Leading Edge
The Journal of No-Till Agriculture
September 2007 • Volume 6 • Number 3
No·till On The Plains

Reinventing the Corn Belt

by Roger Long

We've probably all heard the saying, "Down the creek,"—as in, a lost cause or a lost possibility. For an agriculturalist, it isn't just the flotsam that's getting away—the water itself is a lost resource, since it could have been stored in the soil for use by a crop, if only infiltration rates and soil organic matter were high enough. It was thinking along those lines that inspired Randy Rink to totally reinvent his farm operation in the last 7 years.

The Rink farm near Pender, NE—not so far from Sioux City, Iowa—is where Randy, his father, Harold, and hired man Dave Frederickson crop 2,000 acres amidst a seemingly endless sea of corn and soybean fields. Yet Randy has moved beyond the standard corn and soybean rotation, as well as dramatically revamping his operation to rebuild his soils. Randy is resolute in his crop diversity, which includes wheat, proso millet, field peas, and cover crops, along with some spectacular corn and soybeans. All these crops, all this diversity, because Randy saw far too many bushels were gushing down gullies, waterways, and creeks after spring rains: "Seems like we catch rain events of 3 – 4 inches at a time here in northeast Nebraska. If you can't take that rain in quickly, it runs off and it's gone. We still can run out of moisture [later in the year] so we need those 4 inches. For instance, the 4 inches of rain that ran down the river in early June this year would be very beneficial if it could

Photo by Roger Long.

In the steep hills of northeast Nebraska, Randy Rink finds a successful mix of diverse crops, no-till, and smart management.

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have been captured to provide a little help in late July." The old adage says, "Rain makes grain," but Randy knows the precipitation must first be acquired by the soil, then extracted by a crop, to truly make grain.

In 2000, Randy was a conventional-tillage guy looking for better ways. He attended a field day near Mead, NE, featuring no-till guru Dwayne Beck, and the conversion began. Need met opportunity on that fateful day when Beck provided both the motivation and thought processes for Randy's foray into no-till agriculture. Randy saw a rain simulator demonstration that showed a 15-minute rain event dumping two inches on a no-till field without any runoff. He knew that his soil needed that kind of infiltration to take his yields to the next level. Most farmers equate adequate and timely rain with good crop yields, but few take seriously their own influences on the effectiveness of the rain received—in making the most of what moisture they do get by storing as much in the soil as possible, and by maximizing crop usage of that soil moisture. Water that runs off is a lost resource, a lost opportunity.

Fast forward seven years and Randy finds himself digging soil pits, washing equipment, cleaning up the farmstead, and getting his mind ready for the barrage of questions that comes with hosting his very own . . . no-till field day (in this case, a Whirlwind Expo in 2007 by No-Till on the Plains). Seven years may not seem like a great deal of time to go from an absolute rookie no-tiller to someone who is charged with being an 'expert' no-tiller and telling others the 'how-to' of no-till. However, Ray Ward and Paul Jasa, who were in the soil pits on the Rink farm during the Expo, were surprised at the quality and structure of the soil they found. Their comments suggested that Randy had reached in just seven years, with his diverse rotations and the application of cattle manure, what had previously taken no-tillers 15 years to accomplish.

Beyond Corn & Beans

In 2000, Randy understood that no-till was the solution but needed a few more details such as what kind of rotation to implement, thus more consultation with Beck. Beck

Photo by Roger Long.

Randy's double-crop proso millet emerges nicely, having been carefully placed with a JD 1590 drill with spoked closing wheels.

Leading Edge

No·till On The Plains

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$75 per year (U.S.) subscription rate

No-Till on the Plains Inc. publishes ***Leading Edge*** three times per year.

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No-Till on the Plains, Inc. is a non-profit organization under I.R.C. § 501(c)3, funded by fee-based activities and by generous donations from many individuals as well as organizations such as Kansas Department of Health & Environment, Kansas Soybean Commission, and Kansas Corn Commission.

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.

stressed the need for a more diverse rotation and suggested a cereal. They settled on a plan of corn >>corn >>soybean >>soybean >>spring wheat >>winter wheat, with a possible substitution of oats in place of the spring wheat. The concept rotation was way outside the proverbial box—a big departure from the local fare of strictly corn and soybeans. But would wheat be viable in the land of big crop revenues?

Randy's mind is attuned to economics, and he certainly likes the profits wheat has provided in his seven years as a no-tiller: "Wheat will almost always out-do soybeans for a cash crop. . . . Two out of the last 4 years I've had 100-bu/a wheat. That pencils out pretty good." Achieving those wheat yields requires a stepped-up management regimen, including judicious use of foliar fungicides. Even in the challenging '07 season, Randy still managed to grow 70-bu/a wheat. For comparison, his seven-year soybean average is about 50 bu/a. Despite somewhat higher inputs for wheat, Randy's numbers still show wheat producing more profit than soybeans. And more than just single-year economics, he likes the cereal in his rotation for other reasons as well: "When you get your cropping system diversified, things start working a lot better." He points out, "The cover provided to the soil by the wheat, and the immense fine root structure of wheat, help build up the carbon and soil structure. . . . One year of wheat in a 5-year rotation isn't that radical, but the effects are huge."

Ever the student, Randy provides another insightful observation, "Growing different crops makes you better on the crops you normally grow as well." Instead of a once-per-year planting time (corn planting that immediately turns into soybean planting), he now plants five or six times per year. "When you plant at different times like this, there's more time and more opportunity to observe what is going on—you see better the principles of agronomics. You then can apply those principles more often." Plus, the longer rotational breaks from corn and soybeans often allow for better plant health in those crops, and fewer inputs needed for disease and insect suppression.

Photo by Roger Long.

Irrigated corn on the Rink farm. Whether it's rainfall or irrigation water falling onto the soil, Randy fully understands the need to capture that resource with good infiltration via a thick mulch and the soil porosity acquired under no-till.

Since the initial implementation of the rotation arrived at by Beck and himself, Randy has altered the rotation a bit, going to just a single year of wheat between two soybean crops, and he's added proso millet, field peas, and cover crops with varying degrees of success. Not that the glitches have discouraged the Cornhusker, just exposed more opportunity. Millet is quickly becoming a staple as a 'fill-in' crop following July harvest of wheat, so that his rotation goes corn >>corn >>soybean >>wheat /dc proso >>soybean. Although sold on the concept, he admits he hasn't settled in on all the agronomy details for the millet. Randy drills 20 lbs/a of millet seed on 10-inch row spacing on about July 10th – 15th, and it is headed out by early August. He uses anywhere from 0 to 60 lbs N (thinking 50 lbs is about right) broadcast as dry urea (46-0-0), and has tried both direct harvesting with a flex head as well as windrowing and then using a pickup head. This year he's planning on desiccating the millet and running a Shelbourne stripper head (an idea he got from Mark Watson of Alliance, NE, who spoke at Rinks' field day). Last year's proso yield was a very modest 500 lbs/a, but Randy later realized that his millet stand was inadequate—that he should've planted deeper when going into heavy wheat stubble, especially stubble that was flat on the ground like the '06 wheat crop. "This year's millet crop looks great—but I paid more attention to the planting depth and put on more nitrogen. Instead of treating it like a catch crop, I'm starting to manage it more like a grain crop."

"When you get your cropping system diversified, things start working a lot better."

Field peas are sometimes substituted for one of Randy's soybean crops in the rotation. They're planted at the end of March with minimal to no fertilizer (the correct inoculant, however, is crucial) and are harvested right after wheat. He notes that they generally yield around 50 to 55 bu/a, which he then grinds to add to a ration for his small swine enterprise (peas are about 24% protein).

Randy's canola has been used strictly as a cover (generally mixed with red clover or lentil) following field peas. If the field is going to wheat yet that fall, the cover crop is killed with herbicide a couple weeks before wheat seeding. Otherwise it goes on into the winter to be planted to corn the next year. Randy is intrigued by the nematocidal properties that canola reportedly has in the soil, as well as adding diversity as a robust cover crop. (*Editors: Canola doesn't suppress all nematodes. Canola is actually a host for the lesion species of* Pratylenchus *that causes problems in wheat in some regions.*) Randy likes what canola and long rotations can do for his cash crops, noting that once when he had a crop sequence of soybean >>oats >>wheat /cover-crop canola >>corn, "It was the best dryland corn I ever had up to that point."

Due to calendar-year business cycles, most growers look at their farming operation as a series of single-year endeavors, but Randy begs to differ: "People aren't farming for one year! They think that they are farming for one year, but they're not!" Randy looks at the bottom line for an entire rotation cycle as opposed to merely a single year. After all, who in production ag would look at the profitability of a single quarter of a year to make a cropping decision? Farmers must see the importance of each piece, each link, each crop. Not to say that Randy doesn't recognize the star in the lineup: "Corn is still king . . . but you can't plant the whole farm to corn every year." An interesting aside, even with the rainfall they have, roughly 1/4 of the Rink land is irrigated, and they use the same crop rotation for both dryland and irrigated fields.

Feeding Crops & Soil

Randy also routinely surface-applies manure (mostly from local beef feedlots) once during the crop rotation at 25 tons/a, and then lets the microbes and percolating water do the incorporation. He generally spreads this manure in the fall after the millet harvest. Fully aware of the biology in the soil, he recognizes the importance of feeding that biology with periodic manure applications, and by keeping something growing all the time—especially with diverse crop types, and finer residues such as wheat, canola, and peas for the earthworms. Remember it was the promise of better infiltration that brought Randy to no-till, so it should be no surprise that he places a high value on earthworms and their prosperity: "I really think that part of the secret of no-till is the worms."

Soil organic matter content is a popular statistic that growers and agronomists use in trying to quantify soil health—for the record, the Rink farm currently stands at around 2.4. However, Randy realizes that raising soil organic matter is a *very* slow endeavor, but he can look at other indicators that may be a little less scientific but important nonetheless. (And, as Beck often points out, having a high soil OM number is nice, but it's not enough information on what comprises the OM and what the soil biology is doing.) For instance, Randy has observed "near flash floods" gushing out of neighboring tilled fields after a downpour, while seeing only a trickle coming off his own established no-till fields. Randy also considers the 'earthy' or peaty smell from healthy robust soils that he gets from his seven-year no-till fields (in highly diverse rotations, with manure), but is completely absent from a tilled field that he recently took over. Finally, Randy can see the granular structure his soils now have that is responsible for that coveted fast infiltration so important for bumper harvests. Randy's respect for his resources runs deep: "With a system like this, you're working *with* Nature. You're not out there beating the soil into submission with steel."

Photo by Roger Long.

Rinks' abundant wheat stubble, harvested with a stripper head. The field has been seeded to millet, although the stubble is so thick it is difficult to see.

Photo by Randy Rink.

Randy's cover crop of canola + lentil growing in field pea stubble.

Tools of the Trade

Randy knows that since each field operation must set up the next, no detail is too small. He has made as many changes on his combine as he has on his planter and drill. He replaced his chopper with spinners to more evenly distribute residue the width of his header. He recently purchased a Shelbourne stripper head, which was primarily for his wheat, although he will be trying it on millet this fall and possibly even peas in the future. He really likes the standing stubble the stripper head leaves behind, and the efficiency of the combine that the header affords.

There's no way around it: Corn yielding 200+ bu/a creates lots of residue. Randy's planter is a 12-row, 20-inch—yes, 20-inch planter, and he readily admits that even in biologically ramped up soils, there's still a lot of residue the following spring. All that residue can be challenging for corn on corn no-till, but Randy says they've made great strides in their planter attachments, which now achieve the stands he needs. He attributes much of his success in 2007 to adding aggressive single-wheel Dawn row cleaners that clear a 4-inch swath. This movement of residue allows for better depth control and quicker soil warm-up in the corn row, thereby producing a more uniform and vigorous stand. Because of last year's uneven stand along with drought, 2006 corn yields were down a little, with a dryland farm average of around 150 bu/a. Long-term averages for Rink are around 175 bu/a on dryland corn and 210 to 215 bu/a on irrigated. He reports much improved stands and early growth this year and all indicators are pointing towards that 200-bu/a type of yield.

Randy employs a three-pronged approach for applying fertilizer to his corn crop. He puts down 5 to 6 gal/a of 'pop-up' 10-34-0 in-furrow and then surface-applies in a split stream (one on each side of the row) a blend of 25 gallons 32-0-0 and 3 gallons of thiosul. To top things off, another 10 – 30 gallons of 32-0-0 is broadcast with a pre-emerge herbicide (for both Roundup Ready and non-Roundup Ready corn) right after planting. While not completely regimented in his herbicide program, Randy generally reserves Roundup Ready corn for his second-year corn and uses a conventional post product like Callisto for his first-year corn.

> **"With a system like this, you're working *with* Nature."**

Involved or Committed?

In advising others in preparing to go into no-till during the field day, Randy did mention that he made some final fall tillage passes up and down ditches and gullies to smooth the fields prior to his move into continuous no-till. He then drilled wheat into the disked areas to prevent further erosion from runoff, and then planted corn directly into the standing wheat in the spring. "The corn was always a little behind where it was planted into the wheat, but it was worth it to get the ditches under control." What Randy finds astonishing: "They're spending millions of dollars installing terraces in this area, and it's not the answer to the problem. Terraces don't affect the amount of soil moving down the slope—they only affect where it silts out. No-till helps get the infiltration up so there's less runoff and erosion."

Success in any endeavor is quickly extinguished without total commitment. Responding to an inquiry as to equipment changes he has made, Randy quipped, "I sold the disk to show I was committed." Like raising the flag over conquered land, he had already taken hold of the no-till principles in his mind, but wanted to show friends and neighbors that tillage would be no more. Randy may not have had every detail mapped out yet at his no-till initiation, but there was no question the path he would take. He has never looked back nor snuck in a tillage operation here or there for old-times' sake. It's as though Randy took on his mentor Dwayne Beck's philosophy from Day One: "It's not whether no-till is the right way or not, it is the *only* way. Now [the question becomes], what is the best way to farm with no-till?"

Truth Be Told: Impacts of 'Organic' Farming vs. No-Till

This article in the popular Australian science publication sets the record straight:

www.cosmosmagazine.com/node/1567

Nutrient Stratification in No-till Soils

by John H. Grove, Raymond C. Ward, and Ray R. Weil

SCIENCE

Grove, Ward, and Weil are soil scientists at U. Kentucky, Ward Labs, and U. Maryland, respectively.

Editors' Note: Leading Edge *is privileged to publish this article by three of North America's most respected soil scientists. John Grove, Ph.D., has focused his applied field research program on chemical and physical management of no-till soils for the past quarter-century. Ray Ward, Ph.D., has developed several agricultural testing laboratories from South Dakota to Oklahoma, and has endeavored tirelessly to improve farmer and agronomist understanding of soils and crop nutrition. Ray Weil, Ph.D., is a professor at University of Maryland and has researched soil fertility for over 25 years in a state where no-till has become the convention. Weil is also the author of the textbook* The Nature and Properties of Soils, *14th Edition, Prentice Hall, 2008.*

Nutrient 'stratification' commonly refers to a distribution of nutrients that is non-uniform with soil depth, and especially to situations with higher concentrations of nutrients (such as phosphorus or potassium) near the soil surface. Nutrient stratification certainly does occur in agricultural soils, but is generally not a problem for plant nutrition, and is at times beneficial. Nutrient stratification has existed since soils began weathering and coming under the influence of terrestrial plants with roots. Nutrient stratification apparently was not an issue for the functioning or robustness of prairie or forest ecosystems, which endured and frequently prospered for thousands or even millions of years without any mechanism for redistributing nutrients other than biological processes and water percolation. However, in the minds of many agriculturalists the common assumption or implication is that soil nutrient stratification is inherently a negative attribute for crop production, and one which must be alleviated by deep fertilizer placement and/or tillage. This article will explore the evidence for or against this proposition, as well as reviewing the plant and soil processes involved in both the creation and mitigation of nutrient stratification.

Surface application of lime in no-till can raise soil pH at depths of 12 inches or more over periods of several years.

Photo by Ray Weil.

No-till is becoming the standard practice in place like Pennsylvania. The heavy mulch improves the crop and the soil. But could the situation be improved further by deep placement of fertilizers?

Stratification Concerns: Historical Context

When mechanized no-till cropping first got started in Virginia, Kentucky, and nearby regions in the 1960s and early '70s, we heard concerns about stratification of both nutrients and soil acidity (lower pH near the soil surface). Many agronomists worried that farmers would have to deep plow to periodically incorporate lime and fertilizer. Generally, these concerns never became reality.

For ameliorating soil acidity, many studies in no-till systems have demonstrated that surface application of lime (without mechanical incorporation) is highly effective. This is perhaps not so surprising because it is near the surface that soil is acidified by the actions of precipitation (which is typically acidic even when not influenced by human activities), ammonium oxidation, and decay of organic materials. Surface application of lime in no-till can also be effective in raising soil pH at depths up to 30 cm (12 inches) or more over periods of several years.[1] Percolating water and bioturbation move

[1] E.F. Caires, G. Barth & F.J. Garbuio, 2006, Lime application in the establishment of a no-till system for grain crop production in southern Brazil, *Soil & Tillage Res.* 89: 3-12. See also R.L. Blevins, L.W. Murdock & G.W. Thomas, 1978, Effect of lime application on no-tillage and conventionally tilled corn, *Agron. J.* 70: 322-326. W.W. Moschler, D.C. Martens, C.I. Rich & G.M. Shear, 1973, Comparative lime effects on continuous no-tillage and conventional tilled corn, *Agron. J.* 65: 781-783.

lime into no-till soils. Subsoil pH can be elevated more quickly with tillage incorporation of lime, although this can be very costly and destructive. These and other studies show that surface application of lime in no-tillage tends to produce the desired crop yield response as well as the best economic return.

Fertilizer placement (including deep placement) has been far more extensively studied than liming, apparently with greater expectation of positive results from overcoming nutrient stratification. However, the results have generally not shown favorable responses to alleviating nutrient stratification, as illustrated by early work in Kentucky (see Table 1). Moldboard plow and no-till plots, established in 1970, were incrementally sampled (to the depths indicated) in the fall of 1980 and 1981, and the results averaged in the table. Potassium (K) stratification was substantial, and more pronounced in the no-till soil, although total K was very similar when the increments were added to give a composite over the 0- to 12-inch depth. Potassium fertilizer was surface-applied at a rate of 180 lbs of 0-0-60 per acre each year (both years). In both 1980 and 1981, corn was sampled at physiological maturity and total K uptake determined. Averaged over two years, the uptake of K by no-till corn was 130% of the corn grown on plowed soils, which coincides with the observation that the no-till soil test K was 129% of plowed soil test K, but only in the surface 2 inches of soil (*total* or composite soil test K for 0 to 12 inches was nearly identical between plowed and no-tillage). This strongly suggests that the K nutrition of these two corn crops was *improved* by K stratification.

While plowing has declined in popularity across much of North America, the concern about nutrient stratification is more at the forefront than ever. There has been a recent surge of interest in deep fertilizer placement (without full-width tillage), often termed 'strip-till' or 'zone-till.' (Note, however, that strip-till is occasionally done without fertilizer placement, as a method of warming and/or drying the intended row area, or otherwise aiding planter performance.) Let's look at the science to see if any validity can be found in these methods and theories on deep placement.

Other Research on Nutrient Distribution

In Iowa, José Bordoli and Antonio Mallarino studied P and K placement (deep vs. shallow vs. surface) for corn from 1994 to 1996 at numerous locations for a total of 26 site-years.[2] Sites varied in soil test levels (including some low and very low P values), degree of stratification, and length of time under no-till management (some up to 9 years). All sites were in a corn >>soybean rotation. While some sites were responsive to applied P, there was *no* significant ($P \leq 0.05$) response *to placement* at any site. Several sites were responsive to K application, but only one site-year showed a significant response to K *placement*. When all sites were pooled, a significant positive yield response to K placement was observed, averaging about 2%. However, the authors concluded that "yield differences would not offset higher application costs [for deep-placed K fertilizers]."

At two locations in southern Ontario over a period of years from 1995 to 1998, Tony Vyn and Ken Janovicek were also studying K placement for corn.[3] Locations had been in no-till for at least 6 years when the studies commenced. The corn crops in the study were planted into wheat stubble. While the sites were generally responsive to K application, corn yields tended to be maximized with planter-applied K fertilizer in a '2 by 2' side-band (2x2, i.e., a band 2 inches beside and 2 inches below the seed)[4] rather than by deeper applications the previous fall.

Table 1. Distribution of Soil K and Corn Uptake in Two Tillage Systems in Kentucky

Soil test K: Increment			Soil test K: Composite				Corn K Uptake	
Depth: increment, inches	no-till (NT)	moldboard plow (MP)	Depth: composite, inches	no-till (NT)	moldboard plow (MP)	ratio NT/MP	year	ratio NT/MP
	ppm K			ppm K			1980	1.35
0 to 2	170	132	0 to 2	170	132	1.29	1981	1.25
2 to 6	104	113	0 to 6	126	119	1.06	Avg.	1.30
6 to 12	86	95	0 to 12	105	107	0.99		

In this study, K stratification in long-term no-till actually enhanced corn uptake as compared to plow tillage. Plot tillage systems had been in place for 10 years at beginning of study. K soil test was by neutral ammonium acetate extraction. Source: R.L. Blevins, J.H. Grove & B.K. Kitur, 1986, Nutrient uptake of corn grown using moldboard plow or no-tillage soil management, *Commun. Soil Sci. Plant Anal.* 17: 401-417.

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2 J.M. Bordoli & A.P. Mallarino, 1998, Deep and Shallow Banding of Phosphorus and Potassium as Alternatives to Broadcast Fertilization for No-till Corn, *Agron. J.* 90: 27-33.

3 T.J. Vyn & K.J. Janovicek, 2001, Potassium Placement and Tillage System Effects on Corn Response following Long-Term No Till, *Agron. J.* 93: 487-495.

4 *Editors' Note: With tillage, it was considered important to be 2 inches below the seed as well as 2 inches laterally because the soil was dried by tillage and roots didn't grow well near the surface. In no-till, it has been repeatedly demonstrated that placing the side-band at approximately the same depth as the seed is perfectly acceptable agronomically as well as reducing horsepower and down-pressure requirements. For various reasons, no-till producers often move the opener farther laterally from the row. This is most accurately described as '3x0' or '4x0.'*

At a different location in southern Ontario in 1997 & 1998, Vyn and fellow researchers found positive corn yield responses to K fertilization in fields that had more than a decade of no-till history, but with results pooled, no response occurred for deep placement of K in no-till and zone-till plots as compared with shallow placement.[5]

While many studies found advantages to subsurface application of P and K, the idea that deeper placement is better than shallow has generally not been substantiated by the evidence.

Another study at Purdue University and conducted by Vyn's graduate student, Ann Kline, again could find no response to deep placement of P and K fertilizers for corn.[6] Averaged across 2 years and 2 hybrids, deep placement provided no yield benefit over broadcast fertilizer.

Previous studies by various scientists produced results prompting similar conclusions: Shallow planter side-band applications were as good if not better than deep placement for efficiently fertilizing corn.[7] While these and many other studies found advantages to subsurface application of P and K, the idea that deeper placement is better than shallow has generally not been substantiated by the evidence.

For soybean, Xinhua Yin and Tony Vyn looked at the effect of K placement (deep vs. shallow vs. surface) at two locations from 1998 to 2000 (6 site-years) in Ontario.[8] Once again, shallow placement and surface broadcast tended to outyield deep placement. They concluded that "soil K stratification and the residual effects of tillage and K placement were not major production issues for NT [no-till] soybean production."

An exhaustive study by Rogerio Borges and Antonio Mallarino involved different P and K placement strategies for soybean over 31 site-years (20 site-years at university research farms; 11 site-years of short-term trials established in producers' fields).[9] Pooling all the site-years, they found only a slight yield response to P application, and *no* response to placement. K application also resulted in a slight yield advantage, and placement effects were very subtle—less than a 1% yield advantage to deep placement over planter side-band when the 20 site-years were pooled. Other studies have produced similar findings.[10] Although nutrient stratification in many soils is well-documented, and theories for alleviating it abound, positive crop yield responses to deep placement of fertilizers are almost nil despite extensive studies looking for this effect.

As the foregoing studies tend to demonstrate, deep placement into a nutrient-stratified soil may actually be detrimental for crop uptake, and especially so when the soil is medium-low in overall nutrient availability. This is further verified by some recent Kansas work reported by Greg Schwab et al.[11] Three locations in southeast Kansas (all in Bourbon County) were studied for three years in various sequences of corn, grain sorghum, soybean, and wheat. These fields averaged 11 to 16 ppm Bray P-1 for the 0- to 6-inch depth, with P values 2-fold to 5-fold higher in the surface 0 – 2 inches compared to the deeper 2 – 6 inches (the sites were deliberately chosen for their P stratification and reduced-tillage history). Tillage and no-tillage treatments at the sites were further subdivided into four fertilizer P treatments: no P

Positive crop yield responses to deep placement of fertilizers are almost nil despite extensive studies looking for this effect.

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5 T.J. Vyn, D.M. Galic & K.J. Janovicek, 2002, Corn response to potassium placement in conservation tillage, *Soil & Tillage Res*. 67: 159-169.

6 http://www.agry.purdue.edu/staffbio/KlineMSThesis2005.pdf

7 D.B. Mengel, S.E. Hawkins & P. Walker, 1988, Phosphorus and potassium placement for no-till and spring plowed corn, *J. Fert. Issues* 5: 31-36. B.G. Farber & P.E. Fixen, 1986, Phosphorus response of late planted corn in three tillage systems, *J. Fert. Issues*, 3: 46-51. See also G.W. Randall & R.G. Hoeft, 1988, Placement Methods for Improved Efficiency of P and K Fertilizers: A review, *J. Prod. Agric*. 1: 70-79. (In reviewing a number of pre-1987 studies, Randall and Hoeft found that deep placement seldom conferred a yield advantage over shallow or surface placement for corn and soybeans. Yields from planter side-band placement of P and/or K generally equaled or exceeded those from deep placement. The only studies finding advantages to deep placement were comparing to surface applications only, not shallow placement as with a planter side-band.)

8 X. Yin & T.J. Vyn, 2002a, Soybean Responses to Potassium Placement and Tillage Alternatives following No-till, *Agron. J.* 94: 1367-1374. A similar set of studies by Yin & Vyn found no significant response of soybean yield to tillage method or residual fertilizer placement from the previous corn crop. X. Yin & T.J. Vyn, 2002b, Residual Effects of Potassium Placement and Tillage Systems for Corn on Subsequent No-Till Soybean, *Agron. J.* 94: 1112-1119.

9 R. Borges & A.P. Mallarino, 2000, Grain Yield, Early Growth, and Nutrient Uptake of No-Till Soybean as Affected by Phosphorus and Potassium Placement, *Agron. J.* 92: 380-388.

10 C. Hudak, R. Stehouwer & J. Johnson, 1989, An evaluation of K rate, placement and tillage systems for soybeans, *J. Fert. Issues* 6: 25-31. (The study found that placing K in narrow bands increased soybean yield for both surface and deep placement.) See also Randall & Hoeft, 1988.

11 G.J. Schwab, D.A. Whitney, G.L. Kilgore & D.W. Sweeney, 2006, Tillage and Phosphorus Management Effects on Crop Production in Soils with Phosphorus Stratification, *Agron. J.* 98: 430-435.

Table 2. Bray P-1 (ppm P) by Depth after 20 Years of Tillage or No-till. Rogers Memorial Farm, Nebraska, fall of 2000.

Soil Depth	Fall Plow +Disk +Disk	Fall Chisel +Disk	Spring Disk (twice)	Spring Disk (once)	No-till
0 – 2″	14.3	24.5	27.0	27.7	46.1
2 – 4″	12.4	14.9	10.3	11.4	14.2
4 – 6″	12.1	9.1	5.7	6.4	8.9
6 – 8″	11.3	6.1	5.7	5.4	6.8
Avg.	12.5	13.7	12.2	12.7	19.0

Extractable phosphorus for five tillage systems (3 replications each) that had been in place continuously for 20 years during which no P fertilizers were applied. Source: Paul Jasa, personal communication Dec. 2006.

Table 3. Bray P-1 (ppm P) by Depth for Tillage Study at Rogers Memorial Farm, NE, fall of 2004.

Soil Depth	Fall Plow +Disk +Disk	Fall Chisel + Disk	Spring Disk (twice)	Spring Disk (once)	No-till
0 – 2″	25.5	46.1	62.6	64.9	75.9
2 – 4″	26.2	36.6	45.3	29.1	34.4
4 – 6″	21.8	13.3	11.6	11.8	11.7
6 – 8″	17.9	8.3	7.7	8.3	10.0
Avg.	22.8	26.1	31.8	28.5	33.0

Same study as Table 2, but 4 years later. After soil sampling in the fall of 2000, fertilizer was broadcast at 100 lbs/a of $P_2 0_5$ on all plots prior to fall tillage treatments. Source: Paul Jasa, personal communication Dec. 2006.

Table 4. Multi-Year (1995–2000) Average Soybean & Sorghum Yields (bu/a) for Tillage Study at Rogers Memorial Farm, Nebraska.

	Fall Plow +Disk +Disk	Fall Chisel +Disk	Spring Disk (twice)	Spring Disk (once)	No-till
Soybean	42.8	46.8	46.2	48.4	51.3
Sorghum	96.4	98.8	93.6	104.5	109.5

Same study as Tables 2 and 3. Source: Paul Jasa, personal communication Dec. 2006.

added; 40 lbs/a of P_2O_5 applied 6 inches under the row before planting; in a 2x2 band at planting; and, surface broadcast prior to tillage, if any. Subsurface P placement (either by 2x2 or deep-banding 6 inches below the row) improved early crop growth and P uptake about 50% of the time, but positively influenced yields only 25% of the time. As with some other studies discussed, the planter side-band often provided greatly improved P uptake at V6 growth stage for both corn and sorghum as compared to other treatments (including deep placement), although there was little relationship between early plant growth and/or P uptake responses and the final grain yield response for any of the treatments.

Further insight can be gained from a set of long-term tillage plots that has been in place since 1981 near Lincoln, Nebraska, under the care of Paul Jasa (UNL Extension Agricultural Engineer), located on an upland silty clay loam soil. No phosphorus was applied until 2000, just after the first incremental-depth soil sampling. The Bray P-1 extractable P values are reported in Table 2. Phosphorus distribution with depth was similar for fall chisel + disk, spring disk, and no-till regimes.

After samples were taken, 100 lbs/a of P_2O_5 was broadcast on the surface of all plots as 192 lbs/a of 11-52-0 late in the fall of 2000. After 4 crop-years in a grain sorghum >>soybean rotation, incremental-depth soil sampling was repeated in the fall of 2004, and the Bray P-1 extractable P values are reported in Table 3.

Jasa commented in 2002, with soil test results similar to those presented in Table 3: "No-till 'adjusted' P levels deeper into the soil than disking 4 times over 2 years. When looking below the surface layer, stratification is less of a problem with no-till than with the disk systems."[12] The effect persisted, as Table 3 shows: After disking 8 times in 4 years, the P distribution was still no better than no-till.

Another aspect of these UNL data is the higher soil test P values (average) under no-till. One possible explanation would be reduced no-till yields and associated lower P removal in grain. However, yield results show a distinct long-term no-till yield advantage (see Table 4).

A more plausible mechanism for causing the higher P values in the no-till plots involves the greater concentrations of P and organic matter at the soil surface. These will tend to reduce net P 'fixation' (the sorption onto soil particle edges and formation of insoluble compounds which render the P unavailable to crop roots and other soil organisms). The reduced mixing of P in no-till soils allows the greater soluble P concentrations to 'swamp' the finite number of P-fixation sites, reducing the soil's P buffer capacity, and thereby increasing the plant-available P. Certain organic compounds bind to various cations (calcium, aluminum, and iron) located at these fixation sites, preventing the formation of P-fixing compounds. In other words, shallow placement of P fertilizers in no-till can and does provide an efficient supply of this nutrient to crops under the old rule: "Minimize P contact with the soil, but maximize P contact with roots."[13]

Proponents of deep placement often worry that crop nutrient uptake will be poor in drought years if nutrients are concentrated in dry upper soil layers. However, this

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12 Paul Jasa, personal communication Dec. 2006.

13 Yet another possible explanation for the greater P values in the UNL no-till plots is the greatly reduced runoff and erosion in those as compared to the tillage plots (the site was on upland soils.) Many studies show that P loss via soil erosion is substantial when tillage is done. As important as this may be, the authors suspect that biological processes in no-till are likely the primary contributor to increased P soil test values. See Figure 1.

Photo by Brian Lindley.

Even in semiarid climates during the worst drought on record, crops still produce many roots near the surface in continuous no-till with good mulch. The photo shows proso millet roots at Gabe Brown's near Bismarck, ND in '06. Every small rain shower moistens the soil near the surface, allowing renewed root growth and nutrient uptake. Meanwhile, the subsoil becomes drier and drier. Shallow nutrient placement works well in continuous no-till.

is not borne out by research results. For instance, in the Nebraska study, the summer of 2006 was considerably drier than normal, yet the yield advantage to the no-till system persisted despite the nutrient stratification (see Table 5).

However, the argument will be made that preserving the majority of crop residues on the soil surface *plus* deep placement of P and/or K (via strip-till or zone-till), could be beneficial to grain yield if dry weather occurs during rapid vegetative growth. The Bordoli and Mallarino corn study found a correlation of greater relative K-placement yield response with drier June weather, although

Table 5. Soybean & Sorghum Yield in 2006 for Tillage Study at Rogers Memorial Farm, NE.

	bu/a	
	Soybean	Sorghum
Plow +disk +disk	43.2	92.1
Chisel +disk	55.7	90.2
Disk +disk	56.2	90.1
Disk	58.9	91.3
No-till	62.0	99.6

Source: Paul Jasa, personal communication, Dec. 2006.

the relative response comparison discussed was between deep-banded K and *broadcast* K. Bordoli and Mallarino did not discuss the relative response of deep K to planter side-band K as being correlated to drier June weather—presumably there was less correlation, or none. Other studies tend to show little, if any, positive yield response to deep placement of nutrients with strip-till or zone-till (with residues retained between the strips) as compared to no-till with shallow nutrient placement, even in dry growing seasons.[14]

Deep mechanical nutrient placement has additional drawbacks. Both fixed and variable costs are greater. Leaching losses of nutrients may be substantial for some soil types and climates. Moisture losses associated with residue movement and degradation in the row area may impede uniform seed germination and plant emergence in dry years. Erosion (and nutrient losses in runoff) will be increased with strip-till or zone-till on slopes. While many studies find increased early growth of crops planted over the tilled and fertilized strips or zones, often along with increased P and/or K uptake in the plant tissues, there is typically little relationship between early plant growth (and P and/or K uptake responses) and final grain yields in those studies.[15]

Studies tend to show little, if any, positive yield response to deep placement of nutrients with strip-till or zone-till (with residues retained between the strips) as compared to no-till with shallow nutrient placement, even in dry growing seasons.

The only real downside to nutrient stratification that has been consistently observed is that more dissolved P (both organic and inorganic) may be lost in surface runoff water. This is usually far less of a problem than the P lost in sediments eroded from tilled soils.

Normal Plant/Soil Relationships (Long-Term Nutrient Cycling)

Plants themselves move nutrients within their tissues (that's why they're called *vascular* plants: because of

[14] See Vyn et al., 2002. (During the dry season of the study, 1998, the deep banding actually caused substantial yield *reduction* in the no-till plots. Pooling the zone-till and no-till treatments for that year, there was still a slight disadvantage to deep placement.) See also Vyn & Janovicek, 2001, which included a dry season. See also Paul Fixen's study on dryland corn in South Dakota, which also found that planter 2x2 placement outyielded other treatments including deep placement, regardless of tillage system, as reported in Randall & Hoeft, 1988. (*Editors: For another example, see the data tables in 'Another Look at Strip-Till' in the Dec. '05* Leading Edge.)

[15] The occasional differences in grain yield found in these studies likely are not due to fertilizer placement so much as other mechanical and physiological factors, such as plant population disparities, advancing or retarding crop development with coincidental weather effects, etc. When multiple years and locations are pooled from these studies, yield differences due to fertilizer placement and/or in-row tillage practices tend to disappear.

Photo by Ray Ward.

Native ecosystems, such as this grassland in south-central Nebraska, thrived for millions of years with nutrient-stratified soils. Indeed, the stratification likely slowed leaching losses of nutrients, conferring a benefit.

large-scale transport of fluids and dissolved substances by specialized conductive tissues). The majority of the N, P, K, and other nutrients will be moving from the roots to the leaves and stems, which eventually die and fall onto the soil surface to decompose. This is how most stratification occurs under indigenous non-fertilized ecosystems, as well as in cropland. Intensive cropping, especially with deep-rooted species and cover crops, will accelerate nutrient pumping from greater depths and actually enhance stratification (see Figure 1). Nature relies on such mechanisms to keep nutrients from leaching below the rooting zone. Numerous biological and climatic influences then operate to redistribute nutrients

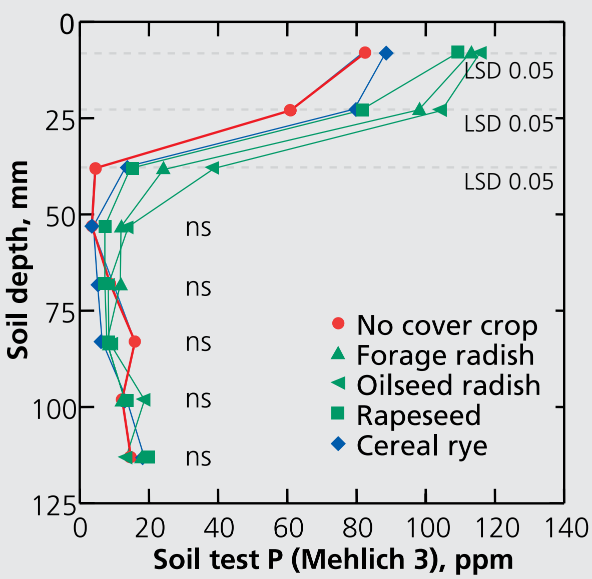

Figure 1. Cover crops enhance natural stratification by bringing nutrients up from deeper layers and making them more available for crops in the surface soil. This Maryland coastal plain soil (silt loam) has been cropped for over a century, with the last 6 years under low-disturbance no-till in a corn >>soybean rotation. Only the last 3 years with the cover-crop treatments are presented (graph values are 3-yr averages). The dramatic long-term stratification of soil P is enhanced by the cover crops, especially the radishes. These plants not only bring up P from deeper layers and deposit it (via their residues) at the surface, but also their roots excrete organic acids that make soil P more available to plants. Before a killing freeze in December, the radish tissues contained very high P concentrations, averaging 0.6% P. (Source: Unpublished data from Weil and graduate students.)

from areas of high concentration (such as upper soil layers) to areas of lower concentration (e.g., at depth).

Plants have evolved to cope with the resulting nutrient stratification, with the ability to produce extensive root mass in the volume of soil near the surface. This especially happens in no-till systems with abundant surface mulch, which tends to maintain sufficient moisture beneath the mulch for crop root growth during much of the season. (Uptake of some nutrients only occurs at the root tips, which must be actively growing.)

Further, the plant's roots are extremely adaptive, responding to areas of higher nutrient availability by causing root growth to proliferate there, so long as conditions remain suitable for nutrient uptake at that location. (*Editors: See 'Roots: The Foundation' by Rick Waldren in the March '06 issue.*) Finally, an undisturbed soil covered by plant residues encourages the formation of mycorrhizae, the beneficial association of certain fungi with roots that enormously enhances the nutrient-gathering ability of many crop plants.

Four things needed for root uptake: the nutrient, water, oxygen, and roots themselves, all in the same place at the same time. This occurs readily in soil biopores, unless mechanical disturbance interrupts them.

The four things that are needed for nutrient uptake by roots are: the nutrient (in a plant-available form), water, oxygen, and the roots themselves, all in the same place at the same time. Where you have poor (short) crop rotations, you typically have poor roots. For instance, in *Wheat Health Management*, Jim Cook and Roger Veseth discuss placing nutrients in a disturbed zone. The soil disturbance interrupted pathogenic *Rhizoctonia* hyphae, allowing root growth in the zone where the nutrients were placed. The roots did not use the whole soil mass, only the part where till-

Photo by Brian Lindley.

Healthy plants grow many fine roots, visible here. (This was corn in long-term no-till.) You would need magnification to see the mycorrhizal hyphae network.

age was done, because of *Rhizoctonia* diseases associated with monoculture or alternate-year wheat. As long as it rained enough (or rotations were very conservative), the disturbance plus fertilizer placement system was reasonably successful.

To take this somewhat further, consider ridge-tillage, where the plant row is located in the same place each year. Many studies were conducted to figure out how much extra fertilizer was needed to offset the management-induced problem of root pruning in this system. With ridge-till, plant growth extracts nutrients from beneath the ridge and cycles a portion to the row middles (where the residues fall). The roots from next year's crop grow from the ridge down to and under this mat of residue. The roots proliferate until the first cultivator pass, which both rebuilds the ridge and cuts off roots. The growing plant must then subsist on a reduced root mass which is located where nutrient concentrations are lower (under the ridge).

Prior to human intervention, virtually all terrestrial ecosystems exhibited considerable nutrient stratification. Although nutrients were more concentrated near the soil surface for millions of years, ecosystems didn't crash, and many became increasingly robust over millennia.

The differences between these scenarios and long-term low-disturbance no-till are considerable. When undisturbed, soil macropores are created by fauna and flora. Plants contain nutrients in their roots. When the roots decay, these nutrients are left behind in these biopores, which subsequent roots tend to follow. Earthworms do similar things. Their burrowing engulfs and mixes soil, adds uptake-enhancing enzymes (e.g., phosphatase), and deposits excreta with other characteristics that happen to be beneficial for plant uptake. Roots follow these channels as well. The roots do this primarily because it is an easier path, not because of greater nutrient availability. These macropores are higher in oxygen and they tend to conduct water deeper into the soil when they are continuous and open to the surface. When someone tills, uses high-disturbance seeding, heavy harrows, etc., they interrupt macropore openings to the surface, thus negating the macropore ability to conduct water during rainfall or irrigation. Subsequent precipitation washes disaggregated soil particles into the remnants of the pores, clogging them; oxygen is then less available in the macropore than the surrounding soil. Essentially all studies that have been conducted show that earthworms and other macrofauna are more abundant in undisturbed (no-till) soil. No-till's mulch cover also moderates soil temperatures and retains moisture to create conditions suitable for root growth near the surface during most of the season.

Prior to human intervention, virtually all terrestrial ecosystems exhibited considerable nutrient stratification. The foundation of land ecosystems is photosynthesis, which means that some plant tissues must be exposed to the sun, and are therefore aboveground. When these tissues die, they soon decay and the relinquished nutrients enter the upper portion of the soil. Hence, stratification. But ecosystems did not stall from nutrient deprivation, and indeed were relatively efficient at conserving nutrients over many eons. Infiltrating moisture would move dissolved nutrients downward in the soil profile at varying rates, depending on nutrient solubility, soil texture, etc. Earthworms, mycorrhizae, and vascular plants would redistribute the nutrients acquired from the upper portion of the soil profile. As herbivores fed on the aboveground plant material (and carnivores fed on the herbivores), their excrement again came to rest on the soil surface, which often was moved into the soil by dung beetles (and other fauna); the manure was mixed *in situ* with low-N carbon material and 'injected' just below the surface. As the herbivores (or carnivores) died and the carcasses came to rest on the soil surface, decay processes ensured that even the bones again reached soluble mineral status and moved into the soil. Although nutrients were more concentrated near the soil surface for millions of years, ecosystems didn't crash, and many became increasingly robust over millennia. *Stratification is normal*.

Returning to agriculture, some studies and experiences do find a favorable crop yield response allegedly due to

Photo by Roger Long.

Here, the soil-like clumps you see are actually nightcrawler poop, forming a midden around their permanent burrow home. In continuous no-till with abundant crop residues, earthworms will typically become prevalent and enhance soil nutrient availability for plants. Photo is from the irrigated portion of Dakota Lakes Research Farm (nightcrawlers were 'seeded' in the early '90s there).

'zone-building' or strip-till. In many of these reports, the response is to redistributing a compacted layer, or to N and/or P and/or K placement in proximity to a corn row, not the fact that the nutrients were placed at depth or that a certain implement was used to place them. These studies are usually not breakthroughs, often because of inadequate control treatments (what happened when the fertilizer was banded shallowly near the row but without the deep shank? what happened without the fertilizer when just the shank ran through the soil?). Several other factors can confound the results. If secondary nutrients (e.g., sulfur) or micronutrients (e.g., zinc) are limiting, the tillage done in the strip or zone may increase availability of those nutrients as soil organic matter is mineralized. Also, if the planter is not reasonably equipped to do an adequate job of placing seeds in the low-disturbance no-till plots, the study may be biased by an inadequate plant population and/or less uniform emergence. If crop rotations are unfavorable for low-disturbance no-till, such as being too low in water extraction, or previous crop residues are allelopathic, the study will again be inadvertently biased against the low-disturbance (and shallow placement) treatments.

Side-band and seed-furrow fertilizers are sometimes found to be more important in no-till than tilled systems. Again, this isn't unusual or unexpected. Early planted no-till crops often find the soil environment a bit wetter and colder and their early growth responds favorably to use of side-band and pop-up fertilizers, and the enhanced early growth occasionally improves grain yield, especially in areas where pollination or grain fill is adversely affected by delays in crop maturity. In such studies, be careful to determine if there was a treatment where N and/or P and/or K in the side-band and/or pop-up were used in all tillage systems. (Producers and researchers often overlook the good combinations: pop-up *plus* side-band, not just one or the other.) Carefully look at the treatment methods and treatment rates. Broadcast N is not as efficient as banded N. Surface applications are often not as efficient as shallow placement. Has the no-till treatment been in place for a number of years prior to the start of the study, or is the soil structure and biology still in transition?

Deep P (and K) may be needed for higher yield in a few soils or fields, but the evidence is extremely weak (despite intense study) and the measured yield effects are typically quite small to nonexistent. Having appreciable P and other nutrients at depth has intuitive appeal, and may yet prove important in arid environments. But, looking at long-term no-till systems with earthworms, the fauna are often moving nutrients *and organic matter* deeper than mechanical placement does, and the biology does that in all areas, not just the shank area. Nutrients are going to depth as linings in the faunal burrows. Roots follow these channels, which are also the pathway for water and oxygen to enter the soil. The crop benefits when roots, water, and available nutrients are in close proximity. With deep mechanical placement *the nutrients will get cycled back to the surface by the plants* and the mechanical placement will need to be repeated. Earthworms and other soil organisms, however, continue moving nutrients effectively year after year, as well as making some nutrients more available to crops.

In long-term no-till systems with earthworms, the fauna are moving nutrients and organic matter deeper than mechanical placement does, and the biology does that in all areas, not just the shank area. Earthworms and other soil organisms continue moving nutrients year after year, while mechanical placement must be repeated.

The fertilizer placement studies discussed here are typical of other unpublished experiments across the U.S. and Canada. Agronomic soil and crop sciences are often broken into pieces that are easier to study, but the pieces are not necessarily easily fitted back together into a system by producers or by the investigators (including the authors of this article). Many crop nutrition researchers do not understand no-till sufficiently, and so they design experiments that are supposed to define this mysterious tillage by fertility interaction instead of just focusing on nutrient cycling and distribution characteristics under continuous no-till, and what needs to be done to efficiently fertilize no-till crops.

Conclusion

Stratification is best thought of as *normal* nutrient distribution. Deep placement of fertilizers or manure (while disturbing as little of the soil volume and surface mulch as possible) may have some applicability as a *one-time* corrective measure on a soil with exceptionally low nutrient status at depth, but which is otherwise productive. However, the best long-term approach will be to ensure an adequate (or slight surplus) crop nutritional status using shallow (e.g., 2-inch depth) subsurface placement or surface applications, and allowing natural processes to gradually redistribute those nutrients to depth. Improving other aspects of no-till agronomy will likely have a better economic return for producers than repeatedly attempting to mechanically place nutrients at depth, especially when the deep-placement operations disrupt the network of biopores and aggregation that form slowly under many years of continuous no-till.

Soil Biology Trumps Other Factors for Yield Influence

by the Editors

SCIENCE

A study was conducted in Western Australia to assess the individual influence of various climatic factors, agronomy, and soil properties on wheat yields in 40 paddocks (fields) over a 12-by-30-mile region. Fields were chosen to compare high- and low-yielding areas and soils that over- or underperformed. The average values for the attributes of the fields are presented in the table (the fields were from 2 catchments, or watersheds, designated A and B); average grain yield was 26 and 48 bu/a in A and B respectively. All significant attributes have been presented (same letter denotes no significant difference between catchments for that attribute); most non-significant attributes assessed were excluded from the table in the original paper, such as degree of mycorrhizal colonization of roots, and levels of diseases and pathogenic nematodes—all of which had very low occurrence in these fields.

Among the significant attributes is clay content, but it should be noted that WA's soils are extremely sandy in general. 'Labile C' is the portion of soil carbon with rapid turnover, i.e., the active fraction. 'Microbial biomass C' is the portion of soil carbon found in the microbes. PMN is an index of biological N supply, i.e., a measurement of the quantity of N being made available to the crop from the organic fraction of the soil, via biological activity.

Despite growing-season rainfall varying from 6 inches to 9.5 inches, this explained less than 4% of the yield variation among the fields. Nor did chemical properties of the soil, despite relatively low pH values (pH 5.6 – 5.7 averages by $CaCl_2$ test; roughly equal to pH 6.1 by water test) that some agriculturalists would consider limiting. Total soil carbon explained almost nothing, although soil organic matter is often touted as the key measurement of a soil's health or productivity. N fertilizer applied explained 9% of variability, *while the index of biological N supply (PMN) accounted for 21%, and microbial biomass C explained a whopping 30% of yield variation.* The researchers interpret these data to support a conclusion that microbial populations and biological N supply are extremely important to cropping systems. Note that biological N was more than twice as important as fertilizer N. And while total soil C explained nothing, microbial C was the single largest factor—so maybe it's time to replace the old soil OM test with something more useful. (As a practical matter, no-tillage with abundant mulch is an excellent method for increasing soil microbial biomass.) In further modelling, the researchers found that a full 58% of yield variability was not accounted for by any of the attributes measured, so plenty remains to be learned!

Table results from bivariate regression analysis. Source: D.V. Murphy, N. Milton, M. Osman, F.C. Hoyle, L.K. Abbott, W.R. Cookson & S. Darmawanto, 2005, Soil biology and crop production in Western Australian farming systems, in *Agribusiness Crop Updates 2005,* W. Australia Dept. Ag. in partnership with Australia Grains Research & Development Corporation (GRDC).

	Attribute	Catchment		Coefficient[a]	P-value[b]	Variability explained[c]
		A	B			
Climate	Rainfall (mm)	211a	206a	—	ns	3.7
Agronomy	N fertilizer (N kg/ha)	20a	24a	0.02	0.055*	9.4
Physical	Clay content (%)	11.0a	10.4a	0.08	0.062*	9.1
Chemical	Total carbon (C t/ha)	9.0a	10.8b	—	ns	0.2
Chemical	pH (by $CaCl_2$ test)	5.7a	5.6a	—	ns	0.4
Chemical	Electrical conductivity (mS/m)	80a	63b	—	ns	0.1
Biological	Labile C (kg/ha)	83a	118b	0.01	0.041**	10.5
Biological	Microbial biomass C (kg/ha)	107a	183b	0.01	0.001***	30.3
Biological	PMN (N kg/ha)	7.0a	10.1b	0.14	0.003***	21.2

[a] Coefficient can be interpreted as t/ha yield change per unit change in attribute.
[b] ns = not significant; * = significant at $P < 0.10$; ** = significant at $P < 0.05$; *** = significant at $P < 0.01$.
[c] The variability explained has a maximum of 100% and is not additive between attributes.

Livestock Manure Utilization in No-till Cropping Systems

by Ron Wiederholt, Dave Franzen, and Bridget Johnson

SCIENCE

Wiederholt, Franzen, and Johnson are NDSU Extension Specialists in nutrient management.

Editors' Note: Reprinted from bulletin NM-1292 (August 2005) with permission of the authors and North Dakota State University. The authors emphasize that the publication in general is referring to beef manure from an open-air feedlot. Other manures can be surface-applied as well, but N losses may be significant.

Concern for the environment, water conservation, and economic savings through reduced fuel use have been the driving forces for adopting no-till crop production in North Dakota. Concern for the environment, economic savings through reduced commercial fertilizer dependence and, more recently, federal government incentives have driven enhanced manure management in the state.

North Dakota livestock producers have increased their reliance on manure nutrient credits to supply their crops with needed plant nutrients. They have done this voluntarily because they realize the value of the nutrients in the manure or they want to take advantage of government incentive programs.

Photos by Jay Fuhrer.

Beef feedlot manure being spread at Gabe Brown's near Bismarck, ND. No tillage will be done—rain does the incorporation. Manure contains many secondary and micronutrients as well as N, P, and K. (See the Dec. '06 *Leading Edge* for more on Gabe Brown's operation.)

No-till crop producers with livestock are concerned with surface, nonincorporated manure application for several reasons: availability of nutrients to the crop, increased weed competition, and nutrient stratification in the soil surface. Environmentally, a major concern is surface water contamination when surface-applied, nonincorporated manure leaves the field in runoff.

Environmental Issues

The transport of manure nutrients off-site in runoff is a major source of surface water contamination. Phosphorus and nitrogen in surface runoff are the major contributors to the impairment of lakes and ponds through the process of eutrophication. Eutrophication is the result of excessive bacteria and algae growth in surface waters due to nutrient enrichment, usually of nitrogen and phosphates. When this growth dies, other bacteria decompose the material, depleting the waters of oxygen, resulting in fish kills. Eutrophic waters contain high levels of bacteria and algae that cause taste and odor problems. In addition, certain types of algae in eutrophic waters are toxic to livestock and humans.

A recent study in Wisconsin[1] assessed the amount of phosphorus (P) in runoff from no-till plots with nonincorporated manure applications versus chisel-plowed plots with incorporated manure applications. The researchers found higher concentrations of dissolved P in the runoff from the no-till plots versus the chisel-plowed plots, but the total amount of P lost was lower for the no-till versus the chisel plow. They stated that the increased infiltration of water in the no-till plots lowered the sediment loss and reduced the total P load in runoff.

These results showed opposite effects on total P loss than what was expected from surface-applied nonincorporated manure. The researchers suggested examining all aspects of a cropping system when designing nutrient management recommendations to minimize losses of P that cause surface water pollution.

No-till crop production increases the amount of soil macropores and allows for greater water infiltration, which could lead to nitrate (N) contamination in groundwater.

[1] L.B. Bundy, T.W. Andraski & J.M Powell, 2001, Management practice effects on phosphorus losses in runoff in corn production systems, *J. Environ. Qual.* 30: 1822-1828.

A study published in 1995[2] showed increased nitrogen leaching in the soil profile under no-till compared with conventional tillage. More recent studies[3] showed no difference in nitrogen leaching between tillage types. These studies emphasize that no-till has an increased risk of macropore flow that may impact N leaching. Soil type, rainfall, crop rotation, and other external factors will influence the amount and rate of the macropore flow. Therefore, proper nitrogen fertilization management is important to prevent producers from applying too much crop-usable nitrogen and increasing the risk of nitrogen leaching in macropore flow.

Several studies report stimulated root growth in the upper portions of the soil and higher nutrient uptake by the plants grown under no-till vs. tillage.

Nutrient Stratification

Lack of tillage to mix the topsoil and surface application of nutrients in no-till crop production systems can lead to nutrient stratification in the upper several inches of the soil. Several long-term studies[4] have shown nutrient accumulations in the upper 2 to 5 inches of the soil after nine to 13 years of no-till row crop production with surface application of nutrients.

They also report stimulated root growth in the upper portions of the soil and higher nutrient uptake by the plants grown under no-till vs. tillage. They attribute these results to nutrient stratification at the soil surface and more consistent soil moisture conditions under no-till. Yield-limiting problems due to the positional unavailability of nutrients caused by stratification in the upper 2 to 5 inches of the soil are a concern. To address this, banding nutrients at 6 to 8 inches deep may be advisable. However, under dryland conditions, any rainfall will tend to wet the surface more than the subsurface when crops are growing. Therefore, the benefits of deep banding vs. surface application of nutrients are minimized under dryland conditions.

Nutrient Availability

Research has shown that 40 percent of the total nitrogen (N) in beef feedlot manure and 15 percent in composted beef feedlot manure is plant available in the first year it is applied and incorporated.[5] When beef feedlot manure is applied and not incorporated in a no-till system, research has shown first-year availability of 38 percent of total N for manure and 20 percent for compost.[6] In this study, surface application of manure or composted manure did not show significant N loss because the N in both manure and compost was in very stable forms. The study also indicates no difference in corn yield between no-till and tillage, or manure, compost, or fertilizer treatments. Soil test P levels increased when manure or compost was applied at rates higher than crop uptake, regardless of tillage.

From another study, corn, soybean, and wheat yields were not different among chisel plow, moldboard plow, or no-till when composted swine manure was the fertilizer source.[7] The study also showed soil test P and potassium (K) levels can be elevated when those nutrients are applied with compost at rates higher than crop uptake.

In all these studies, nutrient availability is not an issue when manure or composted manure is surface-applied and not incorporated under no-till cropping systems.

Barley and oilseed crop yields were similar between manure incorporated in conventional tilled plots vs. surface-applied nonincorporated manure in no-till plots.[8]

[2] R.C. Izaurralde, Y. Feng, J.A. Robertson, W.B. McGill, N.G. Juma & B.M. Olson, 1995, Long-term Influence of Cropping Systems, Tillage Methods, and N Sources on Nitrate Leaching, *Can. J. Soil Sci.* 75: 497-505.

[3] A.D. Halverson, B.J. Wienhold & A.L. Black, 2001, Tillage and Nitrogen Fertilization Influences on Grain and Soil Nitrogen in a Spring Wheat-Fallow System, *Agron. J.* 93: 1130-1135. Y. Zhu, R.H. Fox & J.D. Toth, 2003, Tillage Effects on Nitrate Leaching Measured by Pan and Wick Lysimeters, *Soil Sci. Soc. Am. J.* 67: 1517-1523. S. Gupta, E. Munyankusi, J. Moncrief, F. Zvomuya & M. Hanewall, 2004, Tillage and Manure Application Effects on Mineral Nitrogen Leaching from Seasonally Frozen Soils, *J. Environ. Qual.* 33: 1238-1246.

[4] F.S.R. Holanda, D.B. Mengel, M.B. Paula, J.G. Carvaho & J.C. Bertoni, 1998, Influence of crop rotations and tillage systems on phosphorus and potassium stratification and root distribution in the soil profile, *Commun. Soil Sci. Plant Anal.* 29 (15-16): 2383-2394. G. Robbins & R.D. Voss, 1991, Phosphorus and potassium stratification in conservation tillage systems, *J. Soil & Water Conserv*. 46: 298-300.

[5] B. Eghball & J.F. Power, 1999a, Phosphorus- and nitrogen-based manure and compost applications: corn production and soil phosphorus, *Soil Sci. Soc. Am. J.* 63: 895-901.

[6] B. Eghball & J.F. Power, 1999b, Composted and noncomposted manure application to conventional and no-tillage systems: corn yield and nitrogen uptake, *Agron. J.* 91: 819-825.

[7] J.W. Singer, K.A. Kohler, M. Liebman, T.L. Richard, C.A. Cambardella & D.D. Buhler, 2004, Tillage and compost affect yield of corn, soybean, and wheat and soil fertility, *Agron. J.* 96: 531-537.

[8] F.C. Stevenson, A.M. Johnston, H.J. Beckie, S.A. Brandt & L. Townley-Smith, 1998, Cattle manure as a nutrient source for barley and oilseed crops in zero and conventional tillage systems, *Can. J. Plant Sci.* 78: 409-416.

In all these studies, nutrient availability is not an issue when manure or composted manure is surface-applied and not incorporated under no-till cropping systems. Nitrogen typically is the limiting nutrient in crop production, and nitrogen mineralization from beef feedlot manure or composted manure is the same whether it is incorporated with conventional tillage or left on the surface in no-till systems.[9]

Manure vs. Composted Manure

Composting manure is becoming more popular. In comparison with manure, compost is a more stable product since almost all of the nutrient fractions are in an organic form and the material is semi-decomposed. Plants take up the majority of nutrients in an inorganic form. Therefore, the nutrients in composted manure need to undergo biological breakdown (mineralization) in the soil before they are available to the plants. In essence, composted manure is a slow-release fertilizer, so consider the timing of the application.

Composted manure is a slow-release fertilizer.

Studies have shown that the slow mineralization of nutrients in compost increases soybean yields at a higher rate than commercial N fertilizers applied in-season.[10] Composting also is a good method of producing a more nutrient-stable soil amendment with a lower moisture content and less volume, compared with raw manures. The composted material can be hauled longer distances at less cost, it has less odor when applied, and pathogens and weed seeds are killed during the composting process if temperatures generated during the process are high enough.

Both manure and compost can improve the soil's physical, chemical, and biological properties, which helps increase crops' nutrient uptake efficiencies and leads to higher yields. Research has shown that soils with compost applications had a 13 percent higher organic matter concentration than those without compost.[11]

Many crop producers have noted weed problems following manure applications. Of the research conducted to investigate this issue, one study showed that weed production was more highly correlated to the nutrient availability of applied manure than to the weed seeds in the manure.[12] If weed seeds are a concern, one sure method of reducing the viability of weed seeds is to compost the manure properly. The temperatures in properly composted manure reach a high enough level to kill weed seeds.

Some disadvantages of using compost would be the loss of some nutrients, particularly nitrogen, during the composting process; additional labor needed to manage the process; and the possible investment in specialized equipment. Standard farm equipment can be utilized to compost successfully; however, some producers choose to purchase compost turners to gain efficiency during the process.

Manure Nutrient Values

The rate of manure or compost applied to fields depends on the crop being grown, soil test levels and nutrient composition of the manure or compost. Manure or compost should be tested to determine the actual nutrient levels.

Knowing soil test levels can help producers plan their manure application rates based on N or P needs. If soil test levels for P are in the low range, then manure application rates can be based on N needs of the crop to be grown. If soil test levels for P are high, then manure application rates are based on P needs of the crop to be grown. (*Editors: Omitted here are approximate N-P-K content for various manures, sampling information, example calculations, and summary remarks. For these, see the original publication online at www.ag.ndsu.edu/pubs/ansci/waste/nm1292w.htm.*)

Summary

Long-term studies have shown increased carbon sequestration, higher cation exchange capacity, lower bulk density, and increased levels of organic matter in soils where manure was applied consistently.[13] These side benefits of manure application have a beneficial impact on water and air movement in soils, which helps enhance crop growth.

[9] B. Eghball, 2000, Nitrogen mineralization from field-applied beef cattle feedlot manure or compost, *Soil Sci. Soc. Am. J.* 64: 2024-2030.

[10] Singer et al., 2004.

[11] Singer et al., 2004.

[12] Eghball & Power, 1999a.

[13] B. Eghball, 2002, Soil properties as influenced by phosphorus- and nitrogen-based manure and compost applications, *Agron. J.* 94: 128-135. See also C.W. Wood & J.A. Hattey, 1995, Impacts of long-term manure applications on soil chemical, microbiological, and physical properties, in *Animal Waste and the Land-Water Interface*, CRC Press.

Marestail Menace: Glyphosate Resistance

by Matt Hagny

TECHNIQUE

Hagny is a consulting agronomist for no-till systems, based in Wichita, Kansas.

Marestail, a.k.a. horseweed or fleabane (*Conyza canadensis*), a very common weed across the U.S. and Canada, now has many localized populations that are resistant to glyphosate, including a number of locations in Nebraska, Kansas, Oklahoma, and Missouri. Marestail often produces 100,000 seeds per plant, which disperse in the wind as well as being carried on farm equipment. The seeds are very small and germinate readily when in contact with the soil surface and moisture is adequate. Marestail can act as a winter annual that germinates in the fall, or a summer annual that germinates in the spring or early summer. Dallas Peterson, KSU Extension Weed Specialist, indicates they typically have achieved nearly complete control of marestail with late fall treatments in research at Manhattan, KS—suggesting mainly fall germination—but they had a significant number of marestail emerge in the spring of 2007 in an experiment near Wellington, KS, despite good moisture in the fall. Research in Indiana and Ohio also indicates greater fall germination of marestail in the northern areas of these states with more spring germination in the southern parts of the states. Cropping systems and herbicide programs undoubtedly exert major selection pressures, perhaps accounting for some of the regional variation. Because of these factors, it can be quite a challenge to control this highly adaptive and prolific weed.

Photo by Dallas Peterson.

Marestail in cotton.

Several herbicide modes of action (MOAs) remain effective in Kansas and the nearby region, at least for now. One of the most important is the triazine/urea family of chemistries which includes atrazine, simazine, metribuzin (e.g., Sencor), and diuron (Karmex). Fall or winter applications of 1 – 1.3 lbs/a of atrazine (preferably tank-mixed with 2,4-D) are excellent for fields going to corn or milo, followed by appropriate use of atrazine in the springtime. In high-rainfall areas, simazine (corn only, not milo) may outperform atrazine. Similarly, Sencor is useful ahead of soybeans, while Karmex can be used ahead of cotton so long as soils aren't too sandy. These herbicides provide both foliar and residual activity, although including 2,4-D is wise to improve control of emerged marestail (and other species) and to provide a second MOA. The triazine/urea family can also be useful in 'burndown' applications after wheat harvest, although marestail are more difficult to control at this time. Try to include other MOAs whenever possible, since marestail in Michigan are already resistant to the triazines & ureas and we don't dare get overly reliant on a single chemistry.

Dallas Peterson: "Once we start relying more on this chemical family for marestail control, it won't take long for the ALS resistance to appear."

Growth-regulators such as 2,4-D, MCPA, and Stinger will be extremely important in this fight. These chemistries are excellent for springtime applications in-crop for wheat, barley, and some millet types, as well as non-selective burndowns in non-crop intervals (preplant or post-harvest). In regions with sensitive crops such as cotton, summertime burndowns will have less trouble with volatile vapors from amines as opposed to ester formulations, although esters have in fact been used adjacent to cotton without problems—however, the utmost caution must be observed with *any* 2,4-D application if cotton or other sensitive plants are nearby. For both 2,4-D chemistries, fine droplet and vapor movement

Photo by Doug Palen.

Marestail in wheat stubble. This is a relatively large weed with aggressive growth that can compete with many crops. Marestail germinate during at least 10 calendar months in Kansas, and can produce 100,000 seeds/plant, which are easily carried by wind. Control is becoming more challenging.

during spraying can be reduced by drift retardants and careful nozzle/pressure selection. 2,4-D has also been applied post-emerge on corn and milo for 40 years, but crop tolerance is always a bit touchy. Dollar-for-dollar, Starane and dicamba are notably weaker on marestail than 2,4-D and Stinger, although those chemistries have some other useful attributes. Springtime applications of 0.75 lb/a of 2,4-D usually provide complete marestail control without assistance from other chemistries such as glyphosate, while larger marestail in summertime frequently survive applications of 1.5 lbs/a of 2,4-D. Growth-regulator performance declines on all species as plants get close to reproductive stages.

As growth-regulator applications get closer to the crop planting date, be careful of rates since some of these chemistries can seriously damage crop germination. For instance, 2,4-D *amine* and dicamba are far more likely to be taken up by germinating seeds than is 2,4-D *ester*, although it too can cause problems under some conditions. Crop species vary in their sensitivity to soil residuals of these compounds.

Another MOA of great importance (at least for now) for marestail control is the SU/imi (ALS) family. Although ALS-resistant marestail have been documented in Michigan, these chemistries exhibit good control yet in Kansas and surrounding states. Products such as Finesse in wheat or FirstRate in soybeans generally provide excellent soil activity against marestail and some foliar activity on small (< 4-inch) marestail. However, Dallas Peterson notes: "Once we start relying more on this chemical family for marestail control, it won't take long for the ALS resistance to appear."

Another herbicidal tool is Callisto for post-emerge use on corn, and for preplant applications in corn or milo as a component of Lumax. Callisto is from the bleaching (HPPD-inhibiting) class of herbicides, and has some activity on marestail.

Glufosinate (Liberty, Ignite) from yet another chemical family will kill *small* marestail also, although high spray volume (15 – 20 gallons per acre) is required. Mechanical control such as intensive grazing, low-cutting sickles, etc., are also options since marestail generally get some height before setting seed.

You may have noticed a theme here: Small marestail are much easier to control than larger older ones. This is true for most weedy species, but perhaps especially for marestail because of its cylindrical shape after it has bolted—nozzles spraying straight down will find a reduced target, especially if weed density is thick. Spray coverage becomes all the more critical. A good many instances of failed control of marestail with glyphosate are indeed attributable to inadequate spray coverage due to droplet size and/or weed density, or to subpar spraying conditions, or to inadequate glyphosate rate (many experiments with allegedly resistant populations are in fact controlled by higher glyphosate rates; however, some populations truly are resistant, not to mention that some of the higher glyphosate rates become impractical anyway because of crop safety issues in Roundup Ready crops).

Even if you don't yet have glyphosate-resistant marestail, using more diversified control methods (with less reliance on glyphosate) is a good idea anyway. The marestail problem is spreading rapidly, as are other glyphosate-resistant weeds such as waterhemp—its glyphosate resistance is now documented in Kansas as well. Others will follow. Adaptation by weeds is to be expected, so the key is to stay one step ahead by using diverse crop rotations and diverse control measures.

Photo by Doug Palen.

Waterhemp now has biotypes with glyphosate resistance in Kansas, too.

A Few More Steps Forward

by Matt Hagny

The original story on Craig & Gene Stehly appeared in the Sept. '02 issue.

From drowning to drought, all in the same year—sounds like farming on the Plains, in this case, eastern South Dakota. Finding a successful path among the weather extremes is a challenge, and Craig Stehly knows it: "You learn something one year, and it might be a valuable lesson. Or you might never want to think about it again [because it was such a fluke]. We keep trying to go down the middle of the road and ignore the extremes."

Stehlys already had 13 years of 100% no-till under their belts in '02, so another 5 years doesn't find them making radical changes, but they've fine-tuned a few things. In an area where corn and soybeans are the only crops for most people, Stehlys still like to have nearly a third of their acres in wheat. Craig says, "You can see the [beneficial] effects of wheat in the rotation 3 or 4 years later."

The Stehlys' top rotations are:
1) (spring or winter) wheat >>w.wht >>corn >>soy >>corn >>soy; 2) wht >>w.wht >>corn >>corn >>soy >>soy; and, 3) wht >>corn >>soy. They have a few variations also, such as when only a single wheat crop is grown followed by 4 years of corn and soybeans. Craig likes the pure stacked rotation (#2) especially for the benefits to the wheat: "Wheat absolutely detests corn residue—even year-and-a-half-old corn residue. So the two years of beans is great for wheat. The tough part of that rotation is the corn on corn, especially in narrow [22-inch] rows." But Craig says they've been making it work with GPS guidance, and now auto-steer, to keep the new rows between the old rows. "We're getting better at it, and we've got better options for seed now, if you can handle the residue [with the planter]." Not always easy in an area where corn sometimes gets 10-ft tall and barely decomposes over the winter. Stehlys run Groff row cleaners, and Craig considers row cleaners absolutely essential for planting 2d-yr corn (or for corn into wheat stubble) in their climate.

"The cover-crop concept is right, and most things we've tried have worked. But some work better than others."

Stehlys have continued to experiment with cover crops in wheat stubble that's slated for corn the next year. They're now in their second year using canola + lentil mixes, and they like that program better than vetch, sunflowers, and various other species they've tried. Craig insists that they have flexibility in the planting window for the cover crops, since they never know when they'll have moisture to get them started. Currently, they're planting 5 lbs/a of winter canola (bin-run, cleaned) + 10 lbs/a of spring lentil in early August. "The cover-crop concept is right, and most things we've tried have worked. But some work better than others; it's just a matter of getting the details right. One of the biggest mistakes we were making early on was not planting them thick enough to get a good canopy and get them to use up some water."

Having too much water at corn planting is a common hazard for Stehlys—they're in a 'prairie pothole' region without much slope for natural drainage, and no opportunity to run drain tile. They've learned to manage the problem. Even in '07, which was an exceptionally wet spring, the Stehlys got all their corn planted (with good stands), even in the stacked wheat stubble. Part of their success is being set up to plant in wetter conditions: Craig attributes less mud behind the gauge wheels to three items: air-bag down-pressure on their new 32-row DB central-fill planter, thicker (3.5-mm) opener blades, and R-K Products' hardened seed tube guards.

While Stehlys put down pop-up fertilizer blends in the seed row with both the drill and the planter, the bulk of their fertilizer still goes out as a dry blend broadcast on the surface in early spring. Craig admits the shortcomings, "There's no easy answer. We definitely tie up some in the residue. . . . I don't see any good way to put it in the ground. We have too many wet spring [seasons]. We could pull [an air cart] behind the planter, but we've already got a [big tracked] Cat on the planter. And side-dressing with a coulter is out of the question—it'd turn wet and you wouldn't get it done and then you're screwed." Craig thinks that encapsulated urea for their preplant broadcast application will be the future for them, and is cautiously implementing variable-rate applications.

Craig assesses their direction: "You keep hearing about no-till yield drag in the farm magazines. But it sure as hell doesn't happen here." —Perhaps it's no surprise that the shrewd Stehlys figured this out long ago.

Second Chances

by Matt Hagny

Most of us derive some satisfaction from watching crop seeds germinate, take hold as vigorous seedlings, and gain strength as they become established and flourishing plants. Similar development can occur when looking at the financial success of a well-run farm operation. Just as a seedling must make the best of the conditions in which it finds itself, so, too, will the farmer himself sometimes thrive by dint of a mixture of skill and good fortune.

Alan Aufdemberge is one producer who's had the skill to sail a prosperous course upon the winds of luck during the last decade. A bit of financial strife in the mid-'90s helped push Alan and his dad into no-till, which, along with other good decisions, has certainly rewarded their perseverance. Their farming operation in central Kansas, just south of Lincoln, reveals the care and thought these guys put into growing crops as well as a farming business.

Talk about a reversal of direction! Having attempted no-till milo in the early '80s, as well as watching some others struggle with no-till cropping, Alan didn't think very highly of the practice by the early '90s. "We didn't have the equipment back then. We got poor stands and we were discouraged." With some justification, he typically associated no-till with poor stands, poor weed control, and lower yields. That attitude is in shocking contrast to today's Alan—a top-notch no-tiller and one who is not only comfortable with the practices involved but also as an outspoken proponent for the new mindset of no-till (he confesses to giving neighbors grief about burning their stubble and so forth).

A Fresh Start

Some hiccups with cattle and crops in the early '90s had Alan and his dad choosing to sell nearly all of their machinery in the spring of '94 to get out from under some debt. They worked with two of Alan's cousins that year to put in their crop—all with tillage. The following year ('95), Alan and his dad scraped together some old machinery (including a neighbor's 6-row Allis planter from the early 1960s, which they rigged to apply fertilizer) to plant the milo crop themselves using solely no-till. Alan says, "We ran that old planter day and night to get everything planted [that spring]." They also used the archaic planter to install double-crop milo after some of the wheat that year: "We beat our brains out running that planter!" Also in '95, they rented a JD 750 drill for one field of no-till soybeans that yielded 50 bu/a.

"I've never missed a stand of alfalfa, and I don't burn the stubble."

What made Alan think this gutsy no-till adventure would meet with success? He says simply, "It had to work, if we were going to stay in farming." They rented a Krause drill to plant some no-till wheat that fall ('95), although they v-bladed some other fields to put on anhydrous. "I'm still bouncing across those v-blade furrows," he says ruefully. By '96, they were 100% no-till on everything, having bought a JD 750 drill and an 8-row 7200 planter.

Photo by Vicki Meier.

Aufdemberge seeding wheat into killed alfalfa.

Looking back on the chain of events, Alan remarks, "I didn't really have the foresight then, but [the equipment sale] really helped me out by not having the tillage equipment to fall back on." They soon were no-tilling, sink or swim. Apparently some open-mindedness runs in the family, as Alan reports that his dad was very supportive of the switch to no-till, and he was excited by it (even though he occasionally "helped out" by disking around some field borders, which Alan says is still visible). Despite some rough sledding in the early years as they learned how to no-till, it all worked out: "I'm not exaggerating when I say that I wouldn't be farming today if it wasn't for no-till. What we were doing before with tillage just wasn't making any money."

Skewed perspective: "On the failed wheat this year, they'll say it's just a fluke—this is really wheat country. But if milo burns up, or soybeans on a hilltop, they'll say we shoulda known better."

Today's Vantage Point

Looking at Alan's operation today reveals little of its highly improvised beginnings to no-till. He now runs a 30-ft Deere 1860 air drill, a 16-row 7200 planter, a couple 150-hp tractors, and a JD 9750 combine. He custom plants and harvests for a neighbor, Tim Meier, who in turn provides custom spraying for Alan. Meier also bales Alan's alfalfa.

Going from the wet years of the late-'90s, regarding which, Alan says, "We could do no wrong," into the drought of the early 2000s, it took steely nerves to keep with the more intense rotations he was developing. Today, Alan's crop rotations have evolved into a wht >>wht >>milo >>milo >>soybean rotation, with double-crop soybeans following the 2d-yr wheat whenever the season allows. On bottomland (river and creek floodplains), corn is often substituted for the milo, and where he plants corn he generally does so 2 years in a row ('stacked'). The stacked wheat has also been a longtime practice for Alan, ever since he started continuous no-till. Aufdemberge's alfalfa may go in following any crop: "I've put it into wheat stubble, as well as following corn, beans, and milo. Much of this is spring-planted. I've never missed a stand of alfalfa, and I don't burn the stubble. One remarkable thing is that I generally get 3 to 4 tons/a in the first year, even with spring-planted alfalfa. Guys with alfalfa going into tilled ground don't count on much of anything for the first year's cuttings, especially with spring-planted alfalfa." Once established, Alan will keep an alfalfa stand as long as it remains productive—which is contrary to his original plan of keeping a stand no longer than 5 years.

In a land where wheat is king, Alan has always paid a lot of attention to growing good milo crops: Aufdemberge has a 10-year average of slightly over 100 bu/a on milo. Nearly all his milo goes in with a planter on 30-inch rows, although he continues to dabble with drilling it in hopes of getting that perfected. Alan's planter is equipped with row cleaners, Keetons, and heavy downpressure springs, plus two separate liquid fertilizer systems—one that goes in-furrow, and the other in a side-band. All the fertility needs for Alan's corn and milo go on at planting. Usually around 100 lbs of N and 5 lbs of S go in the side-band, while some 10-34-0 and zinc go into the seed furrow. A liquid cart trails behind the planter to supply the side-band mix.


Photo by Matt Hagny.

It's not just wheat country anymore, and Alan has the yield history to prove it.

Alan is a bit perplexed why he has such consistent stands now, but in the '80s the same planter row unit with a straight coulter produced lousy stands. He says, "It's no problem now. I wouldn't have any concerns now about pulling into any field and getting a stand, even with the row cleaners lifted all the way up." He speculates that some of it is improvement in soil structure, along with wheat varieties that produce less straw. (And maybe getting rid of the coulter and adding Keetons did some good.)

For soybeans, Alan uses his air drill to place them in 15-inch rows at 155,000 seeds/a for the main crop, and slightly less for double-crop. "I really like 15-inch beans with the drill. They're spaced nicely and canopy quickly." He is pleased with his stands, saying that they

Photo by Matt Hagny.

Alan's grinning at the prospect of '07 soybean harvest.

previously had to plant 180,000 to 200,000 seeds/a, but, "We're getting more consistent stands now." He explains that his drill doesn't have the ability to shut off one rank, so he instead runs 2 secondary lines into a single opener, using a Y from Flexi-coil. Alan's soybean maturities range from early to late Group 3s, although he notes the later maturities came through the '06 drought much better: "We had some 40-bu/a beans in '06."

Wheat is merely one piece of the puzzle in Alan's operation: "I grow wheat, but I'm not a wheat farmer." One might initially get the impression that he under-manages his wheat, but that's not what he intends by the comment. Rather, he is very committed to diverse and lengthy crop rotations. In the fall of '06 when many were planting wheat like mad in response to lofty wheat prices (the other grain prices hadn't yet spiked upward), Alan played it cool, keeping his wheat acres at only a slight increase from his normal percentage. Markedly improved pricing opportunities for corn, milo, and soybeans in the spring of '07, along with a favorable growing season for those crops, and Alan will once again reap the rewards of staying the course.

Following the havoc wrought by the late spring freeze on the '07 wheat crop, many in Alan's area were hoping for a hailstorm to finish it off. Meanwhile, Alan was nervously applying fungicide to a crop that was partially recovering: "You can't tell me that 14 degrees [F] down where the head was developing didn't do some damage. [Several weeks later] the heads in the boot looked green and viable, but were all the flowering parts okay yet?" But Alan's diligence paid off with a wheat crop that was 20 to 25 bu/a better than county average, including an almost unheard-of 60-lb test weight—although Alan seems very reluctant to discuss his good yields publicly, lest he arouse envy in the community.

What methods did Alan employ to snag a good wheat crop despite the tribulations of the '07 season? Alan comments, "Dave Wilcox [of Farmway's agronomy program], Phil Needham, and you [Hagny] always emphasize planting late [in comparison to popular earlier planting]. We did, and our wheat fared a lot better." While many locals have a big portion of their wheat planted by the end of September, Alan doesn't even start until the second week of October. He's well aware that a wet October could hamper his plans, but he doesn't sweat it: "It's not going to blow away like the tilled fields if I don't get it planted. I have options." He suspects the local thinking is skewed anyway: "On the failed wheat this year, they'll say it's just a fluke—this is really wheat country. But if milo burns up, or soybeans on a hilltop, they'll say we shoulda known better."

Guided by Wilcox's consulting, Alan does a bang-up job on his wheat agronomy. The crop gets a 20-30-0 blend at planting, plus another 60 – 100 lbs of N in February or March. If conditions are good, he will stream on additional N at jointing. Alan is definitely one to keep pushing the limits of yield and profitability with improved practices, although he maintains a healthy skepticism for information handed down by the experts: "You can study anything you want and show a response in at least one experiment." But he's certainly not averse to pushing the envelope: "You don't know till you try. Why *are* we satisfied with these yield levels? Why not 150- or 200-bu/a milo? Why not 100-plus-bu/a wheat?"

Challenges Old & New

Alan ascribes a fair amount of his no-till success to improved equipment, and stops to ponder for a moment that he can't recall ever replanting any crop since he went to full no-till. He adds the caveat, "But it has limits. I did have to replant 2 passes of wheat once—I knew it was too wet when I tried the first time. Just don't [try to plant] if it's too wet."

Alan reflects on some troublesome weeds. In one field, he has triazine- and ALS-resistant Palmer pigweeds (a single plant is resistant to both chemical families), which annoyingly seem to thrive despite a preplant Lumax application as well as an attempted cleanup post-emerge with 2,4-D. Having clean, healthy crops is clearly important to Alan, yet he expresses no enthusiasm at all for shortening his rotation to only a single year of milo instead of stacking the crop. We'll see how he solves this dilemma.

Marestail that are increasingly difficult (or impossible) to control with glyphosate have begun to challenge Alan as well. "We had it too good with all these Roundup Ready crops." He's already trying new strategies, including a

Photo by Clarence Aufdemberge.

Aufdemberge's diligence payed off handsomely with the '07 wheat harvest.

wheat stubble burndown with Karmex (diuron) which seems to be effective.

Another challenge is the '07 wheat harvest running too late to get all Alan's 2d-year wheat seeded to double-crop soybeans. The wet summer has him concerned about planting conditions next spring, and he is conjuring on what cover crop to plant to alleviate that situation.

Alan doesn't seem to mind the new hurdles, appearing confident that they too will be overcome. Like their initial move into no-till, one shouldn't underestimate the ingenuity of guys like Alan. With a distinctive whimsical streak, Alan often supplies a mischievous joking perspective to everyday conundrums. That playful mind of his comes in quite handy in finding unique ways to navigate the latest problems on his farm. —I sure wouldn't want to bet against him.

To Our Subscribers:
The winter issue will now be published in January instead of December. If you received the Sept. '07 issue because of your attendance at the '07 Winter Conference, this is the final installment of that subscription. To continue receiving *Leading Edge* uninterrupted, you may renew your subscription by check or credit card (contact details on p. 370), or you may renew by attending the '08 Conference set for Jan. 29 – 30th (AIM Symposium: Jan. 31st). The '08 Conference's all-star cast includes Dwayne Beck and Wayne Smith—more details at www.notill.org.

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