Demand for increased production of crops and improved environmental quality has created an opportunity for agriculture to refine nutrient management in agricultural systems. This sentiment has been stated by Dobermann and Cassman (2002), in which they called for increased efforts on nutrient management practices that optimize profit, enhance soil quality, and protect natural resources in the context of building crop production systems that produce consistently high yields. The concept of improving nutrient management is not new. Nearly 40 yr ago Frye (1977) observed improvements in corn (Zea mays L.) yields with sulfur-coated compared with non-coated urea. More than a decade ago, Shaviv (2001) detailed the advances in controlled-release fertilizers and proposed these could be an effective means of enhancing synchrony between soil N availability and plant uptake demand for N.

During the past 10 yr there has been an increased interest in the use of "enhanced efficiency fertilizers" (EEFs) for their potential to reduce the environmental impact. A point of confusion that often exists is what constitutes an EEF. The term has been recently defined by the Association of American Plant Food Control Officials (AAPFCO) as "fertilizer products with characteristics that allow increased plant uptake and reduce the potential of nutrient losses to the environment (e.g., gaseous losses, leaching, or runoff) when compared to an appropriate reference product" (AAPFCO, 2013). In the AAPFCO definition, enhanced efficiency reference products are defined as "soluble fertilizer products (before treatment by reaction, coating, encapsulation, addition of inhibitors, compaction, occlusion, or by other means) or the corresponding product used for comparison to substantiate enhanced efficiency claims." Nitrogen products that would be considered as EEFs would include nitrification and urease inhibitors, uncoated slowly available fertilizers, and coated N fertilizers. These materials would be used to increase N availability to crops throughout the growing season while decreasing environmental impacts.

The need to understand the effects of EEFs for their effect on nitrous oxide emissions and agronomic performance was the motivation underpinning this multi-location study across North America. To accomplish this goal the research was supported by Agrium, Koch Agronomic Services, and USDA-ARS with cooperation from universities across the United States and made possible through the administrative efforts of the Foundation for Agronomic Research (Monticello, IL). Research locations participating in this study included Ames, IA; Auburn, AL; Bowling Green, KY; Fort Collins, CO; St. Paul, MN; Pullman, WA; University Park, PA; and Winnipeg, MB, Canada. All of these sites collected observations on various potential EEFs for their effect on nitrous oxide emissions throughout the year and agronomic performance of corn, cotton (Gossypium hirsutum L.), and/or wheat (Triticum aestivum L.).

These studies compared several products designed to perform as EEFs to their standard forms; the products included polymer-coated, controlled release urea (46% N) (Environmentally Smart Nitrogen or ESN, Agrium, Loveland, CO), stabilized urea (46% N) containing urease and nitrification inhibitors (SuperU, Koch Agronomic Services, Wichita, KS), and a urease and nitrification inhibitor for urea–ammonium nitrate (32% N, UAN + AgrotainPlus, Koch Agronomic Services, Wichita, KS). An additional study evaluated nitrapyrin (Dow Chemical Company, Indianapolis, IN) for its effect on corn production in the Corn Belt (Burzaco et al., 2014).

The studies commenced in 2008 and continued through 2011 with the goal of quantifying the effect of these different materials on nitrous oxide emissions and agronomic response. Similar techniques were employed to quantify nitrous oxide emissions and provide a statement on the seasonal responses of different EEF materials for their greenhouse gas reduction potential on a site-specific basis. The experimental treatments for these studies were designed to ensure the ability to statistically evaluate results and document quality assurance/quality control for each measurable attribute. The experiments were conducted with a common goal and followed the guidelines provided by Parkin and Venterea (2010), but did not necessarily use exactly the same methodologies for nitrous oxide emissions. Agronomic observations were measured with the techniques appropriate for each crop, and yield was the common parameter among sites to compare these different N materials.

Several articles demonstrate that EEF materials can affect the nitrous oxide emission rate from soils, especially during the period immediately after fertilizer application and more consistently under irrigated production systems. Research in Colorado by Halvorson et al. (2014) showed ESN reduced...