Nitrogen Loss in 2008

By Peter Scharf

The two biggest fertilizer stories for 2008 are nitrogen loss and fertilizer prices (see other story this issue). My current estimate is that nitrogen loss cost Missouri corn producers $305 million in 2008. The problem was widespread across the midwest, and I estimate that total corn yield loss was about 460 million bushels. Due to a sharp decline in fuel prices, demand for corn (ethanol) is also down and the lost production is not causing major problems for grain users. This means that the price of corn is staying relatively low, so at least the grain production that was lost was not worth what it might have been.

Wet weather and nitrogen loss

How did this happen? All across the midwest, spring and early summer precipitation was heavy. Nearly all of Missouri and Iowa had more than 16 inches of rain from April through June, along with southern Illinois, southern Indiana, southern Wisconsin, eastern Nebraska, eastern Kansas, and southeastern Minnesota. All nitrogen fertilizer eventually converts to nitrate in soil, and nitrate is vulnerable to loss during wet weather.

This year that vulnerability translated into real and widespread nitrogen loss. How do I know this? In early August, I drove almost 2000 miles through Missouri, Kansas, Iowa, Illinois, and Wisconsin, and I also had a pilot take about 1500 aerial photographs in Missouri and Iowa. I saw light-green or yellow-green fields of corn in all of those places with the exception of Illinois north of Interstate 80. In most of these fields, the color was patchy, which I believe related to wetter vs. drier areas of the fields. I stopped to look carefully at 6 or 8 fields and all of them had the classic nitrogen deficiency symptom: a yellow or brown 'arrow' of dying tissue pointing up the midrib of the leaf toward the stem. This symptom is caused by nitrogen deficiency and nothing else.

In southern Wisconsin, where I'm from, I saw several fields in the neighborhood of 100 acres that I estimated would yield 100 bushels below their yield potential due to severe and widespread nitrogen deficiency. That's a 10,000 bushel hit in a single field. At $4 corn, that would be nearly enough to pay for a used high-clearance machine just to take care of that one field.

Any field showing nitrogen deficiency symptoms in early August has lost yield potential. I estimated the amount of yield potential lost in each region based on corn color and more than ten years of experience with tracking yield loss due to nitrogen deficiency. A presentation showing these yield loss estimates and some of the aerial photographs is available online, along with other articles on N loss in 2008, at: http://plantsci.missouri.edu/nutrientmanagement/nitrogen/loss.htm.

Nitrogen management

Often fields with severe deficiency were adjacent to fields with minimal or no deficiency. Nitrogen management, as well as soil properties and weather, had an impact on how much nitrogen and how much yield potential was lost. Sidedress application of nitrogen paid big dividends this year: there was a 44 bushel yield advantage in our experiment near Columbia. Although wet weather creates the risk that sidedressing won't get finished, all of the producers that I know who sidedress all of their corn were able to finish.

Among pre-plant application strategies, spring application of anhydrous ammonia has the lowest risk of N loss. However, I saw a field at the University of Missouri's Hundley-Whaley research farm in northwest Missouri that received 180 lb. N as preplant anhydrous ammonia and another 50 lb. N with the herbicide but that was still severely nitrogen-deficient. Any nitrogen management strategy can be overwhelmed by weather.

Nitrogen loss inhibitors (N-Serve, Agrotain, ESN coated urea) probably produced substantial benefits this year. I didn't have any experiments with N-Serve, but Agrotain-treated urea produced a 14 bushel yield benefit and ESN produced a 31 bushel yield benefit relative to urea broadcast at planting in an experiment near Columbia.

Rescue nitrogen applications: do they work?

Rescue application of nitrogen fertilizer is the key to maintaining yield and profit potential in a year like 2008. I sometimes run into people who are skeptical about recovering yield once the corn has experienced substantial nitrogen stress. My experience and research shows that corn has great capacity to use rescue N to produce additional yield until at least silking. Research by others suggest that this capacity extends at least a week and probably usually two weeks past silking. However, the likelihood of reaching the full yield potential of the crop drops off if rescue applications are delayed until after silking.

I worked with some southeast Kansas producers who applied all of their N preplant but received excessive spring rainfall in 2005. They used a high-clearance sprayer to apply 12 gallons of 32% UAN solution (40 lb N) per acre on June 29 to corn that was head-high. This nitrogen was not applied to the whole field, but to alternating strips (100 feet with N, 100 feet without), resulting in 8 strips with rescue N and 8 without. On about half the field the corn was light green, and in this area the strips that received rescue N were clearly visible from the ground and in an aerial photo taken on July 16. Side-by-side comparisons of yield monitor data showed an average yield response of 35 bushels/acre in the area of the field where stress was visible (light green color). About half of the field did not show stress symptoms, and in this area the rescue N strips were not visible and produced only a 2 bu/acre yield benefit. It's clear to me that rescue N can pay big dividends, but only when an actual N deficiency exists.

Diagnosing deficiency

This leads to another question: How do you know whether a nitrogen deficiency exists? How do you make the decision on whether to pull the trigger on rescue N applications?

This is a difficult question to answer. Soil samples are one possibility. Ron Catlett of Central Missouri Agri-Services in Saline County sampled a number of fields for a customer this year and found N loss ranging from 40 to 100 lb N/acre. Details on how to do this can be found in MU Extension guide G9177 (http://extension.missouri.edu/explorepdf/agguides/soils/G09177.pdf).

However, soil samples need to be deep to work. When weather has been wet enough to cause N loss, it has been wet enough to move much or most of the N into the subsoil. Deep sampling of wet soil on a lot of fields is an unpleasant job, it takes a lot of time, and then you probably will wait at least a week for the lab results even though you may have a short window for rescue N application.

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I like aerial photographs as a tool for diagnosing deficiency. They work best if taken when the corn is waist high or taller, so that soil color is not an issue. However, this limits your rescue N options to high-clearance equipment or airplanes. I've known others who were able to identify and treat nitrogen deficiency in knee-high corn using aerial photographs.

Aerial photographs also work best after the field is no longer saturated and the corn has time to take up whatever nitrogen is left. Corn will appear nitrogen-deficient (and actually be nitrogen-deficient) in saturated soils even if the nitrogen has not been lost.

The biggest advantage of aerial photographs is speed. You can probably photograph all of your corn fields in a few hours. Usually it's not very expensive to hire a pilot for a few hours. A high-wing plane works best, so that the wing is not between you and your fields. It's generally pretty obvious where the problems are.

August 1 aerial photograph of a corn field in the Missouri river bottom in northwest Missouri with severe and patchy nitrogen deficiency. There are a few drowned-out areas, but nitrogen loss is limiting yield much more than stand loss. The dark (dark green if you're seeing the photo in color) areas have sufficient nitrogen, and the light areas are highly nitrogen-deficient. The streaky, patchy mix of color in this field reflects the topography and where water runs or stands in the field. The nitrogen-deficient areas are the lower, wetter parts of the field. Applying rescue N only to the deficient areas could potentially be done using a plane or using a ground-based applicator equipped with crop color sensors.

We have developed a procedure for turning an aerial photograph into a map of potential yield loss if rescue N is not applied. When you're thinking about dollars and effort required to make a rescue application, it would be helpful to have some knowledge of how much you're losing if you don't make the application. This product is not currently available commercially, although we are looking for ways to get it on the market (we were trying to license it to John Deere's aerial imagery program before they got out of the business in fall 2007). If and when this service becomes available, I think that it will be the fastest and most reliable way to make decisions about rescue N applications.

Making rescue nitrogen applications

I think that every producer, retailer, and retail organization in Missouri and the humid corn belt should have a 'Plan B' of exactly how they will apply rescue nitrogen if it's needed. If this plan is not in place before planting, it's unlikely to be successfully developed in the heat of the moment. Although I saw more nitrogen-deficient corn in 2008 than in any other year in the last 12, nitrogen-deficient corn due to wet weather has been a problem somewhere in Missouri almost every year.

Virtually any method of making rescue N applications is a good method, with the exception of broadcasting UAN solution onto a crop that is taller than one foot. That said, we have compared several methods and learned that:

1) Broadcast urea causes almost no yield loss due to leaf burn. In our research, we applied 150 lb N/acre as urea on corn up to four feet tall, and the yield difference between broadcast and in-row placement of urea was generally less than 4 bushels/acre. However, we made an attempt to use non-dusty urea at times when no dew was on leaves. Dusty urea on wet leaves might cause more yield loss. Urea is clearly a better N source than ammonium nitrate for aerial application (see #3 below).

2) Agrotain coating of urea improved yield response of corn when the corn was 1 or 2 feet tall, but not when the corn was 3 or 4 feet tall. The taller corn has less air movement at the soil surface, which probably reduces volatilization loss from the urea. Also, corn leaves can absorb ammonia from air, so ammonia that volatilizes from urea applied to tall corn may be captured by the leaves before escaping into the air above the canopy.

3) Ammonium nitrate causes substantial yield loss (about 20 bushels/acre) due to leaf burn when broadcast over 3 or 4 foot tall corn, moderate yield loss (8 bushels/acre) when broadcast over 2 foot tall corn, and no yield loss when broadcast over 1 foot tall corn.

4) UAN solution dribbled between rows was an effective rescue N treatment. Broadcast UAN solution caused severe yield loss due to leaf burn.

Spatial variability and rescue N applications

The aerial photograph shows a field with severe but patchy nitrogen deficiency. This is typical because the amount of nitrogen lost depends on wetness, which is different in different parts of the field. There are areas that need no nitrogen, and other areas that probably need more than 100 pounds of N per acre. How would you fertilize this field once you had equipment in place that could apply N?

If you apply a uniform application that will bring the most deficient areas to full yield, large amounts of fertilizer will be wasted

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in the areas that already have enough N. If you apply a half rate, you will lose yield potential. Ideally you would apply the N only to areas where you will get a yield response and return to investment.

The simplest way to do this would be to hire an aerial applicator with instructions to follow the light green streaks with the plane. With an ground-based applicator, it's probably necessary to drive through the N-sufficient areas, but preferable to not apply fertilizer in them. One way to accomplish this is to equip the applicator with crop color sensors; then you could turn off (or at least down) the fertilizer rate applied in these areas, while applying high rates in the deficient areas. We've worked extensively with using crop sensors to control variable-rate N applications, which I will write about for another newsletter in the near future. Another way would be to use an application map based on an aerial photograph that would only apply N in the deficient areas.

Logistics of rescue N application

Equipment is a major issue in making rescue N applications. Many producers do not have equipment that can apply N once corn is too tall for tractor clearance, and if they do it's probably busy spraying beans and not plumbed for N. These two factors apply to much of the equipment at retail locations as well. Figuring out which piece(s) of equipment will be used for rescue N applications if a severe N deficiency situation develops, and making modifications in the off-season if needed, is the biggest part of a successful 'Plan B'.

Except in the bootheel, there is minimal tradition and availability of aerial applications in Missouri. This has changed somewhat over the past two years as fungicide applications have taken the midwest by storm. Aerial applications are an excellent option for rescue N application.

I have heard that there is simply not enough equipment available in the midwest to have taken care of all the nitrogen deficient corn fields this year. This is probably true. I have estimated that there were almost 15 million acres of corn where it would have been clearly profitable to apply rescue N this year. By comparison, Laura Sweets estimates that we went from less than 100 thousand acres receiving fungicide in 2006 to 12 million acres receiving fungicide in 2007. Much of the equipment used for fungicide application could also be used for rescue nitrogen application, and in 2008 probably it should have been. In my opinion, lack of information and decision tools limited acres of rescue N in 2008 much more than equipment availability did.

Another important logistical consideration in a year like 2008, once we get our act together and TRY to rescue the corn, is whether the fertilizer can be moved into place in time. This is an important question as we move away from domestic production of nitrogen fertilizer. Not much nitrogen is warehoused in North America in excess of anticipated seasonal needs any more. I estimated that it would take 300 million lb N to take care of all of the profitable rescue applications in 2008. If supplied all as urea (one of the most easily mobilized and easily spread forms of N), this would be roughly 300,000 tons. I spoke with Mike Stegmann of Lange-Stegmann in St. Louis and he felt that this could all be moved into the corn belt by July 1 if orders and signals of need started by mid-May, but that rail car availability might be a bottleneck. Adding in UAN as part of the solution (sorry) would make the logistics easier.

How orders could start by mid-May is a problem. My thought is that this is where computer models might come in. An online program called Adapt-N has been brought online in New York. It uses weather, soil, and management data to predict how much N loss might have occurred, might occur in the future, and what the likelihood of a yield response to rescue N would be. I do not think this approach would be as accurate as aerial photography for field-by-field diagnosis, but I think it could work earlier to 'sound the alarm' at a regional scale and put in motion the process of moving more fertilizer into the region.

Summary

- 2008 started with a wet spring and late planting. The wet weather continued into early summer, with more than 16" of rain from April to June over most of Missouri.
- The wet weather was widespread over the corn belt states.
- In windshield and aerial photo surveys over five states I saw lots of nitrogen-deficient corn. This was due to excess water causing nitrogen loss.
- My estimate of yield loss due to N deficiency is 68 million bushels for Missouri and 460 million bushels across the midwest.
- Sidedress N application out-yielded preplant N application by 44 bushels in our experiment near Columbia.
- Anhydrous ammonia was probably the preplant N source least vulnerable to loss.
- N-Serve, Agrotain, and ESN coated urea were probably very profitable this year.
- Application of rescue N would have been very profitable in many corn fields in Missouri. My impression is that only a small percentage of stressed fields received in-season nitrogen fertilizer.
- Obstacles to rescue N application include:
  - difficulty in deciding how big the problem is
  - equipment availability and setup
  - possibly fertilizer availability if rescue applications are done on millions of acres
- I think that every producer, retailer, and retail organization should have a plan in place as to what equipment and fertilizer they will use to make rescue N applications in years when they are needed.
- The most practical options for rescue N are:
  - UAN solution dribbled or injected between rows.
  - urea broadcast with an airplane or a high-clearance spinner or boom spreader.

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