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Managing Nitrogen for Corn in 2020

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As was the case a year ago, there have been limited opportunities to apply nitrogen fertilizer since last fall. Rainfall in Illinois through the first three weeks of March has been at or above average, and temperatures have been a few degrees above normal. Soils remain wet, and there is little in the current weather pattern to indicate that a drying period is on its way soon. Potential drying rates will increase as temperatures rise, though, and we will hope that rainfall remains at or below normal to allow soils to dry as we move into April.

N Rate

Despite difficult conditions in 2019, Dan Schaefer of the IFCA and John Pike in southern Illinois, with funding from the Illinois Nutrient Research & Education Council (NREC), were able to conduct on-farm N rate trials that showed that responses in most regions, even with late planting, were similar to those found in recent years. Yields were generally not as high as in 2018, but in central and northern Illinois, the fact that responses were similar to those already in the database meant that adding the data from the 2019 trials didn't change the guideline N rates (MRTN values) by very much for this part of the state.

The 2019 data in southern Illinois, however, continued the trend we saw in 2017 and 2018, in which higher yields required higher N rates to reach those yields. Such a correlation between optimum N rate and yield across trials does not exist in higher organic-matter soils in central and northern Illinois. We think this is because weather conditions (warm temperatures and plentiful moisture) that lead to high yields (and high N uptake) also increase the amount of N supplied by mineralization of soil organic matter, leaving the amount to be supplied by fertilizer unchanged, at least on average. In contrast, soils in southern Illinois have less organic nitrogen to mineralize, so high yield levels there make the crop more dependent on N from fertilizer.

This correlation between N rate and yield in southern Illinois supports the idea that we consider adding more fertilizer N to corn growing in lower organic-matter (<2% OM) soils in southern Illinois if the crop has high yield potential. I suggest using the MRTN rate for yields up to 190-200 bushels per acre, and for yield potentials above that (determined based on crop condition when corn is 2 to 4 ft tall), use a total of 1 lb of N for each bushel of expected yield. That may often mean applying N with high-clearance equipment, either as broadcast urea or as UAN dribbled near the row. Dribbled N often distributes more uniformly, and leaving UAN on the surface near the row moves it closer to the root system and may improve uptake.

Use the N rate calculator to calculate best (MRTN) N rates for corn in Illinois. We updated the database in early March, adding the 2019 data and removing some of the older data. Using a corn price of $3.50 per bushel and the current ammonia price of about $500 per ton ($0.30 per lb of N) produces the MRTN values and ranges shown on Table 1 below. Low and high ends of the range are those N rates at which the return to N ($ per acre) are $1.00 less than at the MRTN. MRTN values are also shown for N prices of $0.40 and $0.50 per lb, keeping the corn price at $3.50 per bushel. N prices for UAN and urea are currently around $0.43 per lb of N.

Remember that the MRTN rate (and ranges) generated by the N rate calculator includes all of the N applied to the field, not just to the main application. This means counting into the total any N applied with MAP or DAP in late fall or spring, any N applied with herbicide or with the planter. If N from several different sources is used, base the rate of the last application (adding in all previous amounts) on the price of fertilizer N that is used for the last N application.

Table 1. Current MRTN (guideline N rates) for Corn in Illinois, after Adding the Data from the 2019 Growing Season

		No. of	MRTN and range, $0.30/lb N			MRTN, N at:	
IL Region	Rotation	trials	Low	MRTN	High	$0.40/lb	$0.50/lb
North	Soy-C	65	153	169	185	162	152
	Corn-C	69	186	200	216	196	183
Central	Soy-C	274	166	180	193	175	166
	Corn-C	151	183	193	209	193	182
South	Soy-C	122	182	195	210	191	179
	Corn-C	30	183	198	216	191	181

N Timing

In about 90 percent of on-farm trials comparing N rates applied as ammonia in both the fall (with N-Serve) and the spring, fall- and spring-applied N have produced virtually identical responses to N rate, at the same yield levels. Across 16 trials, including several in which spring-applied N performed better, and several in which fall-applied N performed a little better, the optimum N rate averaged about 12 lb higher—181 versus 169 lb/acre—and the yield at the optimum N rate 1 bushel less—235 versus 236 bushels per acre—for fall-applied N compared to spring-applied N. That meant an advantage of $9 per acre in return to N for spring-applied N, but since getting that added return would have required knowing when and by how much to decrease N rates for spring-applied N, it would have been difficult to realize this benefit. The average optimum N rate for fall-applied N was almost identical to the MRTN for central Illinois (Table 1): using the MRTN would meant using more than the optimum N rate in more of the spring-applied N trials, and so would have meant less advantage for spring-applied N across these trials.

One of the main lessons we've learned from our N timing and N form studies in recent years is that, in order to maximize yield potential, corn plants need to have a substantial amount of N available in the soil near the row after plants emerge and before their nodal (main) root system starts to develop. In one study in 2019, the crop was planted in late April but fertilizer rates couldn't be applied until early June due to wet May weather. As a result, N responses rose in a straight line up to the maximum N rate used (250 lb of N), and did not reach a maximum. We also saw several instances in which cover crop rye was not controlled early, and probably because the rye roots had stripped the N from the upper soil, corn yield suffered even when high rates of N were applied after the crop emerged.

We don't know exactly how much N needs to be present during early corn growth, but we believe that this N needs to be in the soil near the plants when the nodal roots begin to appear—at about growth stage V2. To have 40 to 50 ppm available N in the upper soil at V2 means incorporating 40-50 lb N in the top 3.5 inches of soil, and having most of the N stay there. If we incorporate N into a zone 7.5 inches wide by 3.5 inches deep centered on the row, only 10 to 12 lb N per acre will produce 40 to 50 ppm, if the N uniformly distributed and if it stays there for at least 3 weeks (300 GDD) after planting. That amount (but not much more than that) could be applied in-furrow, but any downward movement of that N would take it out of the rooting zone of small plants. Applying 30 to 50 lb N in a 2 x 2 placement, or dropping liquid or dry fertilizer over the row to provide 30 or 40 lb of N per acre would better assure having N when it's needed early, if there's equipment to do that. In-furrow placement of 10-12 lb of N as UAN is better than nothing. Seedling damage from such applications is rare, but split-tube placement with a seed firmer will protect a little better against this.

Even if planting is delayed and takes precedence over N application, some N really does need to be applied into or atop the row before the crop emerges: it is too risky to wait for several weeks to get the first N applied, especially if even that N is not placed near the row. If it stays wet this spring, some producers and retailers might need to get creative in order to get this done. Delayed planting means warmer soils at planting, and warmer soils mean more mineralization. This will boost the soil N supply some, but especially if rain moves some of the mineralized N down, there may still not be enough to maximize yield potential of the crop.

Splitting N

In one set of results from different forms and times of application of 150 lb N per acre, we found that a split with 100 lb at planting and 50 lb applied in-season generally yielded a little more than applying all of the N between the rows at planting. Applying 50 lb N as broadcast UAN at planting (to mimic the use of UAN as herbicide carrier at or after planting) then 100 lb as UAN injected at stage V5 did not yield as well, probably because there wasn't enough N near the root system when it was needed, before sidedress. Most of the treatments with 100 lb N injected at planting followed by 50 lb as sidedressing worked about equally well. Waiting until sidedress time to apply all of the N was not an effective way to apply N, and placing UAN on the soil surface also produced lower yields, even when urease inhibitor was included. All of these point to the importance of having enough N in the soil early enough to maximize yield potential during early growth, and of applying all of the N in a way that results in less loss.

We also found in these studies that splitting N—with some at or before planting and the rest as sidedress—often produces yields no higher than applying the same rate (with appropriate placement) early. That does not mean we shouldn't split-apply N, but we should do it more for logistical purposes than as a way to get higher yields with the same (or lower) rate of N, at least on productive soils. We have found no advantage to keeping back 50 lb N to dribble in-row at tassel, nor have we found an advantage to applying N several time (spoon-feeding) during the season. Very wet June weather, such as we had in 2015, in some cases meant a response to adding *additional* N. But getting N applied under such conditions is not easy, and every trip to apply N brings the added cost of application as well as the risk of not having the N get to the roots for uptake in time for the plant to respond.

Inhibitors

Despite the fact that inhibitors sold as N fertilizer additives have been around for decades, there remains a considerable amount of confusion about these products, including what they do, and when and how they should be used. *Nitrification inhibitors* slow the activity of bacteria in the soil that convert ammonium to nitrate. Both ammonium and nitrate can be taken up by plants, but the ammonium form is attracted to negative charges on clay and organic matter, and so stays in the soil, while nitrate is negatively charged, so moves readily with water as it moves down through the soil. So slowing the conversion of ammonium to nitrate (nitrification) is a way to keep more N in the soil and available to the crop under high-loss (wet) conditions. Chemicals sold as nitrification inhibitors include nitrapyrin (products include N-Serve® and Instinct II® by Corteva); pronitridine, a newer product developed and sold as Centuro® by Koch Ag; and dicyandiamide (DCD), a nitrification inhibitor sold by a number of companies under different trade names.

We normally add a nitrification inhibitor with anhydrous ammonia applied in the fall. The later we apply ammonia in the spring the less likely it is that a nitrification inhibitor will be needed to protect the N. As a biological process, nitrification is slow when soil temperatures are in the 50s (through early-, mid- and late April in southern, central, and northern Illinois), and begins to speed up once soil temperatures reach 60 and above, which usually occurs in late April in southern Illinois and mid-May in northern Illinois. If we add in the effect of the NH_3 itself in suppressing microbial activity, it's unlikely that applications of ammonia made after mid-April in southern Illinois or after early April in northern Illinois will need the further delay in nitrification provided by nitrification inhibitor. There are exceptions to this: May can be warm and wet, with rapid conversion to nitrate, in which case a nitrification inhibitor can be helpful. But if the crop is planted early and grows fast in May, uptake starts early as well. And if the weather is relatively dry, N is unlikely to move in the soil even if it's all nitrate. This makes it difficult to know at the time of application whether we should add a nitrification inhibitor, and we should play the odds based on current conditions and expected planting time to help make this decision.

Because cool soils are slow to dry, early spring (preplant) applications of ammonia are usually done when soils are wetter than ideal. Ammonia application on wet soils means more soil compaction, and with the diameter of the ammonia band very small when application is into wet soil, its concentration in the band is high. If the soil dries out considerably after application (a rarity if it's wet into April), NH_3 can begin to leave the band where it's been dissolved and to move up in the soil through the knife track, where it could damage seeds or roots. Using RTK to apply the band 6 to 8 inches away from where the row will be planted can eliminate such damage. Tilling after ammonia application can also help disperse the band and will usually lower or eliminate the risk of ammonia injury on seedlings. Deeper placement can also help prevent damage, but will leave the N farther from the roots.

The other type of inhibitor sold for adding to N fertilizer is *urease inhibitor*. Inhibitors that do this include NBPT (sold under different brand names), and mixtures of NBPT with duromide (ANVOL® from Koch Ag) and with NPPT (Limus® from BASF). Thiosulfate, which is also used as a sulfur source, is thought by some to inhibit urease, although lab studies tend to show that it's less effective. As the name implies, urease inhibitors are effective only when added to urea or to other urea-containing fertilizers such as UAN solution. They do not slow the conversion from ammonium to nitrate; they only slow the breakdown of urea into ammonia and carbon dioxide. If this breakdown happens on or near the soil surface, ammonia can go off as ammonia gas into the air.

Ammonia is extremely soluble in water, so if urea breaks down in moist soil, the ammonia released will dissolve immediately, and hardly any of it will escape into the air. The urease enzyme that speeds up this breakdown is very common in soils, so if urea or UAN is broadcast on the soil and there is no rain for a week or more, a lot of ammonia can be lost into the air. Broadcast UAN, because it spreads the N in a thin layer over the soil surface, exposes more of the urea to urease activity. But only half the N in UAN is in the urea form—the other half is nitrate and ammonium, which aren't affected by urease. UAN does contains some free ammonia in solution, and some of this may volatilize as the solution dries. Dry urea, once it dissolves in soil water, is all subject to urease, but urea granules that fall into cracks in the soil surface may gain some protection.

Rainfall moves urea into the soil and also wets the soil and dissolves ammonia, greatly decreasing the loss of ammonia. This means uncertainty regarding whether or not to use urease inhibitors. If urea or UAN is incorporated into the soil at or soon after planting or at sidedress time, there is no need to add a urease inhibitor, since ammonia rarely escapes from soil. Dribbling or surface-banding UAN exposes it a little less to urease and moves some into the soil a short distance. UAN dribbled on the surface near the row is a little less exposed to sunlight and wind, and water coming down the plant stems from light rain or dew can help move the N into the soil. Still, surface-applied UAN can never be considered completely safe from volatilization loss, so an inhibitor might be useful if the forecast is for warm conditions without rain for a week or more after surface-banding near the row.

With warm surface soil temperatures, nitrification will begin soon after the urea is dissolved and in the soil (as ammonium). SuperU® (from Koch), which has both urease and nitrification inhibitors, has performed well in trials when broadcast on the surface, and has yielded more than broadcast urea with the urease inhibitor Agrotain (NBPT). Assuming that both products inhibited urease equally, the difference must have been due to more rapid conversion of ammonium to nitrate, and movement of some of the N out of the rooting zone.

Novel Products Sold to Increase Microbial N Fixation

There has been a recent upswing in advertising and products that are said to provide the microbes or to stimulate existing soil microbes that fix atmospheric nitrogen and make it available to the corn crop. Microbial N fixation is the way that soybeans get most of the N they need, but such fixation in legumes involves the pant producing nodules that are attached to the roots below the soil surface, and in which anaerobic (low-oxygen) conditions exist to aid in the fixation process. We've known for a long time that there are some "free-living" (not in nodules) bacteria in soils that can fix N for the atmosphere, but measured fixation rates by such microbes tend to be very low – on the order of a few pounds of N per acre. That's in part because fixing atmospheric N requires a great deal of energy, and a soybean plant can pump sugars into nodules a lot faster than sugars leak out of (corn) roots to feed this process in microbes that live near the roots. There was once hope that corn plants could be genetically modified to produce nodules and house bacteria that could fix much of their own N, but the machinery the plant needs to form nodules and to transport fixed N in the plant is so complex that this seems to be unlikely, or at least a long ways off.

There are two types of these products, mostly developed and marketed by startup companies backed by venture capital. One type is a preparation of the microbes (bacteria) that fix N; these are usually applied in-furrow, with the idea that they'll multiply and grow near the root to eventually get enough sugars from the roots to fix N that the plant can take up. The idea is that corn plants and such bacteria form a mutually beneficial (symbiotic) relationship, with the corn providing sugars and other growth substances and the bacteria giving back N. It's not entirely clear that bacteria can act as little "N pumps" like this, and if they can, it's not clear how such a symbiosis would benefit either the plant or the microbe.

The other type of product being marketed is a chemical product that is said to stimulate the growth and function of bacteria that go on to fix N for the corn plant. It appears that some of these can be applied as foliar sprays, presumably with the idea that they can be released by the roots into the soil, or that they stimulate the plant to release something on its own that in turn stimulates growth of bacteria that fix N.

Claims on websites for these products might say that they make the plant (and roots) grow faster, and often show photos to that effect. Some mention how much N fixation might be expected from using the product. I have not done any work with any of these, but will just observe that pinning down rates of N fixation by microbes when rates are low (25 lb N per acre per season seems to be a somewhat typical amount) is really difficult, and any such numbers should be viewed with caution. One way that some such studies have been done in the past is to use a relatively high rate (say 200 lb N per acre) and then a lower rate, say 160 or 175 lb N per acre, along with the product, and if the yields are about the same, to conclude that product provided the difference.

I'd suggest a wait-and-see approach to products like this. Some companies are asking producers to conduct on-farm trials, and if it's possible to do a set of paired strips, assigning with and without treatments randomly within each pair, that might provide some information. Split-field trials are a lot less satisfactory, since the two halves of a field never yield exactly the same, and field variability is likely to be greater than any treatment effect. But most companies will control the data from such trials, and in most cases products "win" when such results are put up on websites.

Managing N This Spring

One lesson we learned from the 2019 growing season is that we can get nitrogen applied even when conditions are not very good. That doesn't mean that N was used to its best advantage in every field: there were examples of fields where N was not applied early enough to maximize yield. But with proper attention to applying the right rate at the right time, using a form that will protect against loss, Illinois farmers have the ability and flexibility to get N management done right, even when spring conditions are challenging.

While it's wet over most of Illinois now, and the weather forecast doesn't look very promising that it will turn warm and start to dry very soon, we can begin to plan our N management strategy based on principles discussed above. Instead of developing elaborate scenarios of what might happen this spring and how to respond, I'll list here a number of things to keep in mind as we go forward:

- Use the N rate calculator as the start to determining how much N to apply. Note the "profitable range" that extends on either side of the MRTN. For most fields the total N rate should be within this range, and results of hundreds of trials over the years in Illinois tell us that we can expect the return to N (increase in yield and gross income minus N cost) to be maximized at the MRTN.

- While we have said in the past that we might consider moving N rates out of (above) the range given by the calculator, we have found a consistent advantage to doing only when it's been very wet in June. Root damage from too much soil water and/or loss of N may in such cases mean that the crop can benefit from additional N, but only soils dry some to improve root function, and if N can be applied by or before the time of pollination.

- In southern Illinois, apply rates within the MRTN range, and wait until V5 or V6 to decide whether yield potential is above 190 to 200 bushels per acre; if it is, consider adding some N later in vegetative growth to bring the total rate up to 1 lb N for each bushel of expected yield.

- Rainfall from last October 1 through March 23 has ranged from a little below normal to normal in the northern half of Illinois, and from 3 to 6 inches above normal in the southern half of the state. There were a few spikes in temperature and rainfall over the winter, but we don't think that more fall-applied N has been lost than usual; we can count on its being present for the 2020 crop.

- If we get a break in the weather that allows ammonia to be applied before late April, we should consider taking advantage of that. Ammonia is currently cheaper, and is safer to apply, than any other form of N. We should take care to avoid applying it in such a way that planter units can drop into the application band, but otherwise the chances for seedling damage from ammonia are low.

- If wet soils delay both planting and the application of N, it will pay to find a way to get some N (at least 40 to 50 lb N per acre; more may be better if it's not concentrated close to the row) applied so that it is available to the nodal roots as they start to develop at about stage V2.

- If cereal rye is present in fields where corn will be planted, try to spray it to kill it several weeks before planting. The large the rye is when killed, the more critical it is to kill it early. If the rye makes substantial (more than 8 inches) of growth before it's killed, pay additional attention to getting N close to the row at planting in order to replenish when the rye removed from the soil.

- If you plant corn where there was no crop in 2019 and where weeds were controlled by tillage or herbicide, the 2020 crop might benefit from planter-applied phosphorus in order to prevent "fallow syndrome." If there's a flush of spring weed growth, or if MAP or DAP is broadcast this spring, there should be no need for placing P close to the row.

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