gamma Sigma Delta
2003 Chair of USDA Regional Committee on Soil Organic Matter (NCR 59)
2004 Outstanding Teaching Award, CAFNR, Univ. of Missouri
2004 Chair of Environmental Quality Division (A-5), Amer. Soc. of Agronomy
2008 - present Associate Editor, Soil Science Society of America Journal
2009 Maxine Christopher Shutz Award for Distinguished Teaching, University of Missouri

Peter Clifton Scharf

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Plant Sciences Division
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Research and Extension education interests

- developing, evaluating, and promoting tools to predict crop N needs, including variable-rate N management
- evaluating N management alternatives including source and timing
- minimizing environmental impacts of agricultural nutrients
- coordinated management of soil, fertilizer, and manure nutrients
- tailoring fertilizer and lime recommendations to account for soil properties
- economic comparisons of production alternatives

Education

Degree	*Date*	*Institution*	*Major*
Ph.D.	May 1993	Virginia Polytechnic Inst. and State University	Crop & Soil Environmental Sciences
M.S.	July 1988	Virginia Polytechnic Inst. and State University	Agronomy
B.S.	August 1982	University of Wisconsin	Biochemistry, Genetics

Recent Research Publications

Scharf, P.C., D.K. Shannon, H.L. Palm, K.A. Sudduth, S.T. Drummond, N.R. Kitchen, L.J. Mueller, V.C. Hubbard, and L.F. Oliveira. 2011. Sensor-based nitrogen applications out-performed producer-chosen rates for corn in on-farm demonstrations. Agron. J. 103:1683-1691.

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