Improving nitrogen management in cropping systems is important for the economic, environmental, and social goals of 4R Nutrient Stewardship. Increasing nitrogen recovery efficiency (NRE) is part of this [NRE = (nitrogen accumulation with fertilizer – nitrogen accumulation without fertilizer)/nitrogen rate; Mueller et al., 2017]. Corn grain yield increases with increased nitrogen application. Recent research conducted as part of the 4R Research Fund reported that from 0 to 200 lb N/ac, grain yield increased by 42%, but beyond that rate, no further grain yield response to nitrogen fertilizer was seen (Omonde et al., 2017). As fertilizer nitrogen application rates increase, nitrous oxide (N₂O) emissions are likely to increase linearly. Nitrous oxide emissions are negatively related to NRE; as NRE increases, N₂O emissions decrease (Omonde et al., 2017). Increases in NRE can be driven by greater uptake of nitrogen by the plant or reduced nitrogen rates, but the largest gains in NRE will be achieved by higher nitrogen uptake and lower nitrogen rates.

The source, placement, and timing of nitrogen fertilizer can all impact nitrogen uptake by the plant. The magni-
tude of the decrease in N₂O emissions with increased NRE varied depending on the number of 4R management practices considered. When only nitrogen rate was adjusted, N₂O emissions decreased by 0.011 lb N/ac for every 1% increase in NRE (Omonde et al., 2017). However, N₂O emissions decreased by 0.017 lb N/ac for every 1% increase in NRE when rate and timing of nitrogen application were adjusted (Omonde et al., 2017).

In-field research has shown that NRE consistently improves with a late split nitrogen fertilizer application, but corn grain yield does not (Mueller et al., 2017). Further research is needed on the impact of combining source, rate, time, and placement changes in a single experiment and their impact on NRE.

Improving NRE can have economic and environmental benefits, and how nitrogen rate recommendations are made can have an impact. Multiple factors influence the amount of nitrogen available to the plant for uptake from the nitrogen that is applied and the resulting NRE of that crop. While many of the weather- and soil-related factors that influence NRE and timing recommendations can increase NRE (Omonde et al., 2017). The challenge for producers and consultants is whether or how changes in source, timing, and placement can be accounted for in nitrogen rate recommendation systems.

Nitrogen recommendation challenges

The 2016 USDA Chemical Use Survey reported that 13.22 million lb of nitrogen fertilizer were used across the 94 million acres of corn planted. Current research and recommendation systems assume that anywhere from 35 to 75% of the nitrogen fertilizer applied to corn is taken up by the plant (Morris et al., 2017). This range presents multiple challenges. First with a range this large, it is difficult to be accurate in the fertilizer recommendations. Second, even at a 75% recovery, farmers are still potentially losing 25% of the nitrogen fertilizer applied. Timing of nitrogen fertilizer applications plays a role in uptake. Depending on weather conditions, nitrogen uptake after silking can range from 22.4 to 40.8% of the total nitrogen uptake by the plant (Mueller et al., 2017).

A group of scientists recently published a review on nitrogen recommendation systems currently in use and what the options are for advancing recommendation systems into the future (Morris et al., 2017). The article covers yield-based recommendations systems, the Maximum Return to Nitrogen (MRTN) recommendation system, soil nitrogen tests, plant sensing and tissue testing, computer simulation models, and adaptive nitrogen management. This article will cover a few of these and some other recent research on tools for in-season nitrogen recommendations and recent research on late-season nitrogen application.

Yield-based nitrogen recommendations

Land grant universities in 34 states make yield-based nitrogen recommendations (Morrie et al., 2017). One of the largest challenges to this method is how the yield or yield goal is determined. This varies depending on the state; some base it on the expected yield of the soil from USDA data, others require a five-year average of yield, and a majority of states using this method do not provide any guidance on how to determine the expected yield. The second major component of this system is the expected amount of nitrogen taken up by the plant. This number varies across geographies from 0.8 lb N/bu to 1.6 lb N/bu (Morris et al., 2017). The base of the nitrogen recommendation in this system multiplies the yield goal by the nitrogen uptake. However, adjustments can be made for soil conditions or type, credits from manure applications, credits from legume crops, and weather, and so the nitrogen recommendation can vary widely across the states using this method. The simplest form of the yield-based equation is

$$\text{nitrogen fertilizer} = [(\text{N uptake} \times \text{yield goal}) – \text{N credits}]$$
One of the strengths of yield-based recommendations is that farmers and farm advisers see this as a “logical” system where fertilizer nitrogen rates match the expected yield of the crop (Morris et al., 2017). However, the uncertainty of this system makes it inaccurate for many locations and management systems. Factors like the lag time between estimating yield to calculate nitrogen fertilizer needs, soil nitrogen mineralization, fertilizer use efficiency, corn hybrid ability to use nitrogen, weather, landscape, and soil biological, chemical, and physical properties can all influence the accuracy of this method (Morris et al., 2017).

Maximum Return to Nitrogen system

The Maximum Return to Nitrogen (MRTN) system calculates nitrogen recommendations by incorporating data from nitrogen yield response trials, farm corn yield, corn grain price, and nitrogen fertilizer price. The calculator (http://cnrc.agron.iastate.edu/) currently covers seven states (IL, IN, IA, MI, MN, OH, and WI). The development of the tool involved compiling nitrogen yield response data and using regression analysis for each nitrogen rate trial across a large trial database and determining the average return to nitrogen rate across specific groupings of the response trials (Morris et al., 2017). The main strengths of the MRTN approach are the direct relationship to nitrogen response trials and the incorporation of economic variables into the determination of nitrogen recommendations. A challenge with this tool is the ability to make a compiled list of field-by-field recommendations or subfield recommendations.

Nitrogen soil-testing methods

There are soil tests for nitrate that can be conducted pre-plant or in season. Pre-plant nitrate tests are more commonly utilized in drier regions with deep soils where leaching and/or denitrification losses are minimal (Morris et al., 2017). The pre-plant nitrate test value represents the residual carryover of fertilizer nitrogen (Morris et al., 2017). The pre-sidedress nitrate test (PSNT) was developed in Vermont for making in-season nitrogen recommendations for sidedress or to adjust nitrogen sidedress recommendations that could have been impacted by weather or the rate of nitrogen mineralization from animal manure applications. A third option for soil nitrate testing is the Illinois Soil Nitrogen Test (ISNT). The soil can be sampled for the ISNT anytime during the year, except within five weeks after manure spreading or sod/cover crop turnover.

Using a soil nitrogen test can be a valuable tool to adjust nitrogen rates, increase nitrogen use efficiency, and reduce nitrogen loss to the environment (Morris et al., 2017). However, there are many challenges to this method. Sampling for pre-season and PSNT soil tests requires deeper sampling depths—23.6 to 47.2 inches for the pre-season samples and 11.8 inches for PSNT samples. These depths can be a challenge to obtain, depending on the soil conditions and equipment available. Other challenges for soil nitrogen tests are sample timing and processing time. Nitrogen or nitrates in the soil can change rapidly in humid or wet conditions, so soil sampling as close to the desired nitrogen application time is ideal, but weather conditions can delay sampling. Finally, depending on the lab service and shipping time, turnaround for sample analysis can slow down when field applications can be made, and conditions can change if the results take more than three days to obtain.

Plant spectral sensing

Using tools for sensing the nitrogen status of the corn plant can be very useful for in-season evaluation of crop nitrogen needs. Nitrogen status of a plant is reflected in physical properties of the plant like leaf coloring. Spectral-sensing tools can be used to evaluate that status and have the advantage of continuous evaluation during the season (Morris et al., 2017). There are multiple tools available for measuring chlorophyll or light reflectance of leaves that can be related to nitrogen rates. The challenge of these tools is that many of them require a check strip to test against a non-nitrogen-limited sample. There is also evidence that time of day can influence the reading of the instruments (Morris et al., 2017). However, the strength of the nitrogen rate predictions based on these tools is that they are usually found to be more accurate than predictions based on soil samples, other soil properties, or crop yields (Morris et al., 2017).

Recently work has been done to evaluate nitrogen requirements based on the Dark Green Color Index (DGCI; Rhezali et al., 2018). Development of a relationship of this index to nitrogen response trials could allow for in-season nitrogen recommendations based on a digital photograph. Ten treatments were tested at two locations in Arkansas to compare no N applied, various in-season timing of recommendations made using the DGCI, a high rate of 270 lb N/ac, and the extension recommendation of 220 lb N/ac. Additionally, at each site, one set of plots received no N and one received 60 lb N/ac pre-plant. Nitrogen application for the high rate and the extension recommendation was adjusted for the sidedress application if the plots received the pre-plant nitrogen application.

As reported in Morris et al. (2017), when in-season measurements of the nitrogen status of the plant were used to make the recommendation for the in-season nitrogen rates, nitrogen use efficiency increased (Rhezali et al., 2018). Specifically, when no pre-season nitrogen was applied using the DGCI to calculate nitrogen recommendations for sidedress, the nitrogen use efficiency for the season increased by 44 to 45% compared with the
university-recommended rate (Rhezali et al., 2017). This was due to lower nitrogen application rates with the DGCI method and no differences in corn grain yield. The DGCI method evaluated in this study required samples to be taken to the lab and photographed; future research and development will create a tool that can be used in field.

Adaptive management

Adaptive management is the process of planning, implementing, evaluating, and adjusting while learning about new practices and feeding the data collected into a new plan (Fig. 1). Adaptive management is a key part of 4R Nutrient Stewardship where using multiple tools for monitoring and determining the right source, rate, time, and place for fertilizer application is recommended. Combining yield monitoring and prediction, soil testing, plant-sensing technologies, weather monitoring, and end-of-season evaluation of crop nitrogen use can all be used together to maximize nitrogen use efficiency. Other tools that can be useful in an adaptive management system are replicated field trials to evaluate changes in nitrogen source, rate, time, or placement (Morris et al., 2017). Monitoring a measurement like NRE as a part of this system over time can help producers and consultants identify the external impact on nitrogen fertilizer applications. For example, Mueller et al. (2017) found a yield response and an NRE improvement in the growing season where rainfall was limited in 32 days between the first and the second nitrogen applications compared with when rainfall was higher in other seasons.

Conclusions

As technology in seed, fertilizer, crop monitoring, and data collection continues to advance, nitrogen recommendation systems will need to adapt. Recommendation systems that focus solely on the relationship of nitrogen rate and corn grain yield are less likely to be successful (Morris et al., 2017). The influence of source, timing, and placement on rate is essential to consider in recommendations. Additionally, the influence of weather, soil, and other conservation practices on yield and efficiency measures like NRE needs further consideration in the advancement of nitrogen recommendation systems. Finally, one of the most important factors to consider is the ease and cost effectiveness of the systems and the resulting recommendations to the producer.

References


