LONG-TERM NITROGEN FERTILIZATION EFFECTS ON CORN YIELDS AND SOIL PROPERTIES

Larry G. Bundy
University of Wisconsin. Madison, Wisconsin

Abstract

A long-term experiment (1958-2002) provides information about the sustainability of long-term nitrogen (N) fertilizer use and continuous corn production in the northern Corn Belt. The experiment includes three N rates (none, medium, and high) applied annually in a randomized complete block design with four replications. Nitrogen rates in the medium and high categories increased over time and are currently 125 and 250 lb N/acre. Lime treatments were imposed on the long-term N rates in 1985 using a split-plot treatment arrangement. Long-term N use increased soil organic C and N content and N availability, likely due to higher residue amounts and N concentrations. Soil pH and cation exchange capacity declined without lime addition, but increased where lime was applied. Average corn yields in N fertilized treatments approximately doubled during the 45-yr history of the experiment with the highest yields occurring in the more recent years. No evidence of a decline in productivity from long-term N fertilizer use was detected.

Introduction

A long-term continuous corn – nitrogen rate experiment has been conducted since 1958 at the University of Wisconsin Arlington Agricultural Research Station. This paper is intended to summarize and update several studies that have examined the effects of long-term nitrogen (N) fertilization on productivity and soil fertility parameters in this 45-year N rate experiment with continuous corn.

Materials and Methods

The experiment is located at the Arlington Research Station (43°18'N;89°21'W), approximately 25 miles north of Madison, WI. The soil at the site is a Plano silt loam (fine-silty, mixed mesic, Typic Argiudolls) developed under prairie vegetation in loess deposits over glacial till (Vanotti and Bundy, 1996). Initial treatments consisted of three N rates (applied as ammonium nitrate) arranged in a randomized complete block design with four replications (Andrew et al., 1963). Subsequent N and lime treatments were incorporated into the experimental design using a split-plot treatment combination (Motavalli et al., 1992). Nitrogen was applied as anhydrous ammonia from 1963-1984 and from 1993-2002. Nitrogen rates changed over time (Table 1), and during 1984 to 1992, each long-term N treatment received N rates of 0, 75, 150, and 225 lb N/acre as urea to study the residual effects of the original N treatments on N availability to corn (Motavalli et al., 1992). In 1985, one half of each long-term N plot was limed to raise the pH to 6.5-7.0. An additional lime application was made in 1988 to achieve the objective pH range.

Table 1. Nitrogen fertilizer rates used in the long-term N-continuous corn experiment at Arlington WI. 1958-2002.

	Long-term N fertilizer rate, lb N/acre		
Years	None	Medium	High
1958-1962	0	50	100
1963-1983	0	80-125	160-250
1984-1992	0	75-150	150-225
1993-2002	0	125	250

Corn was grown in the experimental area each year since 1958 using adapted hybrids and recommended pest management methods. At corn planting, starter fertilizer (200 lb/ acre of 6-24-24) was applied in a 2 x 2 inch side placement. Since 1984, corn was grown in 30-inch rows with seeding rates of 32,000 to 35,000 seeds/acre. Corn was harvested for grain each year and all residues were incorporated into the soil by moldboard plowing in the spring (1958-1983) or fall (1984-2002).

Results and Discussion

Long-term N treatments have influenced soil N supplying capability (N availability) and soil N and carbon (C) content (Motavalli et al., 1992; Vanotti et al, 1997; Bundy et al., 2000). Motavalli et al. (1992) found that the residual effects of long-term N treatments increased corn yields likely due to greater N mineralization in the treatments receiving long-term N additions. The probable source of this increase in N availability is the increase in soil organic N and C observed in the long-term N treatments (Vanotti et al, 1997; Bundy et al., 2000). This increase in soil organic matter likely results from the higher quantities and N concentrations in residues returned to the soil and partial immobilization of excess fertilizer N in stable soil organic matter. Vanotti et al. (1997) showed that, during 1958-1983, soil N at the highest long-term N rate increased by over 650 lb N/acre relative to the control (no N) treatment. The effects of long-term N and lime treatments on total N and C in soil is summarized in Table 2.

Table 2. Long-term N and lime treatment effects on total nitrogen and carbon in soils (Bundy et al., 2000).*

N rate	Lime	Total N	Total C
lb/acre		---------- % ----------	
0	yes	0.158	1.792
0	no	0.160	1.818
125	yes	0.202	2.297
125	no	0.187	2.058
250	yes	0.193	2.175
250	no	0.198	2.129

* Measured in 1997. Soil organic matter = 50-58% C

The decrease in soil pH following long-term ammonium-N additions due to acidity generated during the nitrification process is well known. Barak et al. (1997) found that long-term N use reduced soil cation exchange capacity (CEC) in addition to lowering pH. Bundy et al. (2000) investigated the influence of the long-term N and lime treatments on soil pH and CEC in this experiment (Table 3). Results showed that long-term N additions in the absence of lime decreased soil pH and CEC as noted by Barak et al. (1997). However, where lime was applied to maintain soil pH at or above recommended levels for corn production, CEC was increased relative to the control treatment by long-term N additions.

Table 3. Effects of long-term N rates and lime on pH and cation exchange capacity (CEC) in continuous corn*.

N rate	Lime	pH	CEC
lb/acre			cmol(+)/kg
0	no	5.64	17.78
0	yes	6.50	19.18
250	no	4.91	14.19
250	yes	6.28	21.45

* Measured in 1999 (Bundy et al., 2000).

The influence of long-term N and lime treatments on corn yields since lime treatments were applied is illustrated in Table 4. Lime treatments increased yields by an average of 9 bu/acre, and N additions greatly increased yields over the control, but yields were not significantly different between the medium and high long-term N rates.

Table 4. Effect of long-term N rate and lime treatments on corn grain yield, Arlington, WI, 1985 to 2002.

	Lime		
Long-term N rate	Without	With	Mean †
	---------- grain yield, bu/a ----------		
None	63	73	68 b §
Medium	163	169	166 a
High	165	175	169 a
Mean ‡	130 b	139 a	

† Long-term N rate $p > f = <0.01$.

‡ Lime $p > f = <0.01$.

Long-term N rate x lime $p > f = 0.57$.

§ Mean values followed by the same letter are not significantly different at the 0.05 probability level.

Examination of this response data on an annual basis shows that yields were significantly increased by added N in each of the 18 yr included in the data reported in Table 4. Lime treatments increased yields in 12 of 18 yr, but a significant N x lime treatment interaction was found in only 4 of 18 yr. This suggests that the effects of N and lime on yields usually occur through independent mechanisms.

The influence of long-term N treatments on corn grain yields during several time periods since the start of the experiment are shown in Table 5. Corresponding data for individual years are illustrated in Figure 1. For both Table 5 and Figure 1, the data reported for years since lime treatments were imposed represent the average of limed and unlimed plots. These results show that yields without N fertilization have remained relatively constant over time, but yields increased substantially since 1958 where N fertilizer has been applied annually. The substantial yield increases in the N fertilized treatments can probably be attributed to improvements in corn hybrid yield potential and production practices since the beginning of the experiment. Since the highest yields have occurred in the more recent years (Figure 1), there is no indication that long-term N fertilizer use or continuous corn production results in a loss of soil productivity.

Table 5. Corn yield for several periods in long-term N experiment, Arlington, WI.*

Year	Long-term N rate		
	None	Medium	High
	---------- Yield, bu/acre ----------		
1958-1962	60	90	97
1968-1977	52	107	115
1978-1987	78	148	153
1988-1998	65	156	162
1999-2002	60	188	186

* Yields are means of limed and unlimed treatments.

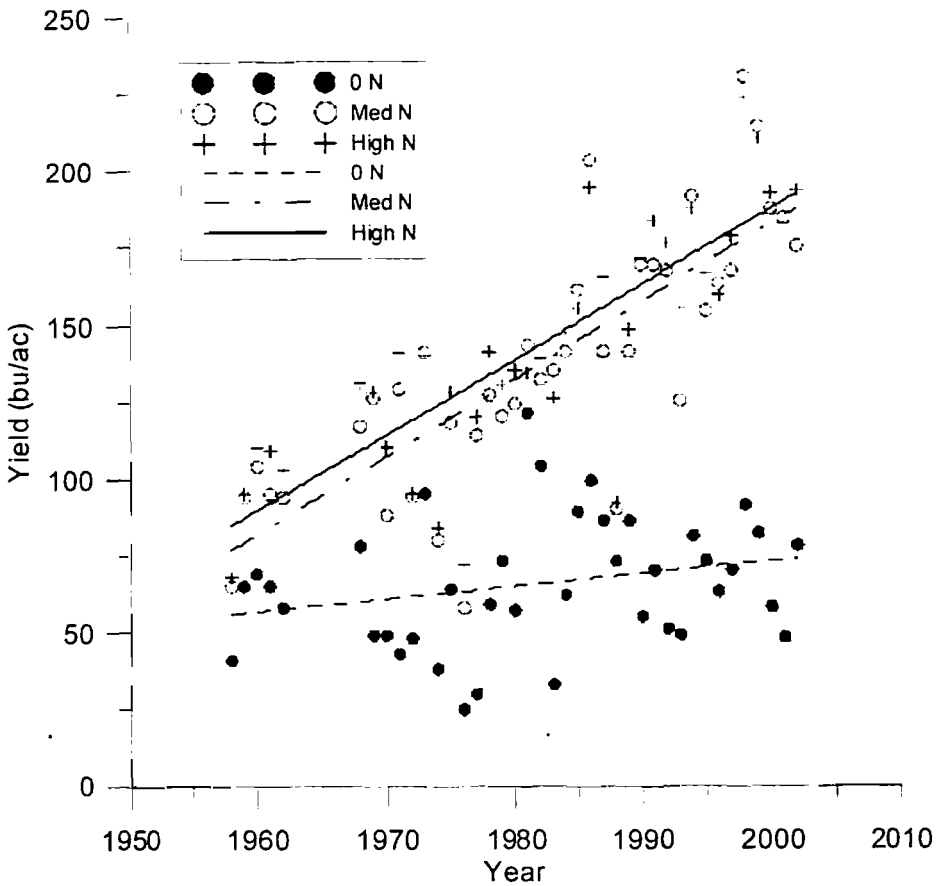

Figure 1. Continuous corn grain yields with three long-term N fertilizer rates, 1958-2002. Arlington WI.

Summary

- Long-term N fertilizer use in continuous corn production increased soil organic C and N content and N availability.
- Soil pH and CEC decreased in unlimed, N-fertilized treatments, but increased where recommended lime applications were made.
- Corn yields were increased by applied N each year and were usually increased by liming. Lime and N treatments usually influenced yield independently.
- Corn yields increased dramatically over time with long-term N fertilizer additions.
- Results provide no indication of a decline in productivity after 45 years of N fertilizer use in continuous corn production.

References

Andrew, R.H., Z.M. Arawinko. J.R. Love. and A.E. Peterson. 1963. Population, fertility and varietal response for continuous corn with minimum tillage. Wis. Agric. Exp. Sta. Res. Bull. 244.

Barak, P., B.O. Jobe, A.R. Krueger, L.A. Peterson, and D.A. Laird. 1997. Effects of long-term soil acidification due to nitrogen fertilizer inputs in Wisconsin. Plant Soil 197:61-69.

Bundy, L.G., M.C. Pellitteri, and P. Barak. 2000. Effects of nitrogen fertilizer use on soil characteristics and productivity. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 39:77-89.

Motavalli P.P., L.G. Bundy, T.W. Andraski, and A.E. Peterson. 1992. Residual effects of long-term nitrogen fertilization on nitrogen availability to corn. J. Prod. Agric. 5:363-368.

Vanotti, M.B. and L.G. Bundy. 1996. Soil organic matter dynamics in the North American Corn Belt: The Arlington Plots. p. 409-418. In D.S. Powlson et al. (ed.) Evaluation of soil organic models using existing, long-term data sets. NATO ASI Series, Vol. 138, Springer-Verlag, Berlin.

Vanotti. M.B., L.G. Bundy, and A.E. Peterson. 1997. Nitrogen fertilizer and legume-cereal rotation effects on soil productivity and organic matter dynamics in Wisconsin. p. 105-119. In E.A. Paul et al. (ed.) Soil organic matter in temperate agroecosystems: Long-term experiments in North America. CRC Press Inc., Boca Raton, FL.

Acknowledgements

The author is grateful to the College of Agricultural and Life Sciences, Univ. of Wisconsin-Madison, and to Farmland Industries for financial support of this study. Appreciation is particularly expressed to Dr. A.E. Peterson for initiating this study in 1958 and for maintaining it until 1984. The author is also grateful to Todd Andraski for assistance with data collection and analysis and to Jeffery Osterhaus for assistance in compiling data from the experiment.

PROCEEDINGS OF THE

THIRTY-THIRD NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 19

November 19-20, 2003
Holiday Inn University Park
Des Moines, IA

Program Chair:
John E. Sawyer
Iowa State University
Ames, IA 50011
(515) 294-1923

Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.ppi-ppic.org