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No·till On The Plains

The Bottom Line

by Matt Hagny

The understated manner of Ralph Holzwarth belies the fiery ambition that drives the man to continually search for ways of doing things better, yet more simply. For this Gettysburg, SD grain farmer, too many things are a distraction from the true task at hand: high profitability over the long haul.

Ralph explains, “First, we had to get comfortable with the fact that we were no-tilling. That took us ten years. Now we’re looking at fine-tuning—changing rotations, changing fertilizer methods, and so on.”

Again, typically understated, humble Ralph. He’s been feverishly revamping rotations and fertilizer methods from the first years of his no-till adoption, it’s just that now he’s got a better handle on the system and isn’t so pressured to react to the latest crisis.

Ralph’s area has traditionally been very low in its cropping intensity due to dry conditions, and during the ’70s and ’80s nearly everyone summerfallowed at least 25% of their land, sometimes with it consuming as much as 50% of the landscape. Ralph explains bringing this mentality into his no-till, “[Initially] I didn’t think we could drop the fallow. But Beck was already preaching back then that we didn’t need the fallow.” Still, Ralph is a good student of numbers: “After we saw the big chemical bill [from chem-fallow], we knew we couldn’t afford it—not without some big yield improvements. Our continuous-crop [non-fallow] wheat was as good as our fallow wheat in ’92, and we’ve never had an acre of fallow since.”

Holzwarth has been evolving his rotations ever since his first no-till efforts, which started getting serious in 1989 when he rented a JD 750 drill, and then purchased his own 15-foot 750 the following year. Back then, his rotation was often spring wheat >>w. wheat >>sunflower (or corn, or chem-fallow). This was during a time when his county was pre-

Photo by Ralph Holzwarth.

Holzwarth’s air drill seeding spring wheat in sunflower stubble.

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dominantly small grains and fallow, and dryland corn was rather unusual and often intended for silage. Sunflowers were not particularly common either, and soybeans were considered something that was grown back East—like in Minnesota.

> **"The first couple years of no-till were kind of a struggle. . . . We weren't real smart—we always had to get hurt before we changed."**

Ralph had some irrigation during his early no-till adoption phase, and presumed he had enough corn acres there, so didn't concentrate much on it for his dryland initially. When he did grow dryland corn, often he planted spring wheat into the corn stalks the following year, which he considers to be a big 'no-no' today, due to scab.

His early rotation also suffered from lack of a sufficient break between the wheat crops. To remedy this situation, they dabbled in flax. Oats were included early on, too, and some barley. They did quite a bit of proso millet for a few years, until the corn borer got bad in it. With the moisture storage from leaving the wheat stubble intact, Ralph's dryland corn yields really responded, and his corn acres exploded. But getting from corn to wheat was still the problem child, so Ralph tried something radical in '93—putting sunflowers after corn. "Up till then, I was convinced I didn't have enough moisture [to do two high water-use crops in a row]." It worked well, and his 'standard' rotation during the mid- and late-'90s became s.wht >>w.wht >>corn >>sunflower. Eventually soybeans displaced some of the sunflowers in that rotation, but Ralph adhered to that basic structure for many years.

"Now we see that four years is not enough . . . . We're in the process of stretching it out to a five-year rotation with more corn on corn and beans on beans, which look promising. Also, we're seeing some success with adding field peas either before or after the winter wheat." (Which would make it either s.wht >>w.wht >>peas >>corn >>sunflower (or soy), or it would be s.wht >>peas >>w.wht >>corn >>sunflower (or soy).) Ralph is a little concerned about lack of moisture in the corn on corn, but so far it has done okay and he thinks they could do up to 25% of their corn acres as second-year corn. "We've quit this practice of every year knowing what is going in a field [with a rigid 4-yr rotation]." Instead, the rotations address the primary weed problems of a particular field, whether "cheatgrass," Canada thistle, or kochia. Ralph sees the longer intervals paying off in a number of ways: "We're not wanting to spend the dollars on herbicides to

Photo by Ralph Holzwarth.

100 bu/a wheat. Ralph likes the looks of this . . . .

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No·till On The Plains

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No-Till on the Plains Inc's Mission: To assist agricultural producers in implementing economically, agronomically, and environmentally sound crop production systems.

Objective: To increase the adoption of cropping systems that will enhance economic potential, soil and water quality, and quality of life while reducing crop production risks.

go after cheat in the wheat, so we go with a longer rotation instead. . . . And I don't know if it's just coincidence or what, but we're seeing better wheat yields following 3 years out of wheat versus just 2."

Getting More from Less

Holzwarth's operation can be described as lean and mean, not just on efficient equipment and workforce deployment, but on getting all those tasks and acres done in a very professional manner. Currently they're cropping 4,300 acres with one 30-ft JD 1895 air drill, an 8-row 30-inch CCS planter, an acre-weary Patriot sprayer, a combine, and a couple tractors and trucks. The labor force consists of himself and one full-time hired man, Curt, plus the help of Ralph's 16-year-old son, Ted. Ralph's wife, Betty, has an accounting degree and does all the farm's books. Aside from additional help from custom cutters during wheat harvest, they do it all themselves, including applying virtually all their fertilizer at planting. With Ralph's widely scattered fields, they probably spend far more time moving stuff up and down roads than anything else.

Ralph has really taken management to task on wheat details, with ideas from Opti-Crop as well as Beck. For spring wheat, Ralph plants 1.8 million live seeds. The double-shoot 3-tank drill is on 10-inch spacing, and a rank of separate fertilizer openers (the '5' designation of the 1895) splits half of the middles. Openers are equipped with narrower 3-inch gauge wheels to trample less stubble. For spring wheat, typically about 70 lbs. of MAP (11-52-0) goes into the seed runs, and 85 units of N as urea in the mid-row banders (the rate actually varies since Ralph subtracts soil nitrate as determined by test results). The spacing works out about right, since it takes some time for the wheat roots to get over 5 inches and 'find' the big supply of N. By that time, the cool wet weather usually is past and the risk of excessive tillering largely diminished. Ralph does some extra applications of liquid N with a stream bar later in the season, often at flag leaf, to boost protein. He is working with SDSU on research to refine these techniques (they did find major differences in protein and baking quality in their '03 study).

Ralph shows me the data from the '04 study, and while there's a 40 bu/a response to the first 80 units of N, additional applications provided no significant yield advantage. But, it was a highly unusual year for weather there, being quite dry early (during tillering), then becoming cool and wet late so that any extra tillers were not sloughed and did contribute to yield. Ralph further cautions that we don't have the protein and milling data yet, and notes the big premiums being paid for high-protein spring wheat currently. He also poses some questions about long-term effects, noting that he's mineralizing the fertilizers he applied several years ago. "My old pivot fields still outyield any of my others—is it left over from the extra fertilizer I used to apply there? How about when we get this other ground back in shape?" We discuss the effects of soil OM accumulation and high soil phos. levels. Ralph is always thinking, shrewdly.

"We're not wanting to spend the dollars on herbicides to go after cheat in the wheat, so we go with a longer rotation instead. . . . we're seeing better wheat yields following 3 years out of wheat versus just 2."

Photo by Matt Hagny.

For starting out so dry, the '04 season really turned around in Ralph's area. His dryland corn yields have been outstanding since his conversion to no-till.

For winter wheat, Holzwarth again runs 1.8 million seeds with 70 lbs. of MAP in the row, and roughly 90 units of N as urea in the mid-row banders unless soil tests indicate significant carryover. The key is likely their climate, since they are frozen up for several months out of the winter—no wheat growth—so the wheat plants aren't tillering like mad all fall and winter. It was an exceptionally good year for wheat in his area in '04, and Ralph reaped the benefits with winter wheat yields of 62 to 105 bu/a (farm average of 72).

Corn gets 60 lbs. of 11-52-0 in the row (Ralph tows his 1910 air cart behind his planter), and 70 to 135 units of N as urea with a separate opener 5x0—that is, five inches over and same depth as the seed furrow. "Maybe five inches over is too far, and I need to move back in a little. I had some [ammonia] damage one year when running too close. But five inches out would definitely be too far away without the pop-up." His planter is equipped with row cleaners, Keetons, and spoked closing. (Those of you who remember a 16-row planter, it actually belonged to a previous hired man, Jim, who farmed his 1,100 acres on the side.)

Holzwarth's corn yields are phenomenal considering pre-no-till experiences in the county: his farm-wide dryland average was 117 bu/a from '96 to '99 and around 100 bu/a for the last 4 years (the drought of '02 really wrecked the average). '04 looks to be astonishingly good. Ralph's success with dryland no-till corn eventually caused him to shut down his pivots pumping from Lake Oahe: "We weren't gaining that much with the pivots. We make just as much money with 120 bu/a dryland corn as we do on 180 bu/a irrigated, with far less work."

Ralph's soybeans go in either with the drill or planter, whichever is convenient. No pop-up is applied. "Last year we planted our soybeans half with the drill, and half with the planter, but the yield was exactly the same. I do think 30 inches is a little too wide. We have a few more weeds in the 30-inch beans—some pigeongrass [foxtail] and pigweeds coming up late. . . . Twenty-inch would be nice on soybeans, and about right on corn and sunflowers too. In the future, if I go buy a new planter, I'd probably go 20-inch. But I know a lot of guys struggle to get everything to work right on 20s—getting all the stalks to go through." When it comes to doing much engineering, Ralph shows little interest: "I'm not wanting to buy a new piece of machinery and take a cutting torch to it right away. You spend all this time modifying something, and then a few years later you want to trade, and they don't want to give you anything for it. I just want to go buy something that works reasonably well. Beck does all this experimenting, and I'm glad somebody does it. But I just want to go to the field and get something done."

Abandoning his irrigation: "We weren't gaining that much with the pivots. We make just as much money with 120 bu/a dryland corn as we do on 180 bu/a irrigated, with far less work."

For sunflowers, Ralph puts a dry blend containing 25 - 30 pounds of P_2O_5 and 50 to 75 units of N five inches over—nothing in-furrow. Seed drop is always at least 20,000. Ralph notes that sunflower stalks catch considerably more snow than soybean stubble, yet the following s. wheat yields are always 5 bu/a less in the sunflower stubble, apparently due to high moisture extraction deep in the profile. "I see the difference every year."

Field peas are a new crop to the area, but Ralph likes what he sees. "It's just like sunflowers coming in during the '70s. At first, people just tried a few acres. Now they're all over." Soybeans were also unheard-of prior to the mid-'90s, and no elevators in his area wanted to handle them. Ralph notes the major change for local soybean markets, and recognizes field peas as having even greater flexibility in end-use. His limited acreage of 'Cruiser' peas made 60 bu/a this year, seeded at 145 lbs/a (falling shy of his intended 180 lbs.) in 10-inch rows. 65 lbs. of MAP went in-row, as did 6 or 7 lbs. of granular inoculant. Spartan was applied pre-plant. The peas were easily harvested with a flex-head, a big change over early less-upright varieties. "I see some potential here. With the LDP, we can get some real nice dollars out of the peas for what little we've got in them. We needed another crop [in the rotation]. And I really like the fact that we're recharging moisture now [early August—the peas were harvested], and getting ready for the next crop. Soybeans and sunflowers use water much later."

"Right away with no-till, we saw higher yields. We made the commitment not to till—it was not an option anymore."

Photo by Matt Hagny.

Ralph's combine finds lots of bushels in the '04 wheat crop. Not everyone in their area fared as well, but Ralph's good production practices and rotations paid off.

Past and Future

Back to the origins of Holzwarth's no-till. "We used to have lots of black fallow, which always got to blowing and washing. I didn't care to see the land eroding." During his early farming career, Ralph kept looking to no-till as the possible solution, if only it were economically viable. Seeding equipment was also an issue. "In the early '80s, the college [SDSU] asked if they could do a no-till study out here. I said, 'Sure, go ahead.' They came out and put in the study with this drill with waffle [wavy] coulters. It slid in the straw, and bunched up. Didn't look too pretty." That didn't dissuade Ralph from further no-till experiments. When he was using that first 750 drill, he hired a neighbor with a hoe drill to plant some of his wheat. "There was no comparison—about a 15 bu/a difference." The hoe drill was the loser in that showdown.

"No-till has definitely improved our profitability."

Ralph's 15-foot 750 drill purchased in '90 was the hot item in the community for a couple years—everybody wanted to rent it to try some no-till. "We ran the wheels off it." Then, to handle the workload, it was traded on a pair of 750 drills on a Houck hitch in the spring of '93 (everything was no-till by then). Those drills were again run hard year after year, and eventually traded on an 1860 air drill in '01, and then on his current Deere 1895 by spring of '03.

Reflecting back, Ralph says, "The first couple years of no-till were kind of a struggle," with so many uncertainties—what rotations would be profitable, understanding the agronomy of new crops, working out the equipment issues. Economic pressures always forced Ralph to find the answers quickly. Ralph grins as he reflects on the bumps in the road, "We weren't real smart—we always had to get hurt before we changed." Yet he envisioned clearly where he needed to go: "Right away with no-till, we saw higher yields. We made the commitment not to till—it was not an option anymore."

Photo by Ralph Holzwarth.

Holzwarth's JD 1895 sowing spring wheat in soybean stubble. Ralph's equipment wasn't always so fancy and new—must be some money in doing this no-till thing right.

Ralph marvels at the number of really top-notch farmers in his area today, all no-till (over 70% adoption in the county). Field after field of excellent crops is a testament to the skills of the neighbors, and how dramatically it's changed. "We can see the success of the higher intensity [of management]. Yield goals have gone up . . . . No-till has definitely improved our profitability, and we're more consistent [year to year]. But I haven't made enough to retire and leave," he says with a sly smile.

While Holzwarth has willingly taken the no-till message on the speaking circuit and hosted many visitors to his farm, his biggest contribution to the development of no-till was largely inadvertent—by being one of the instigators in the formation of Dakota Lakes Research Farm. Some people think it was formed specifically for Dwayne Beck to do no-till research, but that gets it entirely wrong. Ralph explains, "Back in the '70s . . . it was a late night down at Bob's Steakhouse, after quite a few drinks. It was me, Darrel ['Red'] Pahl, and Dwayne—Dan Cronin was there, too—we had been out looking at a study Dwayne had been doing on some of Eldore's [Ralph's uncle] land for his master's degree. We were sure wishing the college would do more research out here [the nearest research site was Redfield, some 100 miles to the East]. We got the bright idea that we should pool some money to get our own research farm going. Nobody at that table ever seriously thought of Beck running it. In fact, that was the joke—'Gee, if we get this farm up and running, then they could give you a job, Dwayne! Ha, ha, ha!' But the next morning, we called each other up, and thought maybe this farmer-owned research idea wasn't so crazy. So we got the coffee pot going, and Darrel, Dwayne, and I sketched out a plan and a list of possible sites along the [Missouri] River. We had in mind strictly an irrigation research farm. The no-till thing came later."

They got busy right away with fundraising, but it still took 10 years before they got it afloat, and then only by some financial maneuvering and by striking an agreement with SDSU to staff it. By then, Dwayne had gone on to do Ph.D. studies, and was managing the Redfield research farm. When SDSU closed the Redfield site, Dwayne really was in need of a job and Dakota Lakes coincidentally had a position available. Ralph was President of Dakota Lakes from '93 to '96 and only in recent months has resigned from the Board, which consists entirely of farmers who continue to direct what research will be done there.

While reminiscing on the old days of no-till, Ralph looks pensive: "We've come a long way, but we have so far to go."

Nitrogen as a Plant Nutrient

by Ray Ward

Raymond C. Ward is a soil scientist & founder of Ward Laboratories at Kearney, NE.

SCIENCE

The author's prequel on soil organic matter was in the March '03 Leading Edge.

Nitrogen atoms are integral parts of plant proteins, chlorophyll, DNA, enzymes, and many other compounds important for plant growth. Plant roots take up nitrogen in the nitrate (NO_3^-) and ammonium (NH_4^+) ionic forms. The predominant molecule taken up is nitrate. Ammonium is 'preferred' by plants during very early growth, but as growth advances and demand increases, plants take up most of their nitrogen in the nitrate form.

The amount of nitrogen fertilizer to apply depends on the nitrogen-supplying capability of the soil. The "pool" of available nitrogen sources includes: 1) organic[1] N sources such as animal manure, sewage sludge, and compost, as well as soil organic matter (OM), 2) nitrogen-fixing bacteria (e.g., *Rhizobia*) associated with legume plants, 3) free-living nitrogen-fixing microbes, 4) nitrogen fertilizer, and 5) fixed soil ammonium. All of these sources of nitrogen are converted to nitrate in time.

Photo by Doug Palen.

The author describes water percolation from his 'deep-six' location in a soils pit during the '03 Whirlwind Expos.

Since nitrate is the predominant form of N used by plants, measuring the residual nitrate in the root zone before planting the intended non-legume crop is an important step in estimating N fertilizer needed. The residual soil nitrate test is a good measure of available nitrate in most Great Plains soils where nitrate leaching is minimal, the exceptions being certain soils prone to leaching and denitrification. Nitrate is soluble; therefore, it is mobile in soil water. Where rainfall is great enough to move water deeper than the root zone prior to or during the growing season, the residual soil nitrate test may be a poor estimate of available nitrogen. In poorly drained soils that remain wet for a period of time, nitrate can be lost to the atmosphere during a process called denitrification. (These mechanisms will be described in more detail later in the article.)

Determining an appropriate amount of nitrogen fertilizer to apply depends on many factors. First, you need to know the characteristics of the intended crop: what is the N requirement of the crop per yield unit, and what is the yield potential? Mineralization[2] of soil organic N is an important factor: a high mineralization rate will reduce the need for N fertilizer. Mineralization of soil organic N is governed by weather (moisture, temperature) as well as the quantity and characteristics of soil organic matter. Legume crops in rotation will increase the rate of mineralization temporarily. Adequate N nutrition of previous non-legume crops will narrow the C:N ratio and accelerate mineralization of those residues (see the March '03 *Leading Edge* article for further discussion of residue decomposition and mineralization). Once the crop requirement is determined and mineralization estimated, the measured soil nitrate can be subtracted to arrive at the amount of fertilizer N to apply.

Fertilizer N Sources

In the selection of an N fertilizer source, crop producers have concerns involving volatilization, immobilization, and availability of N fertilizer. In most studies, when care is taken to avoid potential loss of N, all sources of N fertilizer applied at the same rate per acre had an equal

[1] 'Organic' in this article is in the sense used by chemists to denote molecules containing carbon.

[2] Mineralization is the breakdown of organic molecules to inorganic, or mineral, by loss of carbon.

effect on yield. However, there are many situations where one source of N fertilizer is preferred over others.

Many sources of N fertilizer have been used over the years, such as urea-ammonium nitrate (UAN) solutions (28-0-0 and 32-0-0), urea (46-0-0), ammonium nitrate (34-0-0), anhydrous ammonia (82-0-0), and ammonium sulfate (21-0-0-24). These N fertilizers are all derived from anhydrous ammonia (NH_3). NH_3 is manufactured by combining nitrogen from the air (78% of the atmosphere is nitrogen gas, N_2) with natural gas under high temperature and pressure. It takes about 26,000 BTU of energy to produce and transport one pound of NH_3, so the cost of energy strongly influences the cost of N fertilizers. NH_3 is a liquid at a temperature colder than –28° F at normal atmospheric pressure. It will remain in a liquid state at warmer temperatures if kept under greater pressures. For cost-effective storage and handling, NH_3 is kept under pressure in a liquid form for use by agriculture and manufacturers.

Other fertilizers can then be made from NH_3. NH_3 is treated with a platinum catalyst to convert NH_3 to nitric acid (HNO_3). Nitric acid is added to NH_3 to form ammonium nitrate (NH_4NO_3). Urea ($CO(NH_2)_2$) is made by reacting NH_3 and carbon dioxide (CO_2). Combining NH_3 with sulfuric acid produces ammonium sulfate. Reacting NH_3 with phosphoric acid produces various ammonium phosphate fertilizers.

Anhydrous ammonia (NH_3) was the main N fertilizer source used in the U.S. prior to the 1970s. UAN solutions and urea have steadily risen in popularity in recent decades. Anhydrous ammonia must be injected into the soil deep enough to avoid the loss of gaseous ammonia (as the pressure on NH_3 is relieved, it converts from liquid to gas immediately), and the injection slit must close adequately behind the opener to prevent losses. This NH_3 application may cause more soil disturbance than is desirable for no-till farmers. If NH_3 is to be used as the N fertilizer source in no-till, a coulter should be used ahead of a minimum-disturbance knife. Today, no-till farmers are commonly using other sources of N fertilizer to avoid the soil disturbance.

Photo by Matt Hagny.

Stacked wheat surges in growth, with daily water and N uptake approaching their peak. This wheat field had been fertilized with UAN streams a few weeks prior, and the N had been rained-in.

Timing of Application

The optimum time for application of N fertilizers depends on: 1) N uptake characteristics of the intended crop, including rooting depth, 2) soil texture, 3) climate, and 4) amount of N needed. N management is more critical for shallow-rooted crops grown in sandy soils than for deep-rooted crops grown in silt loam soils. N uptake is greatest during the most rapid growth. Wheat, for example, has the most rapid growth and N uptake during joint and boot stages. Most or all the N fertilizer should be applied early enough that microorganisms have time to convert the N fertilizer to nitrate so it is available for this surge of growth. Cool soil temperature slows the conversion, so the N fertilizer should be applied about 3 weeks before wheat starts jointing, or earlier.

N uptake is greatest during the most rapid crop growth.

The most rapid N uptake for corn occurs from V-8 to tassel, and therefore most of the N should be applied at least 2 weeks before that time to provide adequate nitrate availability for plant uptake. Under irrigation, some N may be applied through the sprinkler system; each N application must be timed so the N is applied about 2 weeks before the crop demands the N.

Volatilization of N

The dry N fertilizer urea (46-0-0) is commonly used by many no-till farmers. Urea applied to the soil or crop residues reacts with water and the enzyme urease and is rapidly converted to ammonium. This is known as urea hydrolysis. If the ammonium (NH_4) remains on the residue it often converts to NH_3 as the residue dries. Since NH_3 is a gas, it volatilizes into the atmosphere. If the NH_4 molecule reaches a soil particle, then it is held in the soil as NH_4 and does not volatilize. Rainfall or irrigation of 0.3 inches is sufficient to move the urea into the soil. Because the urea-to-ammonium conversion is an enzymatic reaction, the rate of conversion gradually increases as temperatures warm. If urea is to be applied to the soil surface in no-till, it is a good idea to do so during cool periods when rainfall is more likely to occur. The longer urea remains on the surface, the greater the chance of ammonia volatilization, especially under moist warm conditions. It is better to apply urea to dry residue because urease activity is slower when water is scarce (the idea is to delay urease's conversion of the urea to ammonium until the urea molecule is in contact with the soil, i.e., precipitation has occurred).

If urea is to be applied to the soil surface in no-till, it is a good idea to do so during cool periods when rainfall is more likely to occur.

For surface applications, dry urea can be laid down in strips or bands to reduce contact with urease. Banding should be on 15-inch spacing for small grains and can be as wide as the row spacing for summer crops. Urea can also be applied as a starter fertilizer placed 2 to 3 inches to the side of the seed. The rate could be 60 to 90 pounds of N per acre placed 2 to 3 inches from the seed furrow. The separation is important because the free NH_3 and NH_4 formed by urea and other N fertilizers are toxic to seed and seedling tissues above certain levels.

Many no-till farmers opt to use one of the N solutions (non-pressurized liquids). The N solutions are manufactured by liquefying a mixture of urea and ammonium nitrate to form a fluid containing approximately half urea and half ammonium nitrate (hence, "UAN"). The concern for NH_3 loss from UAN is the same as for dry urea, except only half of the source is urea (the ammonium nitrate portion is not at risk of volatilization[3]). Again, UAN solution can be streamed on to slow urease activity. The streams should be spaced similarly to what was described for dry urea strips. Broadcast UAN tends to perform more poorly than streamed UAN or broadcast urea, due to the broadcast fluid having the most contact with urease and crop residues. If the N fertilizers have considerable contact with crop residues, immobilization ("tie-up") can occur, which is essentially the microbes that feed on residues acquiring the N before it reaches the soil. While the N is not really lost, the crop cannot access that N until further decay of those residues and microbes occurs. Surface residues such as wheat straw or corn stubble can immobilize large quantities of N from a broadcast application of UAN. (See the March '03 *Leading Edge* for a discussion of immobilization.)

To avoid volatilization loss, the UAN fertilizer can be injected into the soil. The application depth is not criti-

Photo by Matt Hagny.

Corn enters its phase of rapid growth, where most of the N uptake occurs. This field had its total N requirement applied at planting through a 3x0 opener; plus, a very small amount of N and P was applied in the seed furrow ("pop-up") to supply the plant with those nutrients early in its growth. With no-till, pop-up becomes more important.

[3] Volatilization of urea occurs because pH rises in the surrounding solution during urea breakdown, but no pH rise occurs from ammonium nitrate or ammonium sulfate (ammonium sulfate actually lowers pH significantly during breakdown). The specific chemistry is as follows. Urea reactions are: 1) in the presence of urease, urea combines with water (H_2O) and a hydrogen ion (H) to yield the bicarbonate HCO_3 and NH_4, then 2) HCO_3 reacts with another H to create CO_2 (carbon dioxide) and another H_2O. Since H is consumed in both of those reactions, pH rises in the surrounding solution. As the nearby pH rises, more NH_4 converts to NH_3 which can escape into the atmosphere. Only if the solution was sufficiently acidic initially will the NH_4 be stable. In contrast, ammonium in 34-0-0 (ammonium nitrate) and 21-0-0-24 (ammonium sulfate) does not volatilize because no H is consumed during breakdown, and the pH of these ammonium products is low to begin with, since the nitrate and sulfate ions are strong acids and NH_3 is a weak base—the result is an acidic molecule, and the strong acid characteristic keeps pH acidic. CO_2 is a weaker acid than NH_3 is a weak base, so the NH_3 dominates and makes the urea compound itself slightly basic.

cal. It should be deep enough so the opener or coulter performs well. The application may be made at time of planting or at some other time.

N losses from volatilization range from near zero to near 100% of applied urea (the other N fertilizers do not have significant NH_3 volatilization problems[4]), but can often be managed to obtain minimal losses. Still, the risk of substantial losses cannot be eliminated if weather is adverse for a long period after application. Volatilization losses will be worse when the pH at the soil surface is high. Other factors may outweigh the concerns of volatilization.

Loss of N from Leaching

In addition to NH_3 volatilization, N can be lost from soils by 1) leaching, and 2) denitrification. Leaching is simply the downward movement of soluble nitrate (NO_3) with water percolation. The amount of leaching depends on the soil's water-holding capacity and the amount of water that flows through the soil.[5] Soils with a high water-holding capacity can accumulate a considerable amount of water before nitrate leaching is deeper than the root zone.

N fertilizer application should be timed to avoid potential leaching of nitrate below the root zone. For medium- and fine-textured soils that have a high water-holding capacity, N fertilizer can generally be applied anytime before, during, or after planting—so long as the N is available by the time the crop needs it. In much of the North American Great Plains, rainfall distribution occurs primarily during the growing seasons of adapted crops, so leaching potential is minimal. But where rainfall distribution is greater between crops, such as in the U.S. Corn Belt, then timing of N application is much more critical to avoid leaching.

Broadcast UAN tends to perform more poorly than streamed UAN or broadcast urea, due to having the most contact with urease and crop residues. If N fertilizers have considerable contact with crop residues, immobilization ("tie-up") can occur, which is essentially the microbes that feed on residues acquiring the N before it reaches the soil.

Photo by Matt Hagny.

A low-disturbance fertilizer opener mounted on a planter to apply most of the N, sulfur, and whatever else cannot go in the seed furrow safely. Applying all the fertilizer at planting is often desirable from an agronomic standpoint, but certainly isn't the only way to do successful no-till.

For sandy soils, the risk is greater for percolating water to move nitrate below the root zone. Consequently, N applications should be timed to more closely match the plant's uptake. A small portion of the N can be applied with the pre-plant herbicide program and/or with the starter fertilizer. The remainder should be applied just before the crop's greatest demand for N.

Improved soil structure developed by no-till farming has also reduced the amount of nitrate leaching by maintaining macropores. Water can enter the soil by gravity, moving quickly down the macropores and then moving out horizontally. Leaching occurs primarily when water moves by capillary action and carries soluble nitrate downward. Because of the tendency to recharge moisture horizontally from the macropores, less of the soil nitrate is exposed to water percolating downward. No-till also reduces leaching potential by improving the soil's water-holding capacity with slowly increasing soil organic matter content.

Denitrification

Denitrification occurs when certain anaerobic soil bacteria utilize the oxygen in nitrate (NO_3) to support their life processes, instead of obtaining oxygen from air (remember, the soil contains much pore space which is filled with some combination of air and water). As those bacteria strip oxygen (O_2) from the nitrate molecules, the nitrate is converted into various forms of N that can

[4] See previous footnote.

[5] The conventional estimate of nitrate leaching can be calculated by the formula: d = a/Pv X 100, where d = depth of leaching (inches), Pv = field capacity (percent), and a = amount of leaching water (inches). For example, if the water-holding capacity of a silt loam is 46% and 1 inch of water moves below the root zone, nitrate moves 2.2 inches in the soil. In a sandy soil with one-half the water-holding capacity, nitrate leaching is twice as much per inch of water or 4.4 inches per inch of leaching water.

be lost to the atmosphere. The conversion is

$2NO_3 \rightarrow 2NO_2 \rightarrow 2NO \rightarrow N_2O \rightarrow N_2$

A different soil enzyme advances each step. Soil bacteria produce the enzymes. Denitrification occurs when soils lack oxygen but contain a ready supply of carbon and nitrate. The gaseous forms of N are NO, N_2O, and N_2. The loss of these N gasses from soil (denitrification) is a major mechanism of loss in fine-textured, poorly drained soils, or in soils with high seasonal water tables. Denitrification proceeds more slowly in soils with pH below 6. Losses from denitrification can be quite high if anaerobic conditions exist for long periods of time, and all nitrate in the soil is at risk regardless of the nitrate molecule's origin.

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In soils prone to denitrification, producers can reduce this potential loss of N by synchronizing N application with plant demand. This may involve applying fertilizer N after the crop is growing; once the crop is extracting significant moisture and reducing waterlogging at the surface, the denitrification risk is less. If N fertilizer must be applied before plant N demand, a nitrification inhibitor additive will slow the conversion of NH_4 to nitrate, thus reducing denitrification risk.

Nitrogen removal by harvesting:

Crop		Yield Unit Per Acre	N Content Lbs/Yield Unit
Corn	Grain	bushel	0.60 – 0.90
	Stover	bushel*	0.30 – 0.50
Wheat	Grain	bushel	0.85 – 1.20
	Straw	bushel	0.50 – 0.75
Milo	Grain	bushel	0.60 – 1.00
	Stover	bushel	0.30 – 0.50
Sunflower	Seed	pound	0.02 – 0.04
	Stover	pound	0.015 – 0.020
Oats	Grain	bushel	0.60 – 0.75
	Straw	bushel	0.30 – 0.40
Soybean	Seed	bushel	3.10 – 3.70
	Straw	bushel	0.30 – 0.40
Cotton	Lint & Seed	pound	0.05 – 0.08
	Stalks, Burrs	pound	0.035 – 0.070
Field Peas	Seed	bushel	1.85 – 2.10
	Straw	bushel	0.60 – 0.75
Alfalfa	Hay	ton	48 – 65

* The stover associated with one bushel of grain.

Crop N Requirements and N Removal

When crops grow, nutrients are taken up and distributed into the leaves, stalks, grain, etc. The amount of N needed for optimum growth depends on the specific crop and the growing conditions. A significant fraction of the N taken up by the plant may be removed from the field at harvest time, depending on the amount of yield and the concentration of N in the harvested portion. For example, winter wheat harvested for grain contains 0.75 to 1.2 pounds of N in each bushel, depending on the protein level. Harvesting sixty bushels of wheat per acre removes 45 to 72 pounds of N per acre in the grain. The remainder of the N taken up by the wheat plant can be found in the straw, leaves, chaff, and roots. An estimate of N in the straw is 0.5 to 0.75 pounds of N per bushel produced. The straw for a 60-bushel wheat crop would contain 30 to 45 pounds of N per acre. So the 60-bushel wheat crop contains in the grain and straw 75 to 120 pounds of N per acre.

The tables list the N requirements for growing various crops and the amount of N removed when the grain or forage is harvested. 'Straw' or 'stover' includes leaves, chaff, and other aboveground plant remnants. Some N also resides in roots at plant maturity, although for annual crops this is typically substantially less than in the aboveground residues.

A significant fraction of the N taken up by the plant may be removed from the field at harvest.

Nitrogen requirement (uptake) for growing various crops:

Crop	Yield Unit Per Acre	N Requirement Lbs/Yield Unit
Corn	Bushel	1.1 – 1.6
Wheat	Bushel	1.75 – 2.4
Milo	Bushel	1.1 – 1.6
Sunflower	Pound	0.05 – 0.075
Oats	Bushel	1.1 – 1.3
Cotton	Pound	0.10 – 0.12
Soybean	Bushel	3.7 – 4.4
Field Peas	Bushel	2.9 – 3.4
Alfalfa	Ton	48 – 65

Fertilizer N Recommendations

The N *requirement* (uptake) is the total amount of N the crop uses to grow leaves, stems, roots, and seeds. This requirement can be met from the various contributions to the pool of N described at the beginning of the article. After taking into account measured soil nitrate, legume and manure credits, etc., it is generally recommended that any deficit be made up with fertilizer N for a non-legume crop. Soil scientists and laboratories make some further assumptions about fertilizer efficiencies and other N contributions to the soil supply of N, but calibrations and field studies support recommendations for fertilizer N that approximately track the N requirements listed, once the measured nitrate and other credits are subtracted.[6]

N *removal* shows how much N is 'lost' from the field when a given yield is taken. The portion remaining after harvest contains the balance of the N uptake. This organic N will be released slowly over time. However, early in the adoption of a no-till system, more N fertilizer will be needed because the N in the residue is not available until it decays, which happens more slowly when left on the soil surface. After 3 to 4 years of no-till, there will be a relatively continuous supply of nitrate from the decomposing residues. Then N fertilizer rates may be reduced if crop yields are not increasing.

Early in the adoption of a no-till system, extra N fertilizer will be needed because the N in the residue is not available until it decays, which happens more slowly when left on the surface. After 3 to 4 years of no-till, there will be a relatively continuous supply of nitrate from the decomposing residues.

Legumes in rotation will typically supply much of their own N and will yield a supply of N for the next non-legume crop as the legume residues decompose. The guidelines for N contributions from a past legume crop are provided in the table. The range of values indicates the extent of variability in legume crop growth and Rhizobial infection. The range also reflects climatic differences: mineralization of the legume remnants depends on favorable (warm, moist) conditions prevailing between the maturity or termination of the legume and the next crop's time of N demand. For instance, in the northern Plains, not much N credit should be given for soybeans preceding a wheat crop, due to cool conditions.

Nitrogen credit for past crop of legume:

Past Legume Crop	N Credit, Lbs/Acre
Soybeans	0 – 60
Alfalfa	0 – 140
Alfalfa – half grass	0 – 75
Cowpeas	0 – 75
Dry Beans	0 – 40
Vetches	0 – 85
Clovers	0 – 75
Sunn Hemp	0 – 100

The past legume credit should be subtracted from the N requirement. The pounds per acre of residual soil nitrate from the 0-8 inch and 8-24 inch depths must also be subtracted from the N requirement. Any N received from manure, compost, sewage sludge, or irrigation must also be subtracted from the N requirement. When this is done you have arrived at the fertilizer N recommendation for the next crop.

New Innovations in N Fertilizer

Some new products are being developed to increase N fertilizer efficiency. These N fertilizers are more costly but the technology allows for better N efficiency. For those producers with soils that have trouble holding N, or are growing crops that are quite sensitive to N fertilization timing, the products may have high value. Some of the new products are discussed so you have some idea if they fit a scenario.

In the northern Plains, not much N credit should be given for soybeans preceding a wheat crop, due to cool conditions delaying mineralization.

Polymer-coated urea is being developed to control release of urea from the coated granule. As the tempera-

[6] For instance, soil scientists have good evidence that only 50 to 60% of applied fertilizer N is recovered by the crop, on average. Immobilization by microbes and residues, plus various mechanisms of loss, account for much of the discrepancy. Approximately 10% is unexplained in many studies. Further, plants with excessive N nutrition will excrete NH_3 through stomates in their leaves, which is lost from the field. Populations of microbes that feed on the cells sloughed by plant roots will increase rapidly as the crop grows, and with their C:N ratio of 3:1 can account for a large quantity of applied N (this is why soil nitrate tests become meaningless after a crop is already growing on a soil). Very few soil recommendations account for this low recovery of applied N because of offsets by other additions to the pool, such as N in rainfall, N fixed by free-living bacteria, etc.

ture increases, the permeability of the polymer increases to release a greater amount of urea. Crop growth increases with rising temperature, so the release of the urea coincides with growth. The technology is most suited to sandy soils susceptible to leaching and/or soils that are wet or waterlogged early in the growing season of the crop. ESN SmartNitrogen produced by Agrium is a polymer-coated urea product available currently. Another PCU product being introduced to the market is Nitamin by Royster-Clark.

No-till reduces leaching potential.

Agrotain is a urease inhibitor that can be added to urea or UAN solution. Agrotain inactivates the urease enzyme and does not affect soil microorganisms, earthworms, or other soil life. Agrotain could be used where urea or UAN solution must be broadcast over crop residues.

N-Serve is a nitrification inhibitor that has been used for years with anhydrous ammonia to slow conversion of ammonium to nitrate. Ammonium is a cation (positively charged ion) that is held on the cation exchange complex. Ammonium does not leach, but nitrate does. By keeping the N fertilizer in the ammonium form longer, less nitrate leaching occurs. Therefore, the nitrification inhibitor improves N-use efficiency and reduces potential nitrate movement to the groundwater.

Photo by Matt Hagny.

Legume crops such as soybeans need little or no fertilizer N if their roots are adequately colonized by *Rhizobia*. On the western fringe of soybean-growing areas, getting enough of the proper *Rhizobium* on new land is a struggle. The soybeans in the photo are in a field that had been soybeans once before, and have a dark color from adequate N nutrition. If a cool-season crop like wheat follows the soybeans, the N credit from the legume would be minimal.

Summary

I have discussed N as a fertilizer and as a plant nutrient. N is needed to grow healthy, high-quality, high-yielding crops. The amount of N that should be applied to a crop depends on many factors including residual soil nitrate, past/present legume crop(s), N requirement per yield unit, yield potential, immobilization of fertilizer N by crop residue, nitrate mineralization rate of crop residues and soil OM, grain prices, protein premiums, and other crop quality factors.

Nitrogen fertilizer efficiency can be very good in no-till with proper use of the N source selected. There are many effective methods of N fertilizer application. Because of time, equipment, etc., the best method of application may be whatever is currently being done. Typically, N injected in the soil performs more efficiently than other methods of application. However, all methods of application perform well in many cases. I have given you a few pointers for avoiding significant losses of N through leaching, denitrification, and/or volatilization.

Fertilizer N usage will probably increase while converting to no-till due to two phenomena: 1) increased yields and/or greater cropping intensity, and 2) slower release of N from the crop residues left on the soil surface. By leaving the crop residue on the soil surface, organic matter level will stop declining and will soon show an increase. It takes N to do this. Also by leaving residue on the surface, more water is saved to enhance crop yields. Whether this additional potential is tapped is up to you.

One Little Victory

by Roger Long

David Young was one of the South Dakota tour participants who made the journey in 1998, and it forever changed the way he farms. "I came back and told my brothers and Dad that that's the way we should be doing things."

Young's great-grandfather homesteaded one of the quarters that David and his two brothers, Larry and Gary, farm today near Blackwell, Oklahoma. The same pioneering spirit so prominent in his grandfather is alive and well in David today. Like many early no-tillers, David faced the resistance-to-change inertia from both family and community—we've all heard the typical tirade: "My dad farmed this way, and his dad farmed this way . . . ." But David was ready for a better way. "We just weren't making any money—something *had* to change!"

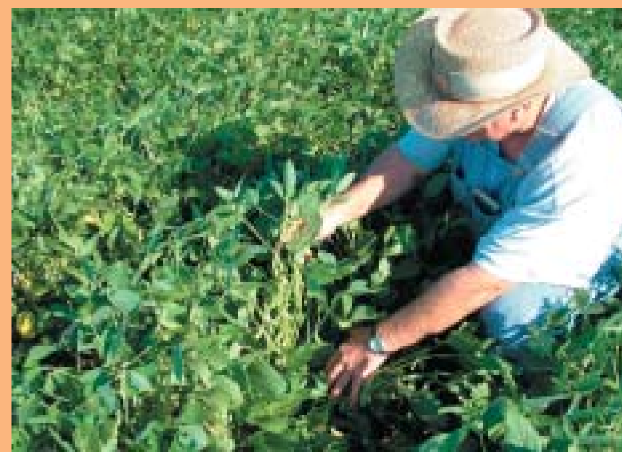

Photo by Roger Long.

David examines his soybeans.

Upon returning from South Dakota, David recollects, "After three hours of talking, I finally had them convinced." Or so he thought. The next step of putting actions to plans hit a little snag. While David was ready to put the entire farm, or at least an entire *field* to no-till, "Dad thought we should try a much smaller acreage." They settled on a 30-acre strip out of a quarter. Thankfully, that 30-acre test plot of no-till soybeans in '98 outyielded the tilled part of the field by a whopping one bu/a. Additional proof would have to be supplied to convince some of the Youngs, but they had begun their trek towards total no-till.

Photo by Roger Long.

David points to earthworm castings—the worms gobble up his corn residue quickly. David has noticed increased earthworm activity in his soils any time he has corn residue. He attributes much of the positive response of crops that follow corn to the earthworms and the root structure of corn.

As we drove through the countryside admiring what plentiful rain can do for any cropping system, David pointed out numerous fields converted to no-till in the last few years. The tilled fields near Blackwell looked good, but the no-till fields often looked better yet. One of Youngs' poorer 70-acre upland fields of corn that had looked 'burned up' earlier was harvested in mid-August and averaged 112 bu/a. David considers '04 to be a bumper crop of corn, and by late August they had harvested a major portion of their acres, with field averages ranging from 45 to 174 bu/a (the low end was from hail at tasselling).

Growers who initially scoffed at no-till and crops like corn and soybeans in the heart of 'maximum-till' wheat country are now following Youngs' lead and converting their fields to no-till. "Some guys that I thought would be in their grave before they converted to no-till have now made the change. . . . This [crop diversity] has been a complete turnaround. This county was nearly 100% wheat not that long ago.

"No-till saved our farm."

What a drastic change in fifteen years." David estimates his county to be 60% no-till already—truly an exceptional county in Oklahoma. A small beam of pride is evident as David knows he played a small part in improving others' livelihoods as well as the surrounding soils and environment—and maybe a little redemption for doing what was right back in '98 and going against the norm.

When first meeting David Young, you are comforted by his patience and jovial grandfather-like nature. And while gentle in demeanor, this veteran Oklahoma producer is tena-

Photo by Roger Long.

David checking fields on a fine August day.

cious in spirit when it comes to no-till. An exuberant student, David carefully considers his own observations as well as the experiences of others as he continues to refine many aspects of his management, from planter setup to crop sequence to fertility and plant populations. Many people lose their inquisitive tendencies as the years go by, but David Young is still young at heart.

The Corn Belt of Oklahoma

Youngs' early rotations relied heavily upon soybeans. Corn is now a favorite crop in their rotations for both agronomic and economic reasons. One may not think of north-central Oklahoma as corn country with its sporadic rainfall and unforgiving high-nighttime temperatures, but some Blackwell producers' long-term averages tell another tale—that no-till corn is quite sustainable here. David also likes corn for its effects on his soil—a noticeable increase in residue cover and earthworms—and improved yields for most any crop that follows. While discussing his earthworms, David points to last year's corn stubble and notes, "This stuff is like candy to these guys." As we toured through numerous fields of Young's, it was evident that there was much more worm activity in old corn residue than in any other type of stubble.

When David first started no-till, he had three years of continuous soybeans in a particular field before starting a more diverse rotation in it; other fields began with a rotation of wheat, corn, and soybeans. David thinks the field that had 3 years of soybeans continues to suffer from lower productivity to this day.

Youngs don't have a set rotation but try to keep a balance of 1/3 wheat, 1/3 soybeans, and 1/3 corn or milo on their 4,500 acres of cropland. The brothers don't always agree on things like rotations, which is why some of their acres are farmed together and some separately. "We don't always get this done but my 'ideal' rotation is corn >>wheat/ double-crop soybeans >>corn >>soybeans. . . . Sometimes we grow two years of corn in a row. Sometimes the double-crop soybeans go to soybeans again the next year. We mix it up. We don't have it written out for the next 8 years."

David has very specific reasons as to why he prefers a certain crop to follow another. "Wheat into corn stubble is just a matter of timing. We are finishing corn harvest now [late August], and the soybeans have a ways to go yet." This requires more explanation. Youngs have two planting times for soybeans: the early planting is in late April to early May using mid- to late Group 3s, which finish up during the August heat. These fields will typically be planted to wheat in the fall. Of their soybean acres the majority is late-planted, from mid-June to as late as July 10th, with a maturity of Group 4 to early 5. These late soybeans often go to corn the following spring. And the late-soybean scheme does seem to work in this southerly area: "We have so much length of season to work with. Our double-crop

"I wouldn't even want to consider going back to the old way of doing it [farming with tillage]. I'm sure glad the 'good old days' are gone."

soybeans yield within 5 to 10 bushels of our full-season beans." *(Editors' Note: The planting-date reasoning on wheat may be a perception left over from tillage-based wheat that was grazed. Despite the late soybean harvest, wheat establishment in that*

Photo by Roger Long.

Youngs' corn really shined with the favorable weather of '04 (except for the hail).

stubble should be feasible most years in this region that would produce normal yields, assuming proper stand densities and pop-up fertilizer. Wheat in corn stalks is at risk for Fusarium *head scab.)*

The thick mat of residue left behind by Youngs' 50- to 70-bushel wheat is great for mid-summer moisture retention, but often keeps their soils too wet and cool in mid-March when they're trying to plant corn—so, much of Youngs' corn goes into soybean stubble, or is 2d-year corn. *(Editors, again: The problem can be overcome with good straw distribution, double-cropping or cover cropping, proper planter set up for moist conditions, and pop-up fertilizer. With good agronomic practices, corn in wheat/dc soybean stubble should easily outyield corn in soybean stubble in this part of the world.)*

Youngs' best corn hybrids are around 113-day; they've tried shorter (90- to 100-day) corn but yields drop 20 – 30 bu/a or more. They plant 22,000 to 23,000 seeds/a and fertilize using 1.1 lbs. of N per bushel of yield goal, using yield estimations of around 100 bu/a on upland fields and 125 bu/a on bottom ground. They use 30 lbs. of N and generally around 25 lbs. of P_2O_5 in a 2x0 placement (2 inches over, same depth as seed) and apply the rest of the N with their herbicide immediately after planting. If wheat stubble does get the chance to lay idle through the summer—marginal upland fields—Youngs go with late-planted crops (generally soybeans) to give those fields time to warm up and dry out a little. David likes most anything after corn, but again, wheat generally wins out.

David doesn't plant much milo, but does substitute it for corn on rare occasion on more marginal soils. Larry and Gary plant a little milo on acreage they farm separately. David comments, "Corn has been paying off better than milo. We've had some trouble with midge in the milo, and had to spray." He further notes the price difference on the grain.

Happier Landlords

Much like Iowa farmers measure each other by corn yields, and Illinois farmers by soybean yields, Blackwell farmers (and more importantly, landlords) measure each other by wheat yields. Thus, Youngs have learned to manage their no-till wheat fields to reap more than neighboring tilled fields. They start by planting more seeds than their tillage peers, generally around 95 lbs/a, and as high as 110 lbs. The variation doesn't come from yearly whims but rather differences in seed weight—what they really want is around 1.2 million seeds/a. Each fall David counts the number of seeds in a gram and calibrates from there.

David would like to put down fertilizer with his old double-disc drills during wheat seeding, but currently he's not set up to do so. To compensate, he keeps his soil P levels high by applying extra fertilizer in other application windows. He soil tests wheat fields in January and strictly adheres to those recommendations for 60-bushel wheat for his N rate top-dressed in February.

As for cotton, the Youngs haven't ponied up to that table yet, as David notes, "It takes big pockets to play that game." He also notes the difficulty of persuading landlords to go along with those extra expenses, and to wait for their paycheck until after ginning (all their rented land is on sharecrop terms).

David is thankful for understanding landlords: "Once they get past the increased inputs of corn, they really like the extra income." No-till dividends come in many forms, but this past year the Youngs picked up an additional 650 acres—"[Local] landlords like no-till and that's how they want their land to be farmed." David points out that landlords also are aware of wildlife and hunting habitat: "They really like what no-till does for pheasant populations."

David appreciates wildlife too, but it's the economics of no-till that has kept them farming: "No-till saved our farm." While he sees little change in costs per acre cropped—high-dollar planters and herbicides roughly replacing tillage tools and big tractors—he does find major benefits on the income side. He notes that they're growing higher value crops—corn and soybeans—with the moisture savings, plus gaining on wheat yield and inputs by having a 3- or 4-year break. David

Photo by Roger Long.

While milo may play second fiddle to Youngs' corn, they do have fabulous milo this year.

really likes the time saved too, "We used to be in the fields all the time in the summer—just trying to get over everything to get it all planted back to wheat. It's now a much more enjoyable pace. . . . And we have time to do custom work—we never had time for that before."

David eagerly anticipates more improvements to his no-till system, such as new or improved seeding equipment (a drill w/ fertilizer capability), possible new crops (canola and cotton), and other innovations not yet conceived. He also reflects on his past: "I wouldn't even want to consider going back to the old way of doing it [farming with tillage]. Continuous wheat was so boring. I'm sure glad the 'good old days' are gone. . . . We're farming more acres now than we ever have, and we're doing it easier."

Photo by Matt Hagny.

David's planter. His brothers run another planter. On the separate-but-together farming: "It spreads risk. You never know whose decision is going to turn out to be right."

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