Forecasting the Contribution of Nitrogen Fertilizer to Greenhouse Gas Emissions from Corn Production

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ABSTRACT

• 109 on-farm trials measuring corn response to N, conducted between 2001 and 2005.
• Previous crops were: Soybeans – 60; Wheat – 31; Maize – 12; Misc. – 6.
• Experiments had a minimum of four different N rates, and at least 8 plots.
• Most on-farm trials used strips the full length of the field.
• Response curves were fit using a Crop Nutrient Response Tool (IPNI, 2006) to determine site-specific optimum rates (MERN, Most Economic Rate of N).
• Using the mean of four fitted curves, weighted by the R² of the fit, the following attributes were calculated for each site-year:
  • MERN, yield, response and removal N recovery efficiencies, and postharvest C:N ratios (see Table 1).

INTRODUCTION

• A continuing challenge in managing N is to predict the most economic rate (MERN) to apply. Owing to unpredictable variability, rates somewhat above MERN are often applied as production insurance. Continuing refinement of recommendation methods accounts for more of the factors controlling MERN. The combination of increasing energy efficiency of N fertilizer manufacture, increasing corn yields and improved N recommendations may reduce the greenhouse gas impact associated with N use on corn.

TRENDS

• Past Improvements: Figure 1 illustrates that the ratio of N removed in corn harvested over that applied as fertilizer has improved in a linear manner since 1970. Projecting this trend forward indicates that inputs and outputs may balance sometime beyond 2030.
• Improving Manufacturing Efficiency: Figure 2 illustrates that as facilities are modernized, CO₂ emissions per unit of N produced decline. Combining gains in both manufacturing and field N use efficiencies, the reduction in emission per unit of corn grain produced could decline by half between today and 2030 (Figure 3). Increasing use of coal gasification, however, could reverse this improvement.
• Nitrous oxide emissions is and will continue to be the largest greenhouse gas impact associated with N use on corn, as illustrated in Figure 4.

NITROGEN RESPONSES (TABLE 1)

• Recovery Efficiencies:
  • Response: With current practices, 37 to 45 percent of applied N is taken up into the crop. This improves to 49 percent if MERN could be accurately predicted. Its increase to 57% in 2030 would depend on improvements in both management and genetics.
  • Removal: With current practices, 76 to 94 percent as much N as applied is removed by grain harvest. The greater values for removal compared to response indicate substantial soil residual or mineralized N contributing to corn nutrition. Removals above 100% associated with MERN scenarios imply a net loss of N from the soil-crop system.
• Post-harvest C:N Ratio: this ratio is increased by higher yields of crop residue and by lower amounts of residual N. Harvest indexes assumed were 47% for C and 73% for N. When C:N ratios are less than 30, mineralization commences without delay and is assumed to be complete (no formation of new organic matter, no N2O storage). For higher C:N ratios, it is assumed that stabilized organic matter is formed, and that 10% of available N stabilizes with available C resulting in new soil organic matter with a C:N ratio of 10:1. CO₂-equivalent of greenhouse gas emissions from ammonia manufacturing and nitrous oxide losses (from Figures 3 & 4)

CONCLUSIONS

• Greenhouse Gas (GHG) Balance: The data suggest that a fraction of N that participates in soil C storage may significantly reduce N rates applied currently. At MERN, however, soil C storage may become N-limited.
• Net GHG emission per unit cropped area may increase by 2030, but projected higher yields imply a 17% reduction per unit of corn grain produced. A fraction of residual N greater than 10% would need to participate in soil C storage to balance GHG emissions associated with manufacturing ammonia and nitrous oxide.

TECHNOLOGY AND RESEARCH

• Technologies Available: urease and nitrification inhibitors, placement, timing, improved prediction of weather and soil water movement.
• Research Needed:
  • Specific products, placement and timing to reduce nitrous oxide emissions.
  • Plant breeding, genetic engineering to further improve yield and N recovery efficiency.
  • Methods to reduce post-harvest soil residual N and thus increase response recovery efficiency.

ACKNOWLEDGMENT

• The cooperation of the Ministry of Agriculture, Food and Rural Affairs (OMAFRA) in sharing and discussing nitrogen response data is gratefully acknowledged.