Cereal Crop Production As A Control Point For Reactive Nitrogen

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The largest input of reactive nitrogen (Nr) in North America is nitrogen (N) fertilizer used for crop production. The mean annual N fertilizer input to North America between 1999 and 2003 was 12.5 Tg (million metric tons). Of this fertilizer N, 66% was used to fertilize cereal crops, mainly corn and wheat (Dobermann and Cassman, 2005).

Corn yield in the USA has increased from an average of 100 bu/ac in 1985 to 136 bu/ac in 2005 as a result of improved nutrient and pest management, expansion of irrigated area, conservation tillage, soil testing, and improved crop genetics (yield and pest resistance) (CAST, 2006). From 1980 to 2000, N-fertilizer use efficiency (NFUE, kg grain produced per kg applied N) increased from 42 to 57 kg kg^{-1}, a 35% efficiency gain during a period when average USA corn yields increased by 40% (Fixen and West, 2002). Despite this steady increase in NFUE, the average N fertilizer uptake efficiency for corn in the north-central USA was 37% of applied N in 2000 based on direct field measurements (Cassman et al. 2002). These results indicate that a large majority of the applied N fertilizer is vulnerable to loss pathways such as volitilization, denitrification, runoff, and leaching. The results also suggest there is substantial room for improvement in N efficiency currently achieved by farmers.

Although progress has been made to increase both cereal yield and NFUE, a concerted effort to further increase NFUE remains a logical control point to reduce production costs, because N fertilizer represents a significant input cost, and to limit Nr leakage (e.g. NH_3, NO_x, N_2O, NO_3^-) from agroecosystems.

The goal of reducing Nr while sustaining adequate rates of gain in cereal production to meet expected food demand will require increases in both total nitrogen use efficiency (NUE) and NFUE, which in turn will require innovative crop- and soil management practices. This need is exacerbated by the recent increase in demand for corn to produce ethanol biofuel. The concept of improved N synchrony—practices that better match the amount, timing, and geospatial location of applied N to crop-N demand and the N supply from indigenous soil resources-- is generally viewed as the most appropriate approach for improving NUE (e.g. Appel, 1994; Cassman et al. 2002). The challenge is for greater synchrony between crop N demand and the N supply from *all sources* (e.g. soil, fertilizer, organic inputs such as manure, compost, or green manures, etc) throughout the growing season. Losses from all N-loss mechanisms increase in proportion to the amount of available N present in the soil profile at any given time.

Several promising technologies and combinations of technologies have emerged in recent years. Significant increases in NUE are often achieved through reductions in N fertilizer use by 10 to 30 %, while increases in yield tend to be small (Giller et al. 2004). Figure 1 indicates where expected greatest gains in NUE are to be realized in the future from different technology options. Each of these improvements in management and genetics helps to better match the amount and timing of applied N to crop-N demand and the N supply from indigenous resources. However, large investments in research, extension education, and technology transfer will be required to achieve the degree of improved synchrony needed to make substantial improvements in NUE. The need to accelerate the rate of gain in crop yields to meet increasing demand for human food, livestock feed, and biofuels represents an additional new challenge. Crop prices are expected to rise as they more closely track the price of petroleum (CAST, 2006). Higher crop prices will motivate farmers to achieve higher yields, and higher crop yields require a greater amount of N uptake to support increased biomass production (Greenwood et al., 1990). Therefore, an explicit emphasis on developing technologies that contribute to both increasing yields and NUE will be needed to ensure that the goals of food security, biofuel production, and protection of environmental quality are met.

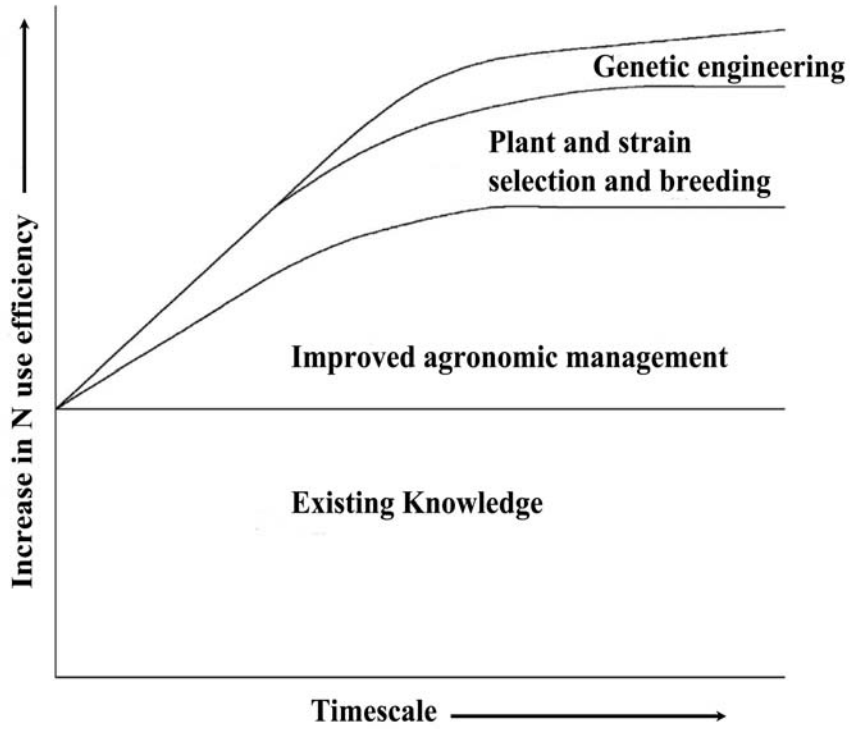

Fig. 1. The likely impact of research investment in increasing N Use Efficiency (Giller et al. 2004).

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