ENERGY EFFICIENCY IN CORN NITROGEN FERTILIZATION

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Corn N Fertilization Requirement

Production of optimal corn yields requires nitrogen (N) fertilization in most crop rotations. For example, the yield increase due to N application rate for corn following soybean (SC) and corn following corn (CC) is shown in Figure 1. The rotation of SC is more efficient with N use due to higher yield and lower N rate requirement. This has important implications for energy use in corn production. The typical corn yield advantage for SC is 15% greater than for CC, and the N rate 30 to 50 lb N/acre lower.

Nitrogen rate recommendations in states across much of the Corn Belt come from the on-line Corn Nitrogen Rate Calculator (http://extension.agron.iastate.edu/soilfertility/nrate.aspx). Crop rotation and economics (price of nitrogen and corn) determine recommended rates, the Maximum economic Return To Nitrogen (MRTN). For example, at a 0.10 N:corn price ratio (example $0.35/lb N:$3.50/bu corn), suggested rates for Iowa corn production are 125 lb N/acre with SC (Figure 2) and 177 lb N/acre with CC (Figure 3). Corn grown in rotation with forage legumes, such as established alfalfa, has an even greater advantage as there is little to no N fertilization need in the first year, and reduced rate requirement for the second year of corn.

Although energy is not directly purchased (such as when buying tractor fuel), N fertilizer application has a large impact on energy use in corn production. Using recommended rates minimizes the energy input with N fertilizers. While applying N rates below optimum would reduce energy input, yield loss would occur and reduce economic return. Applying more N than optimum results in unneeded energy input because corn yield does not increase above the maximum response (Figure 1), and therefore an economic and energy loss. Additionally is the increased potential for nitrate loss to tile drainage and groundwater. Therefore, it makes economic, environmental, and energy sense to apply recommended N rates.

Energy Use In Nitrogen Fertilizer Manufacture

Nitrogen fertilizers are predominantly produced using the Haber-Bosch process. Nitrogen gas (N_2) is combined with hydrogen (H_2) to form ammonia (NH_3). Nitrogen gas comes from the air and hydrogen typically from natural gas. Natural gas is also the main energy source. Combining the N and H to form NH_3 requires considerable natural gas, both as the hydrogen feedstock and energy. Therefore, production of N fertilizers is very energy intensive. Other N containing fertilizers are predominantly made from ammonia; including commonly used fertilizers such as urea, urea-ammonium nitrate solutions (UAN 28% and 32%), and phosphorus (P) fertilizers diammonium phosphate (DAP) and monoammonium phosphate (MAP). Due to the large energy use and consumption of natural gas as an energy source and feedstock in ammonia production, the price of N fertilizer is closely related to supply and price of natural gas.

A modern ammonia production plant has a net energy consumption (balance) of approximately 34.5 GJ/mt N (gigajoules per metric ton N) (Kongshaug and Jenssen). In U.S. energy units, this net energy balance is 29,660,000 BTU/ton N (14,830 BTU/lb N); or 29,660 cu ft natural gas energy equivalent per ton N or 0.107 gal diesel fuel energy equivalent per lb N. Upgrading ammonia to other N fertilizers requires more energy. For example, urea is 0.129 gal diesel fuel equivalent per lb N (17,930 BTU/lb N) and UAN is 0.113 gal diesel fuel equivalent per lb N (15,690 BTU/lb N).

Older ammonia production plants are less efficient. The 1998 US average plant had a net energy consumption of approximately 46.3 GJ/mt N (0.143 gal diesel fuel equivalent per lb N). Therefore, efficiency gains in production of ammonia have improved the energy use for N fertilizers and corn N fertilization.

Energy Use In Nitrogen Fertilizer Application for Corn

At recommended rates, N fertilizer application is the largest energy input into corn production. For example, with SC at 125 lb N/acre applied as ammonia, the diesel fuel energy equivalent for N manufacture is 13.3 gal and with CC at 177 lb N/acre is 18.9 gal. There is additional energy use in fertilizer transport and application. For ammonia, the energy for transportation is roughly 1,100 BTU/lb N and for application 1,000 BTU/lb N (Hoeft and Siemens). Energy for transport and application varies somewhat for different fertilizer products due to analysis and method of application. For the rate examples above in each rotation, and N application as ammonia, the energy use for transport and application is much lower than for manufacturing. For SC at 125 lb N/acre is 1.9 gal diesel fuel equivalent and for CC at 177 lb N/acre is 2.7 gal diesel fuel equivalent. The total energy use as diesel fuel equivalent for corn N fertilization is then 15.2 gal for 125 lb N/acre and 21.6 gal for 177 lb N/acre.

As can be seen from the energy input outlined above, optimal use of N fertilizer can have a sizeable positive impact on energy consumption for corn production. In addition, rotating corn with forage legumes can greatly reduce the energy input due to N supply from the rotation where sunlight and the symbiotic relationship between Rhizobia sp. and the forage legume crop provides the energy input (via sunlight and photosynthesis) for the N supplied to a future corn crop.

Energy Use In Phosphorus and Potassium Fertilizer Manufacture

Phosphorus and potassium (K) are important fertilizer inputs for corn production. The energy use in modern manufacturing technology of commonly used P and K fertilizers is much less than for N. In fact, the production of MAP and DAP has a net energy balance where accumulated energy produced is greater than consumed (-14.1 GJ/mt P_2O_5 or -0.044 gal diesel fuel equivalent per lb P_2O_5) (Kongshaug and Jenssen). This occurs due to several processes in manufacturing that release energy. Net energy consumption (balance) in manufacturing potassium chloride (muriate of potash) is 2.5 GJ/mt K_2O or 0.008 gal diesel fuel energy equivalent per lb K_2O. At typical K application rates for corn, the diesel fuel equivalent per acre is quite low compared to N fertilization, even considering additional energy for transport and application.

Summary

Optimal use and management of N fertilizers (and other fertilizers) is important to maximize return to the energy consumed in manufacture, transportation, and application for corn production. Efficiency gains can be achieved by avoiding losses during and after field application, applying recommended rates, and substituting manure and legume N where energy has already been captured. Choice of N application rate is important for maximizing economic return and minimizing environmental loss. It is also important for maximizing net energy return through crop capture of sunlight and grain/stover production.

References

Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. PM 2015. http://www.extension.iastate.edu/Publications/PM2015.pdf. Iowa State University Extension, Ames.

Do fertilizers waste energy. R.G. Hoeft and J.C. Siemens. 1975. Crops and Soils Magazine. American Society of Agronomy, Madison, WI.

Energy consumption and greenhouse gas emissions in fertilizer production. G. Kongshaug (original author, 1998) and T.K. Jenssen (amended, 2003). International Fertiliser Society Meeting, London, United Kingdom.

Energy Unit Conversions

1 Giga Joule (GJ) = 947,800 BTU
1 Giga Joule (GJ) = 6.819 gal diesel fuel equivalent energy
1 gal diesel fuel = 139,000 BTU equivalent energy
1 cubic foot (ccf) natural gas = 100,000 BTU equivalent energy

Figure 1. Corn yield response to fertilizer N application rate for seven sites across Iowa in 2000-2009, corn following soybean (SC) and corn following corn (CC). Data from J.E. Sawyer and D.W. Barker, Iowa State University, Department of Agronomy.

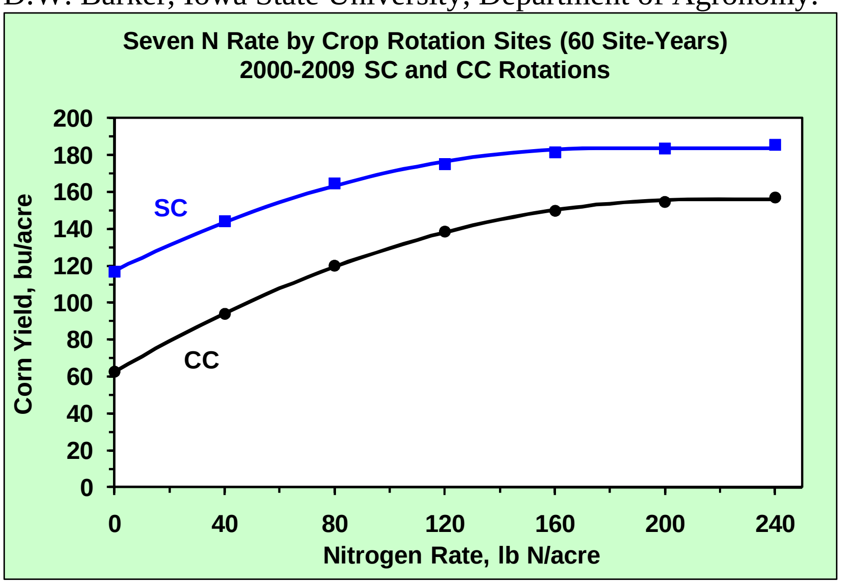

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Figure 2. Recommended N rate (MRTN, Maximum Return To Nitrogen) for corn following soybean in Iowa with N at $0.35/lb N and corn at $3.50/bu (from the on-line Corn Nitrogen Rate Calculator, 2009)

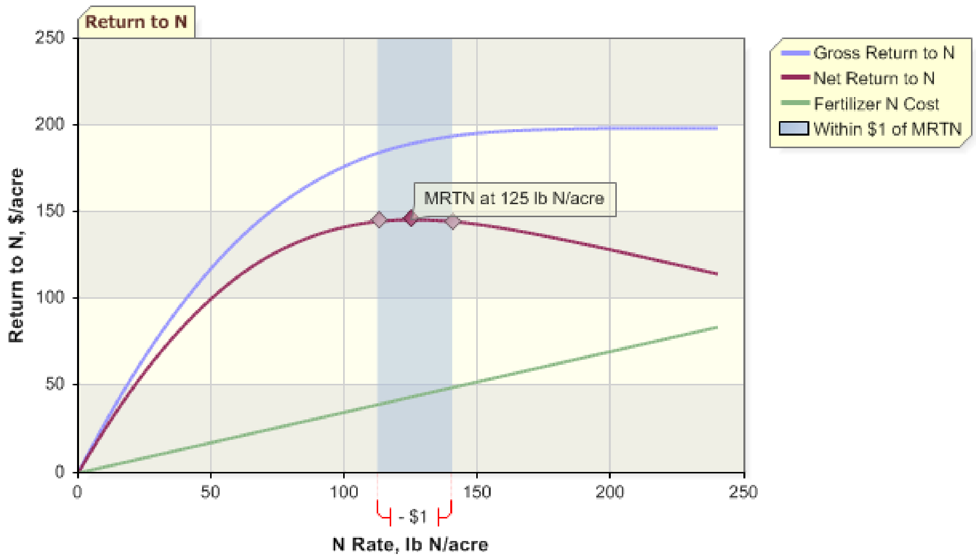

Figure 3. Recommended N rate (MRTN, Maximum Return To Nitrogen) for corn following corn in Iowa with N at $0.35/lb N and corn at $3.50/bu (from the on-line Corn Nitrogen Rate Calculator, 2009).