

FINAL PROGRESS REPORT 2002

Title: Improved Nitrogen Fertilizer Recommendations for Soils Incorporating a Simple Measurement of Soil Physical Properties

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Accomplishments for Second Year:

- A two-year field trial was continued in 2002 at the Bradford Agronomy Center in which 2 levels of surface compaction were imposed (0, 2x passes of a tractor-pulled filled 500 gallon water tank) and 5 rates of N fertilizer (0, 75, 125, 175, 250 lbs N/acre as ammonium nitrate) broadcast applied pre-plant in a factorial design. The tractor (Model 504 International Harvester) and the water wagon had axle loads of 2.8 tons and 3.2 tons, respectively. The water wagon had 7.1 inch-width front and rear radial tires under an inflation pressure of 32 psi. The water wagon was pulled twice over the soil so that coverage of wheel-tracked soil was uniform over the whole compacted area. All treatments were applied in 4 replications to an adjoining area to the 2001 plots and this new area had been planted to corn the previous three years. Fallow plots receiving N fertilizer rates of 0 and 250 lbs N/acre were also established to separate the effects of soil and plants on the fate of applied N fertilizer.
- Soil physical properties measured during the initial growing season in which N fertilizer was applied were soil bulk density, soil hydraulic conductivity, soil pore size distribution, soil penetrometer resistance to a depth of 12 inches and changes in soil water content at depths of 4 and 8 inches. Soil water content was monitored using time domain reflectometry (TDR). The effects of compaction on N recovery of applied N fertilizer were evaluated by periodic soil sampling to determine ammonium-N and nitrate-N to a depth of 12 inches in 4 inch increments and by determination of crop N uptake.
- Surface compaction imposed in April, 2002 before planting significantly increased soil bulk density to a depth of 4 inches and soil penetrometer resistance to a depth of 12 inches (Fig. 1A and B). Averaged over all the years of treatments, surface compaction increased soil bulk density an average of 0.17 g/cm^3 in the 0 - 4 inch depth and 0.08 g/cm^3 in the 4 - 8 inch depth and penetrometer resistance (measured using a proving-ring dial gauge cone penetrometer from ELE International/Soiltest, Inc.) an average of 365 lb/in^2 in the 0 - 2 inch depth, 276 lb/in^2 in the 2 - 4 inch depth, and 145 lb/in^2 in the 4 - 8 inch depth. Surface compaction also significantly decreased total porosity in both the 0 - 4 and 4 - 8 inch depths and significantly increased the proportion of micropores ($<5 \text{ }\mu\text{m}$ pore radius) and decreased the proportion of coarse mesopores (25 - 500 μm radius) and macropores ($>500 \text{ }\mu\text{m}$ radius) in the 0 - 4 inch depth. The decreases in porosity and the proportion of macropores from surface compaction would be expected to affect the fate of applied N fertilizer by reducing drainage and causing poorer aeration.

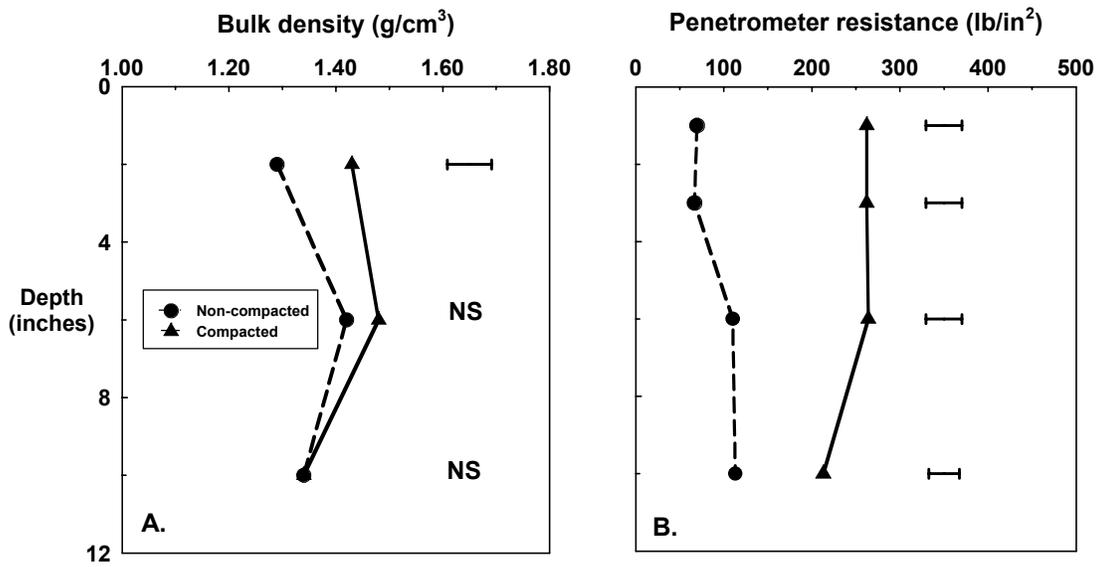


Figure 1. Soil bulk density (A) and penetrometer resistance (B) after surface compaction in a claypan soil in 2002. Bars indicate LSD_(0.05) and NS = not significant.

- A separate comparison of four soil cone penetrometers, selected to represent a wide range of costs and capabilities, was conducted in the early summer of 2002. The soil penetrometers that were compared were the Profiler 3000 (Veris Technologies), the Investigator Soil Compaction Meter (Spectrum Technologies, Inc.), the Soil Compaction Tester (Dickey-john Corporation), and the proving-ring dial gauge cone penetrometer (ELE International/Soiltest, Inc.). The Veris instrument had the additional capability of measuring soil electrical conductivity (EC), a property which may be used to assess relative clay content. In general, the Spectrum penetrometer gave lower and the Veris instrument higher CI values compared to the ELE/Soiltest penetrometer under compacted conditions (Fig. 2A and B). Higher observed CI at lower depths for the Veris and Dickey-john penetrometers was attributed to shaft friction.

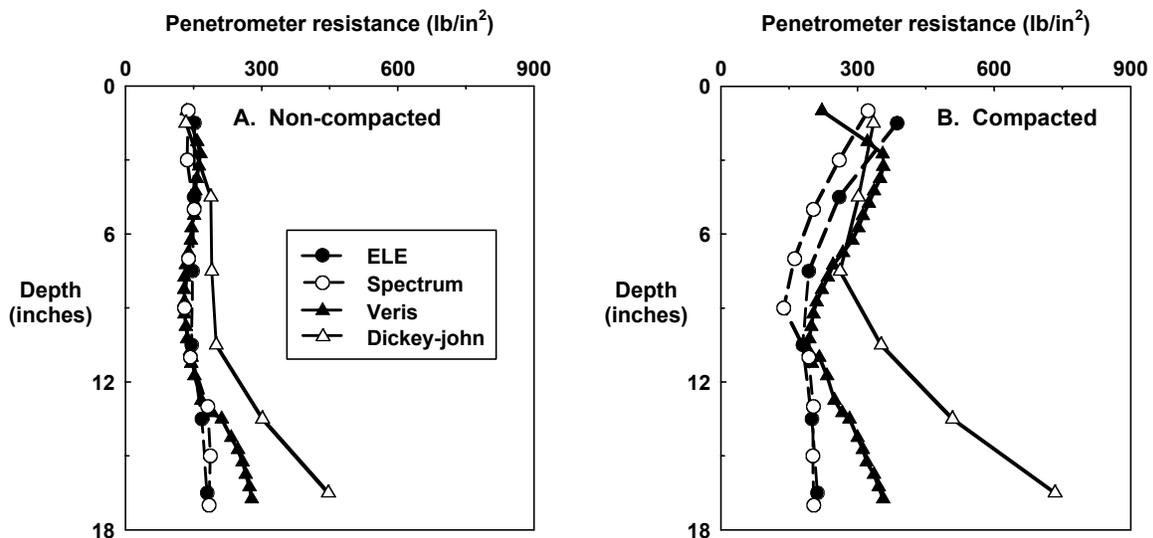


Figure 2. A comparison of soil penetrometer resistance by depth measured by several soil cone penetrometers in treatments of (A) the non-compacted treatments and (B) the compacted treatment.

- Corn grain yields and N uptake in 2002 significantly increased with increasing rates of pre-plant N fertilizer applications in compacted treatments, but were relatively low, probably a result of heavy windstorms knocking corn plants down late in the season (Table 1). The heavy winds especially increased lodging of corn in the non-compacted treatments. Continuous corn over the several seasons of the experiment also may have caused reduced yields. Early season observations showed a large negative effect on growth due to compaction. However, compaction only caused a significant statistical decrease in yield at the 125 lb N/acre fertilizer rate and had no effect on N uptake at any level of applied N.

Table 1. Corn grain yields and N recovery of pre-plant N fertilizer applications at Bradford Agronomy Center in compacted and non-compacted plots during the 2002 season.

N Rate	Grain yield			N uptake		
	Non-compacted	Compacted	LSD _(0.05)	Non-compacted	Compacted	LSD _(0.05)
lb/acre	----- bu/acre -----			----- lb N/acre -----		
0	51	30	NS [†]	46	35	NS
75	91	42	NS	30	38	NS
125	78	45	28	69	40	NS
175	86	57	NS	71	48	NS
250	94	89	NS	58	65	NS
LSD _(0.05)	NS	33		27	16	

[†]NS = not statistically significant at the P < 0.05 probability level.

- Soil inorganic N (ammonium + nitrate N) sampled to a depth of 12 inches in June and September (after harvest) in the fallow plots did not indicate an increased loss of applied fertilizer N (Fig. 3A and B) due to compaction but did show leaching of applied N to the 12 inch depth. This result is consistent with what was observed in 2001. Higher surface inorganic N with compaction is possibly because of reduced water infiltration in the compacted soil reducing leaching losses.

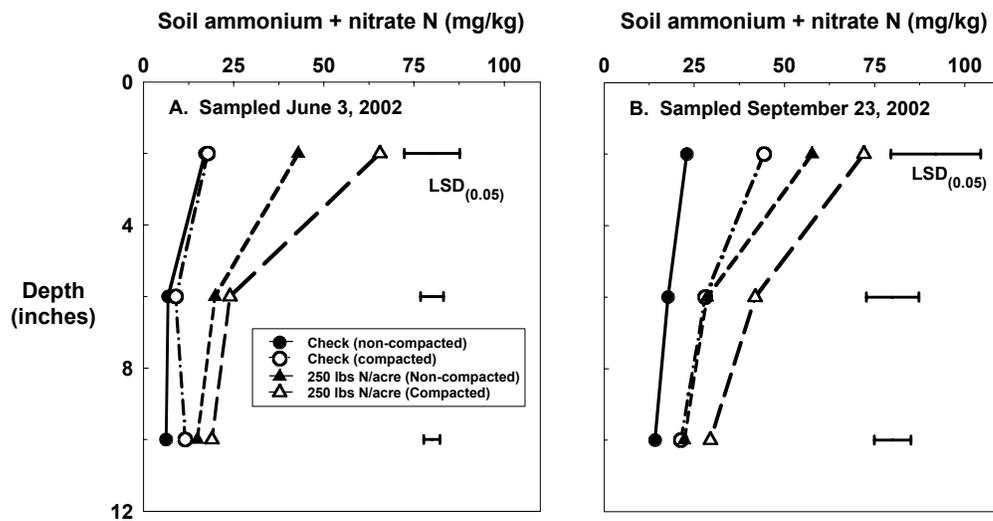


Figure 3. Soil inorganic N at two different sampling dates in the fallow plots.

- A research article comparing methods to assess soil compaction using soil cone penetrometers for possible use in soil fertility evaluation was produced and submitted in 2002 to the peer-reviewed journal, *Soil & Tillage Research*.
- The M.S. graduate student is conducting laboratory/greenhouse experiments to compare methods of assessing compaction and the effects of compaction on corn N efficiency with three soils with sandy, silt loam and clay textures obtained from the University of Missouri Delta Center. These studies will be the major part of the M.S. thesis research of the graduate student funded from this project. We anticipate these experiments will be completed by March, 2003.

Conclusions

- Although the use of the soil cone penetrometer was more sensitive to changes in soil physical properties due to surface compaction compared to measurements of soil bulk density, the routine use of soil cone penetrometers may be complicated by the effects of natural and management-induced variations in soil properties, such as soil water content, and by differences in cone penetrometer design and operation. Standardization of recommended soil sampling conditions and of characteristics of penetrometer design and operation that affect measured cone index (CI) would facilitate use of cone penetrometers for soil fertility evaluation under different environmental conditions. Based on current technology, we also recommend adding the capacity of soil penetrometers to measure soil water content and texture (e.g. through TDR and soil EC technology). However, the current cost of these additional features for penetrometers may discourage their use for routine soil testing.
- For utilization of soil bulk density and penetrometer resistance in soil fertility evaluation among the diverse soil conditions in Missouri, we are evaluating the use of *relative* bulk

density and penetrometer resistance based on a standardized laboratory test of the maximum density and penetrometer resistance achieved for a given soil or category of soils (e.g. defined by soil texture).

- Consistent decreases in corn grain yields and N uptake due to surface compaction were not observed during 2001 and 2002 despite observed early season differences in crop growth and yellowing possibly due to N deficiency. This lack of response was attributed to heavy precipitation during 2001 and strong winds promoting lodging in the non-compacted treatments in 2002. Continuous corn grown over several years also may have contributed to reduced overall yields. Increasing amounts of applied N fertilizer increased grain yields in both compacted and non-compacted areas.
- On-going laboratory/greenhouse experiments to compare methods of assessing compaction and the effects of compaction on corn N efficiency with three soils with sandy, silt loam and clay textures under controlled environmental conditions are being conducted to determine the feasibility of adjusting N fertilizer recommendations based on relationships between soil bulk density, soil penetrometer resistance, soil water content, soil texture, and observed changes in N fertilizer efficiency with increasing soil physical restrictions.

Publications and Presentations Based on Project:

Motavalli, P.P., S.H. Anderson, P. Pengthamkeerati and C.J. Gantzer. Submitted. Use of soil cone penetrometers to detect the effects of compaction and organic amendments in claypan soils. *Soil & Tillage Research* (Peer-reviewed journal article).

Motavalli, P.P. 2001. Soil compaction and nitrogen efficiency. University of Missouri Crop Management Conference (November 28-29, 2001), Columbia, MO (Presentation to agricultural professionals).

Motavalli, P.P. and K. Sudduth. 2001. Soil compaction measurement and impact on production, Missouri Precision Agriculture Center Advisory Board Field Day (August 24th, 2001), Bradford Agronomy Center, University of Missouri, Columbia, MO (Field Day).

Motavalli, P.P. and R.J. Miles. 2001. Soil characteristics and compaction, Crop Injury Diagnostic Clinic (July 24-27, 2001) and Pioneer Sales Representative Crop Clinic (July 31, 2001), Bradford Agronomy Center, University of Missouri, Columbia, MO (Workshop for agricultural professionals).

Motavalli, P.P. 2001. Soil compaction and nitrogen availability, ARC Extension Tour (June 28, 2001), Bradford Agronomy Center, University of Missouri, Columbia, MO (Field day for UM extension professionals).