Leading Edge
The Journal of No-Till Agriculture
September 2005 • Volume 4 • Number 2
No·till On The Plains

Managing His Ecology

by Matt Hagny

Eastern Colorado farmer Gary Maskus quietly hones his craft: bio-engineering. No, not with test tubes, gene guns, and DNA markers, but with carefully assembled crop rotations and maximum residue cover. In the heart of winter wheat >>summerfallow country, Maskus grows a diversity of plants, including corn, proso millet, and sunflowers, along with wheat. He makes cropping decisions within the framework of biological principles, knowing that each of those choices impacts the soil and subsequent crops far into the future.

Not much is ordinary about Gary, who has an Electrical Engineering degree and worked for 15 years in the software industry—first in the Los Angeles, California area and later based in Boulder, CO. In '96, he and his wife decided to take over the family farm near Arriba (120 miles east of Denver). Tired of the jet-set, Maskus thought he'd try life in the slow lane.

But Gary didn't waltz into retirement, nor did he inherit a massive farm operation on which to milk the equity. He needed to support himself and his family with crop production in the wildly variable climate of the frequently parched High Plains. So he did what came naturally—he engineered something better. "Having a technological background taught me some things: Apply a *different* solution to the problem, rather than beating it with a stick in the same old way."

Maskus has assembled an efficient low-risk production system by dint of shrewd investigation, both of his own experiences and testing, and that of others. His thoughts turned toward no-till as he attended events such as

Photo by Melody Maskus.

Maskus seeding wheat Sept. '05 using a neighbor's 20-ft 750 on 7.5-inch spacing.

Contents

Photo by Gary Maskus.

Gary has a "love/hate" relationship with sunflowers. He likes the income, but dislikes the extensive water use and minimal residue production.

Monsanto's Main Event in Denver, and the first No-Till on the Plains conference in Salina, KS in January of '97—which inspired Maskus to start no-tilling that year. He was also influenced by a bus tour (sponsored by the Colorado group, CCTA) during the summer of '99, which included a stop at Dakota Lakes.

By 2000, Maskus was 100% no-till. And for most of the time since, Maskus has been staring drought in the face—and still earning a decent living. And while there are certainly some 'skip-a-till' producers in his area, Maskus was uniquely visionary in seeing that one of the best solutions was to be in continuous no-till. He got busy figuring it out.

Breaking Neighborhood Rules

Rotations and good agronomic practices are at the forefront of Gary's thinking. Perhaps his adeptness at assembling rotations derives something from that tech background. Like the CAD software he used to sell (which allows engineers to 'build' and analyze structures on the computer screen before laying hand on tangible materials), Gary adeptly flips through the pros and cons of various crop sequences with astonishing speed and clarity. He likes: winter wheat >>w. wheat >>corn >>sunflower >>proso, but says emphatically that it is just one of several he considers good—another is: w.wheat >>w.wheat >>corn >>proso >>corn >>fallow.

"I was like a lot of guys when we started—I thought we could pick a [single, inflexible] rotation. That doesn't work. Roll with the punches . . . . I do opportunity cropping—but I don't want to mess up my residue levels, or create weed or disease issues. When I say 'opportunity cropping,' it is within the bounds of other principles . . . . Having a good system in place is what creates those opportunities."

For instance, he really tries to plant corn following two wheat crops—"That's the ideal place for corn." This gives him deep moisture in an area that averages less than 16 inches of precip, and has only been getting 70% of average during the last few years. Maskus is virtually the only Colorado no-tiller to do stacked wheat. He likes the practice, having picked up the idea from S. Dakotans who were doing a spring wheat >>w. wheat sequence within a longer rotation. "I do like the longer rotations. Stacking the wheat lets me stay out of wheat for 3 to 4 years." Hmm, this engineer knows his biology.

Maskus' corn is followed by one of 3 choices—sunflowers, proso millet, or fallow. He doesn't grow sunflowers every year, and notes their attributes of leaving little residue and using lots of water. He's tried going directly from sunflowers to spring wheat, but had poor results. That leaves him with transitioning from sunflowers to winter wheat via a crop of proso, which he notes doesn't provide exactly the right seedbed for wheat either—"Second-year wheat [following a long break] yields about 75 to 80% of summerfallow wheat. Wheat following proso is slightly less than wheat on wheat." So you'd guess he

Leading Edge
The Journal of No-Till Agriculture

No·till On The Plains

Editors:
Matt Hagny
Andy Holzwarth
Roger Long
Randy Schwartz
Keith Thompson

E-mail: editor.leading.edge@notill.org

Subscriptions & Advertising:

Phone: 888.330.5142

$25 per year (U.S.) subscription rate

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

No-Till on the Plains Inc.
P.O. Box 379
Wamego, KS 66547-0379
888.330.5142
Website: www.notill.org

Partial funding for this publication is provided from the USDA-EQIP. The United States Department of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, sexual orientation, and marital or familial status (not all prohibited bases apply to all programs). Persons with disabilities who require alternative means of communication of program information (Braille, large print, audiotape, etc.) should contact the USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint, write the USDA, Director of Civil Rights, Room 3226W Whitten Building, 14th and Independence Ave., SW, Washington, D.C. 20250-9410 or call (202) 720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.

Additional funding provided by U.S. EPA § 319 grant, through the Kansas Dept. of Health & Environment.

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.

avoids that practice? Wrong! Maskus actually considers that sequence to be quite profitable—he makes more than enough from the 2-year transition of sunflowers & proso to make this a clear winner over chem-fallowing corn stalks for a summer to get to wheat.

In one of the most arid cropping regions in the world, Maskus seems intent on eliminating the practice of summerfallow. And remember, he's endured 5 years of drought. "Fallow is a practice that really grates on me. If you ask anyone around here how much moisture it takes to raise a wheat crop, I don't think anybody would say, '32 inches'—but that's what they're using [in a wheat >>summerfallow rotation]." He emphasizes the loss of residue during chem-fallow. He also mentions that the only no-till wheat that ever failed to make a stand for him was in chem-fallow—they had some deep moisture, but none at the surface. The neighbors' wheat all failed that year, too, regardless of crop sequence, tillage regime, or seeding tool. "We start planting wheat here the 10th of September,

On diverse rotations & minimal summerfallow: "Our cash flow is better."

Photo by Gary Maskus.

For Maskus, residue cover is crucial. Here, Maskus has a nice mulch of corn stalks under the sunflowers, which helps mitigate some detrimental attributes of sunflowers.

Photo by Gary Maskus.

Corn is an important component of Maskus' rotations in the Colorado high country.

and need to be finished by the end of September. So we need rain in late August or early September—no matter what the practice . . . . Everyone around here will tell you they do summerfallow to get the wheat up in the fall. But if they don't get the August or September rains, the moisture is too deep anyway."

Maskus finds the expenditures for fallow intolerable, with so little to be gained. "One of the other things not considered is the cost of land in summerfallow. It makes that cost double for those acres. I realize I push the limit pretty hard for eastern Colorado, and we fail sometimes, but overall I know our cash flow is better than it would be for wheat >>fallow."

In a part of the world where summerfallow >>wheat is the norm, 'continuous crop' (non-fallow) wheat isn't insurable as a general rule. However, after 4 years of building yield histories for wheat on wheat, or wheat after proso, Gary is now able to get a 'written agreement' [addendum to his policy] that covers 'continuous crop' wheat.

Maskus further explains that his rotations vary from field to field. Some are capable of handling more intense rotations. Maskus even tried stacked soybeans to bring a field of CRP back into production, but he notes the crop is poorly suited to their dry conditions (he has given up on the crop). But that former CRP—having an extra decade without tillage—is now one of Maskus' most productive fields.

Performance Parts

Maskus thinks differently when it comes to his seeding tools and agronomy, too.

"Fields in no-till the longest are the best seedbeds."

Wheat and proso are planted with the same 15-foot JD 750 drill he's been running for years. The drill is on 10-inch spacing, although Gary really wanted a 7.5-inch drill but couldn't find one. He still thinks the narrower spacing would have some advantages—which probably raises some eyebrows in a region where 12- to 14-inch row spacing for wheat is considered optimum. Low-disturbance no-till wheat is also highly unorthodox in this part of the world, but Maskus does just fine by keeping enough residue on the surface to prevent soil blowing or winterkill—it's merely a matter of proper rotations.

Corn and sunflowers go in on 30-inch rows with an 8-row 1750 equipped with single-disc JD fertilizer openers, row cleaners, Keetons, and spoked closing wheels. "I'm not much of a fan of coulters, since we are usually muddy in the spring." Being the studious observer, Gary mentions, "Fields that have been no-till the longest are the best seedbeds. Everything works better."

The inventive Maskus doesn't jump on every latest fad in production techniques, however. Instead, he analyzes how each idea might fit into the bigger scheme of his ecosystem. Maskus is "very skeptical" of skip-row corn (where every third row isn't used, creating, for instance, a 30-60-30-60-inch pattern) which is all the rage from his area north into western Nebraska. Maskus notes that in his neighborhood crop tour, the skip-row corn is 'burned up' by drought at least as bad as the regular every-row-planting method, which is exactly what skip-row was supposed to prevent. And, Maskus reasons, if skip row's only advantage is to take the edge off a drought, who cares?—his only concern is what happens on average to good years, since insurance covers the drought scenarios.

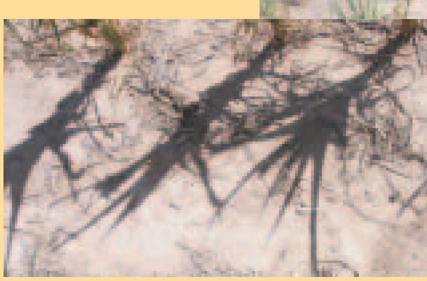
Maskus also points out two more major problems for skip-row: weeds and residue loss. Gary says that in all the skip-row fields he's been in, weeds are much more abundant in the gap. He also wonders what skip-row is doing to long-term production, since future crops of sunflowers, proso, and wheat are dependent on moisture held by surface residues—which will be reduced by nearly a third with skip-row plantings.

And strip-till—whether it's done as a separate pass or on the same toolbar as the planter—doesn't impress Maskus much either. When it comes to planter function in firm no-till soils, Maskus seems to have that problem solved (and his stands attest to this). For fertilizer placement, this has also been addressed with planter setup (Gary notes it really doesn't take that much extra time to apply at planting, and Gary is a stickler for timeliness on everything). Maskus is puzzled as to why anyone would want to burn more diesel to strip-till just to plant weed seeds and destroy residue that you'll wish you had later. "The less disturbance the better. . . . Out here, any time we open up the ground we lose moisture and I figure I need to conserve as much as I can." Instead, fertilizer on Maskus' corn is applied 100% with the planter—doing as little soil disturbance as possible—applying liquid pop-up in the seed furrow via Keetons, and liquid UAN applied 2x0, for a total of 50 to 70 units of N. "I like to place it in close proximity to the row—seems the plants have a better shot at it there than any weeds we might have."

On moisture loss from strip-till: "The less disturbance the better."

Gary's corn hybrids are 95- to 104-day, which is about maximum for their area (elevation is over 5000 ft—even in an August heat-wave, nightly lows almost never exceed 65°F, and average only 54°F during July and August). Corn goes in at 16,000 seeds/acre—he acknowledges that this 'high' population is bucking the trend for the area, too. All corn is RR, since it sometimes follows proso (controlling the volunteer proso can get expensive otherwise), and because it is the only RR crop in his rotation. (Maskus is careful to use a diversity of modes of action, including atrazine on corn, 2,4-D in stubble treatments and burndowns, Spartan & Select in sunflowers, and SUs in wheat.) Otherwise, his biggest weed problems are Russian thistle and kochia—including what tumbles into his fields from neighbors who don't control them.



Photos by Matt Hagny.

While Maskus runs a tightly managed operation, occasional goofs give him learning opportunities. Here, straw wasn't spread properly during '04 proso harvest (2 windrows of 25 feet each were put through the combine together), creating 50-foot 'waves' of corn prosperity or suffering. The differences are tremendous, and due entirely to residue—the soil cover pics were taken in the same location as the ones of Gary standing in the chest-high and ankle-high corn.

Oilseed sunflowers (on years Maskus grows them) are planted at 20,000 and also get all the fertilizer at planting, typically about 30 units of N and 15 to 20 lbs of P_2O_5—all in the 2x0 (no pop-up). Spartan is applied approximately 45 days pre-plant, with another burndown at planting. Select post-emerge cleans up grasses.

Wheat gets a liquid pop-up blend with the drill, and then all the remaining N is applied as urea during late winter, about a month before the crop breaks dormancy. Maskus strives for about 45 units of N and 30 lbs of P_2O_5 for wheat, total. Proso usually gets zero fertilizer—it fends for itself, scavenging what remains from the other crops.

What about perennial grasses? Red three-awn is a pesky plant in their part of the world. Maskus has had considerable frustration with the plant at times in the past, including inconsistent kills with glyphosate burndowns (no surprise, it is a perennial). But by planning his application timing and rates, he can keep it in check. Maskus notes that often it is just a matter of doing a little better job on field edges, since that's where it originates. And, as proof that three-awn and other perennials are no real threat, we walk into a field where Maskus brought CRP back into production in '99 purely with no-till methods—and which certainly had a significant seed bank of all sorts of tough-to-control perennial grasses (and perennial grass seeds have high dormancy rates, so the seed bank lasts awhile). In the former CRP field, we see nothing but clean stubble.

Photo by Gary Maskus.

Maskus' winter wheat has no trouble surviving the winter in the protection of upright stubble. Stacked wheat is standard practice for him.

Necessary Components

So in a traditional wheat >>fallow region, wheat surely is king for Maskus? Not so fast. Maskus points out that his area has a positive basis for corn, and that given average yields, corn makes more money for him than wheat (his proven average on corn is near 60 bu/a). But for him the question is a little silly, since it's about like asking which is the most important piece of the tractor engine (let's see, can we do without these pistons? what about the fuel pump? crankshaft?).

Maskus instead focuses on what each crop can contribute to 1) improving residue, 2) reducing weed and disease pressure, and 3) creating an environment suitable for subsequent crops while generating some income. Maskus points out that keeping the diversity has been a lifesaver in the drought, since almost always one or two of the crop species will find favorable conditions and produce decent yields. He expresses concern, however, "With this drought, we're mining [depleting] our residue."

Ever the good engineer, Maskus keeps checking that each component is doing what he wants. He keeps asking, what's this here for? What else could perform that function? How would this choice impact the production system elsewhere? While many engineers fail to grasp the messiness of biological processes, and the constant change that's inherent in an ecosystem, the clever but modest Maskus clearly relishes each challenge. Indeed, the frontier spirit flourishes in this place where vegetation sometimes does not.

Frozen Wheat in Kansas, 2005

by Matt Hagny

TECHNIQUE

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

The rumor mill is going again, spewing forth the impression of the late spring 2005 freeze being worse in the no-till wheat. Careful observation disproves this.

The freezes that occurred in early May across central Kansas happened when much of the wheat was late boot stage (e.g., at Beloit, Salina). Some areas were beginning to exsert the head already (Newton). Heads that were exposed or partly exposed were killed or rendered sterile. Plants were often extensively defoliated in some areas by freezing temperatures on 5 different nights over a 10-day period. Yield losses were substantial in some areas, none in others, and sometimes greatly disparate across the road, or by moving 5 or 10 feet in the field.

The patterns were unusual in that the cold air didn't necessarily settle into the lowest areas of the field, but instead spilled into the canopy wherever it was thin. Fields that had nutritional problems (and were less-canopied) froze much worse than those with good stands and adequate fertility. In the north-central Kansas region, no-till wheat after soybeans froze worse than no-till stacked wheat (as a general rule) due to canopy. Old chaff streaks were visible (less canopied), and backsides of terraces and headlands froze worse due to thin canopy. Even in fields with minor damage overall, it was easy to find seriously frozen areas, such as where a heavy clump of straw prevented the wheat from establishing—no canopy, no insulation, badly frozen. Or where gaps from the drill resulted in less canopy. Varieties also played a role, and sometimes it was rather indirect, such as powdery mildew reducing vegetation and canopy, which allowed freezing air down into the canopy repeatedly and with great destruction.

Photo by Matt Hagny.

Standing on the line between two quarter-sections of wheat in north-central KS, both of which were wheat the previous year. Freeze damage was severe in the field on the right (tilled system), but minor in the one on the left (long-term no-till with good agronomy). Patterns and effects of the late freeze were totally dependent on density of canopy—anywhere canopy was reduced, the freeze damage was severe.

Photo by Matt Hagny.

Here, a field of no-till wheat was largely unaffected by the freeze, except the headlands (left side of pic) which had extra traffic and residue destruction, and were slightly drought stressed. Wheat canopy was slightly reduced in those areas, allowing the freezing air to spill into the canopy.

Sometimes the no-till wheat froze worse, sometimes it didn't—it was directly related to amount of canopy. Many instances of early spring freezes being worse in no-till do hold some veracity. But that wasn't the case this time, when the wheat was so far along that the amount of residue down below was of no consequence—at least not directly. If the residue had A) interfered with drill opener performance, or B) indirectly created some nutrient shortages, then the resulting thinner canopy did allow more freeze damage. If the methods were inadequate across the field (poor drill performance, insufficient fertility), then the no-till might have fared worse. Where things were right, the no-till wheat came through in better condition (see photo). This should remind us to pay attention to the details of stand establishment and fertility. While excessively thick canopies are wasteful and pointless, having a reasonably thick (and uniform) canopy paid extra dividends this time around.

Photo by Matt Hagny.

The freeze exaggerated unusual patterns already present in the field. Here, sulfur deficiency went undiagnosed and uncorrected in this no-till wheat on soybean stubble, creating huge differences in growth, tillering, and canopy—which were plenty visible before the freeze. After the freeze, it looked even more bizarre.

Photo by Matt Hagny.

In the center foreground, a thin/gapped canopy resulted in severe freeze damage (browning of leaves, no head exsertion) while a slightly better canopy farther back resulted in less browning of leaves and some white (sterile) heads that exserted. Still farther away, the wheat is normal. This field was no-till 2d-year wheat.


Photo by Brian Lindley.

Managing Phosphorus in No-Till

by Ray Ward

SCIENCE

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

Phosphorus is a highly important plant nutrient that is in short supply in many soils in the Great Plains as well as around the world. After carbon and nitrogen, phosphorus is often the next most limiting element for crop growth.

The prairie soils were high in organic matter (OM) when they were broken for crop production. The organic matter contained a large amount of nitrogen (N) and other plant nutrients. A large portion of the soil phosphorus (P) was held in the organic matter. As this organic matter was depleted by cultivation and erosion, and mined by crop removal, P deficiency became an increasing problem. P fertilization practices were implemented to help supply the needs of the crops. As we move to no-till, the rate of P fertilization might need to increase to meet the demands of more intensive crop rotations and rebuilding OM. However, some mechanisms in no-till improve P availability, so it isn't quite that simple.

Mycorrhizal fungi increase under no-till, and can assist some crop species in taking up P from soil.

Research has gradually revealed viable methods to evaluate the P status of soils and to effectively apply P. This article will explore how P reacts in soils and how P fertilization might differ in no-till practices.

Phosphorus Behavior in Soils

Plant roots take up phosphorus in two forms. The monophosphate ion, H_2PO_4, is the predominant phosphate type in soil solution when the soil pH is below 7 (acid). When pH is above 7 (alkaline), the predominant form is the diphosphate ion, HPO_4. Both forms are also called orthophosphates ('ortho' refers to the 4 oxygen atoms). These P-containing ions are attracted to calcium (Ca) ions in alkaline soils, and to iron (Fe), manganese (Mn), and aluminum (Al) in acid soils. The attraction causes the phosphate ions to attach to those other ions, forming more complex molecules that drop out of solution and cannot be taken up by the plant. Abundance of these phosphate-reacting ions (Ca, Fe, Mn, Al) varies


Photo by Doug Palen.

Harvest of grain removes large quantities of P from the field, which must eventually be replaced.

primarily with soil pH (see diagram on page 240); concentrations of these ions will dictate P availability to plants.

Availability of soil phosphorus is directly related to the solubility (ability to dissolve into soil water) characteristic of the various types of P-containing molecules. As plants remove phosphate ions from the soil water, this creates 'room' in the soil water for more orthophosphate molecules to dissolve from the soil particles. How rapidly the P in soil water is replenished depends on the solubility of the P-containing molecules on the soil particles.

In alkaline soils, the solubility of phosphorus is affected by the amount of calcium present. Calcium is the predominant element present in alkaline soils, and reacts with the HPO_4 ion to form dicalcium phosphate. Dical phosphate in alkaline pH has low solubility, but it is still soluble enough to supply P to the crop. As the crop takes up the HPO_4 from the soil solution, more HPO_4 dissolves from dical phosphate. Soil P tests will effectively measure the availability of P in alkaline soils.

In acid soils, the compound formed is *mono*cal phosphate, which is readily soluble. However, acid soil conditions result in iron, aluminum, and manganese becoming soluble especially at stronger acid levels (lower pH). When iron and aluminum become soluble they combine with the phosphate ion, with the resulting molecule dropping out of solution and remaining relatively insoluble; this begins to occur when soil pH is less than 5.5

Photo by Matt Hagny.

Yield of winter wheat is highly responsive to P nutrition.

and dramatically increases when soil pH is below 5.0. Therefore, the ideal pH for phosphorus availability is 5.6 to 7.2 (again, see diagram).

Although P solubility is reduced in alkaline soils it still remains available to crops, although much more slowly. Because of this slowness, the *total* amount of P contained in an alkaline soil would need to be greater than in an acid soil to have the same P-supplying capability. Proper P soil testing will measure the availability in alkaline soils as well as in neutral to acid soils, although the extraction methods and calibrations are different. The rate of P fertilization recommended is based on soil P test level and on crop and yield goal, not on the pH of the soil since the methods already take into account the pH. The reason I have discussed the chemistry is to show why it takes more P fertilizer to increase soil test values on some soils than on others. P availability can be compared between soils and extraction methods using the table of test values (see page 241).

No-till practices increase soil microorganism populations including mycorrhizal fungi. Mycorrhizal fungi can form associations with roots of many plant species and are often important in transporting P to roots since the fungal mycelium is capable of extracting P from beyond the root surface. In some cases, mycelial filaments will explore soil volume that is ten-fold greater than the roots themselves. The mycorrhizal population can improve P availability for some crops when P soil levels are moderate to low.

Phosphorus Availability

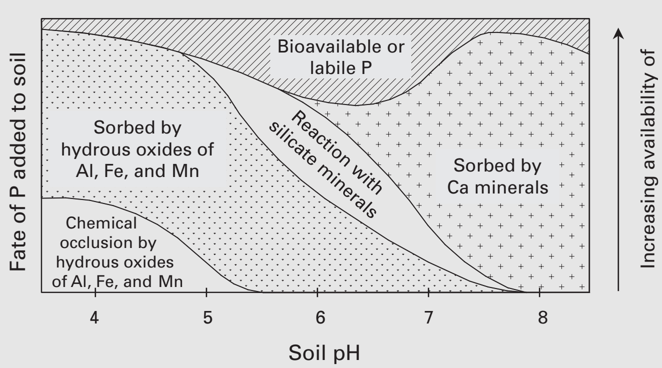
Soil phosphorus is generally thought of in four categories, which are: 1) solution P, 2) "surface" or adsorbed P, 3) "organic P" held in organic matter, and 4) "fixed" or crystalline P. Fixed P is bound tightly in some of the soil compounds mentioned previously and is unavailable to the crops. I consider fixed P to be found 'inside' the crystals. "Surface P," on the other hand, is the phosphorus held on the surface of soil particles and crystals. Surface P is easily diffused from the crystal surface into the soil solution. Solution P is the small amount of P that is in soil water at any given time, usually less than one pound per acre. However, as the plant takes up P from the soil water, more P diffuses from the surface P. The surface P is also called the active P pool.

Organic P is slowly mineralized by microorganisms and enzymes to phosphate ions that crops can use. Some of the organic matter is easily mineralized and some is very resistant. The P mineralized from organic matter becomes part of the surface P. The organic P that is highly resistant to mineralization is considered part of the fixed P.

Surface P (active P) pool determines the availability to crops. Soil texture influences the size of the surface P pool. Clay is the reactive portion of the soil. Clay contains the aluminum and iron that are reactive with P. In alkaline soils, lime is the source of calcium for reaction with P. Soils with more clay will maintain the surface P (active pool) much longer than sandy soils, and therefore have more P-supplying capability.

Plants absorb P as orthophosphate. Common P fertilizers convert to orthophosphate in soil in a matter of days.

Phosphorus soil tests have been developed to estimate P availability. The tests estimate the amount of P held as surface P. The common P soil tests for the Great Plains have been Bray P-1 and Olsen. The Bray P-1 test is well suited for noncalcareous (no free lime) soils, but is useless on high-pH soils with free lime because the acid extractant reacts with the calcium instead of the P-containing molecules. The Olsen test is well suited for calcareous (free lime present) soils, and also performs well



Approximate representation of the fate of P added to soil as a function of soil pH.

in other soils of the Great Plains. A rather new P soil test is Mehlich P-3. It is most commonly used in Oklahoma and Texas. All P soil tests work well when used within the limits of the test.

Phosphorus Fertilizers

The manufacture of most phosphate fertilizers begins with the production of phosphoric acid from rock phosphate. Rock phosphate is tricalcium phosphate, an insoluble mineral also referred to as apatite. The rock phosphate is dissolved with sulfuric acid. When sulfuric acid is added, calcium from the rock phosphate and sulfate from sulfuric acid combine to form gypsum. The gypsum is then separated from the liquid phosphoric acid. Phosphoric acid produced by the "wet method" is 54% P_2O_5 or 0-54-0. (Confusingly, nearly all scientific research is published using elemental P, not the oxide P_2O_5 which is predominantly used in the fertilizer industry. In some countries [not the U.S.], the fertilizer industry and farmers also speak in terms of elemental P. The conversion is P x 2.3 = P_2O_5).

Liquid phosphoric acid has some impurities that cause the fertilizer products to be green or black. The impurities are very small amounts of calcium, iron, aluminum, magnesium, sulfur, and fluoride that are not harmful to the soil. Furnace-grade phosphoric acid is made by heating the rock phosphate in an electric furnace to produce pure phosphoric acid that is white. The analysis of white acid is 0-56-0. This acid is used in the food and chemical industries or included in specialty fertilizers sold by the gallon rather than by the ton.

Superphosphoric acid is made by heating liquid phosphoric acid to drive off water molecules. The superphosphoric acid usually has a concentration of 72 to 76% P_2O_5. When water is driven off, the orthophosphate ion (PO_4) loses an oxygen atom causing two of the orthophosphate ions to bond together, thus forming variable-length chains such as P_2O_7, P_3O_{10}, and P_4O_{13}. The chains are called *poly*phosphate. This is the way the P concentration increases in the superphosphoric acid.[1] The chain development also increases the amount of P that can go into solution. The increased concentration of P reduces freight cost.


Photo by Jerry Bolding.

Phosphorus is critical for grain fill.

Suggested ratings for different P soil test values (ppm):

P Soil Test Method	Low	Medium	High
Bray & Kurtz (Bray P-1)	0 – 12	13 – 25	26 – 50
Olsen Bicarbonate P	0 – 9	10 – 16	17 – 30
Mehlich P-3	0 – 13	14 – 28	29 – 55

Another advantage of the polyphosphate is its capability of holding trace elements in solution. The polyphosphate can sequester zinc and/or manganese, so these elements can be added to the liquid and will stay in solution up to certain concentrations (the sequestering is reversible in the soil). The polyphosphate will hold one pound of zinc and/or manganese for every 30 pounds of P_2O_5 or one pound in seven gallons of 10-34-0.

Liquid phosphate fertilizer, 10-34-0, is made from superphosphoric acid and anhydrous ammonia. The orthophosphate forms, H_2PO_4 or HPO_4, are used by plants as discussed previously. The 10-34-0 is a mixture of 30 – 40% orthophosphate and 60 – 70% polyphosphate. When polyphosphate is applied to the soil and reacts with soil water it begins to hydrolyze or break the bonds and revert back to H_2PO_4 or HPO_4 orthophosphate. This reaction is completed in a few days to a few weeks depending on the nature of the soil. It appears that microorganisms influence the conversion rate, so this happens more quickly in a no-till soil.

Some liquid phosphate fertilizers are made using white phosphoric acid (100% orthophosphate) instead of superphosphoric acid (polyphosphate). The lower concentration of P_2O_5 in white acid produces lower phosphate analysis. The white acid is often combined with potassium hydroxide to produce potassium phosphate such as in 9-18-9, or a variety of other blends marketed as "low salt" fertilizers at premium prices. The low salt term partly refers to the fact that no chloride is found in the fertilizer made with these sources, since the potassium component is derived from potassium hydroxide

[1] The concentration of P-containing fertilizers is often expressed as P_2O_5 equivalent, even if that molecule is not the form of P found in that fertilizer.

rather than potassium chloride. However, the "salt index" of a fertilizer is related to the total amount of nutrients present in the fertilizer. Generally, the higher the nutrient concentration of the fertilizer, the higher the "salt index" of the fertilizer will be. Extensive research has shown that differences in safety to the seed (at equivalent rates of salt) or in plant uptake are negligible when comparing the white-acid specialty fertilizers to "commercial grade" 10-34-0 or 7-21-7.

Dry 11-52-0 and 18-46-0 are produced from wet or green phosphoric acid and anhydrous ammonia, then dried and pelletized. Since these two dry fertilizers contain only orthophosphate and no polyphosphate, P is completely available once they are added to the soil and react with the soil water.

Research shows that early-growth effects from pop-up or starter fertilizers do not always enhance yield. Yield response to earliness depends on climate.

Phosphorus from Animal Waste

Animal manures and composts are very good sources of P. The P is in an organic form (chemically, 'organic' means a carbon-containing compound) so the availability factor has to be considered. When our laboratory analyzes manure or compost samples, we include the availability factor with the report. The test report will give the total analysis and the amount of P that is likely to be available the first year. Different manures have different availability factors. Make sure the animal source is given when submitting samples for laboratory analysis. Most beef and dairy manures will supply 4 to 5 pounds of available P_2O_5 per ton in the first year. Swine manure is usually applied in a slurry form. Since slurry dilution is highly variable, the amount of P per ton covers a wider range.

In a no-till system, surface-applied manure or slurry is workable unless odor is an issue. Most rainfall events in a no-till system produce minimal runoff so potential loss of P in runoff water is very small, although this varies with length of time in no-till, amount of residues, size of precipitation events, etc. During a precipitation event, the water will first wash P and other nutrients into the soil through macropores that have been developed under continuous no-till with adequate soil cover. If runoff does occur later in the precipitation event, the nutrients have already been washed into the soil and generally not subject to runoff. The exception would be rainfall or snow melt on frozen soils with recent manure applications.

Some people advocate injecting or placing the manure or slurry into the soil. However, if a large rainfall event occurs, runoff will be greater with any tillage or soil disturbance that is done. This runoff has a greater chance of carrying both dissolved nutrients as well as soil particles with nutrients bound to them. If manures are to be injected, soil disturbance should be kept strictly to a minimum.

How Much P Fertilizer Should I Apply?

The amount of P fertilizer to apply depends on numerous factors. The most important are: 1) the amount of crop demand, and 2) the P availability status of the soil.

Crops vary in their responsiveness to P fertilization (and soil P availability), but it is universally true that crop harvest removes P from the field. This removal gradually diminishes the soil test values (P availability) unless it is replaced. For example, if you harvest 60 bushels of wheat per acre you will remove 28 to 33 lbs of P_2O_5 in the grain. Other crops commonly grown in rotations on the Great Plains will also remove significant amounts of phosphate (see chart).

This P eventually needs to be replaced at some rate, depending on the soil test level. For example, if a P soil test is very high the probability of a crop yield increase to added P fertilizer is low, so the need to apply P is minimal. However, on a soil with a low test value, it may take several years of applying more than crop removal to improve the P soil test value.

Phosphorus removal by harvesting:

Crop	Yield Unit Per Acre	P_2O_5 Content Lbs/Yield Unit
Wheat	bushel	0.46 – 0.54
Corn	bushel	0.27 – 0.33
Grain Sorghum	bushel	0.28 – 0.35
Soybean	bushel	0.70 – 0.80
Sunflower	cwt	0.95 – 1.20
Cotton (seed)	cwt	0.58 – 0.64
Proso Millet	bushel	0.28 – 0.37
Perennial Grass	ton	8.0 – 14.0
Alfalfa	ton	9.0 – 11.0

Source: Ward Labs, derived from samples analyzed over a period of years.

Crops grown or planted in cool soils are generally more responsive to added P fertilizer than crops planted when soil temperatures are much warmer. For example, it is much more important to apply P for wheat which grows when soil temperatures are cool, than for grain sorghum that is grown when soil temperatures are high. Corn is normally planted when soil temperatures are cool so it responds more to added P than crops planted in warmer soils. (Temperature is important for both the rate of P going into solution, as well as mycorrhizal activity. Mycorrhizal activity is reduced considerably when soil temperatures are below 60°F.) Crop species also have other intrinsic properties that cause variation in responsiveness to P availability. (Crop breeding programs have played a role also, generally selecting for plants that are more responsive to P.)

Probability of yield response to applied P fertilizer when soil tests indicate P is needed:

Crop	Expected response to added P
Winter Wheat	Very High
Corn	High
Grain Sorghum	Moderate
Soybean	Moderate
Sunflower	Moderate
Field Pea	Moderate
Canola	High
Cotton	Moderate
Proso Millet	Low
Perennial Grass	Low
Alfalfa	High

The rate of P fertilizer also depends on the objectives of the grower. Do you want to build or maintain soil P tests at a given level? Or is the sole criteria the probability of obtaining acceptable yield in the current year with minimal expenditure for P fertilizer?

If you want to build the P soil test level, you will need to apply about 18 pounds of P_2O_5 per acre (beyond crop removal) to raise the Bray P-1 or Mehlich P-3 soil test by 1 ppm. It will take 25 – 30 pounds of P_2O_5 to change the Olsen bicarbonate P test 1 ppm. (This information is derived from very large data sets; variations in sampling location and depth in any given field will introduce variation that will prevent accurately detecting changes of a few ppm.)

Methods of P Application

Hundreds of studies have been done to better understand the effects of phosphorus application methods and rates. One example is an experiment conducted in Colorado by USDA-ARS on wheat. Four placement methods were used on a tilled field that was being converted to no-till after Year One of the study. The placement methods were: 1) broadcast incorporated, 2) broadcast without incorporation, 3) subsurface band, and 4) seed-placed. The subsurface bands were placed about 3 inches deep and 12 inches apart. Methods 1, 2, and 3 were as a one-time application, while the seed-placed phosphorus was applied at ¼ the one-time rate but applied each year during the 4-crop term of the study. The P soil test was medium (10 ppm P with bicarbonate extraction), soil pH was 7.8, and organic matter was 2.4%.

Vigorous early growth shades the soil more quickly, reducing both weed pressure and evaporation of soil water.

The results confirmed the need for P fertilizer when test values are in the responsive range. To optimize winter wheat yields, the study found that higher rates of fertilizer P are needed than what is commonly predicted. In other words, for wheat it is advantageous to apply more than recommended until the P soil test reaches the very high level (greater than 50 ppm Bray P-1/Mehlich P-3 or 30 ppm Olsen P). The study showed that surface-applied P fertilizer increased yields effectively in no-till. Annual application of seed-placed P fertilizer at ¼ the rate of the broadcast rate was effective in increasing wheat yields, although total cumulative yield after 4 wheat crops was less than that of the one-time broadcast application, whether incorporated or not. This study's findings are consistent with the results of many other studies in the region. The implication is that if highly responsive crops like wheat are grown in rotation, and soil tests are medium or low, it is important to build soil levels and if this cannot be conveniently or affordably accomplished with seed-placed P then it should be surface applied.

The study confirms that wheat yields continue to respond to increased P fertilizer up to relatively high rates. Additionally, the residual fertilizer P remaining after the 4 crop years will impact crop yields for many more years, which has been shown in other studies. The duration and magnitude of those responses depend on amount applied and amount removed at harvest. The no-till grower will have to determine how much to apply and when/how based on rotations, crop responsiveness, equipment, price of fertilizer sources, etc., as well as yield goal and P soil test value. Of course, the lower the P soil tests the more P fertilizer needed to obtain a given level of yield potential.

Many producers like to apply P fertilizer in the seed furrow ("pop-up") because of the early growth response of the crop to the fertilizer applied with the seed. A recent study by Iowa State University found that although there was a large early growth response of corn to P and K (potassium) fertilizer, the growth increase was not a reliable indicator of grain yield response. The researchers compared a small amount of P and K with the seed to a broadcast application of P and K that was based on estimated crop removal. The seed-placed fertilizer never increased yield more than the broadcast rate. However, the seed-placed P and K was about ⅛ of the broadcast rate. Five of the 16 plots were managed as no-till systems. I mention this research because farmers often think a pronounced early growth response should enhance yield. However, this research shows otherwise. It is important to apply pop-up or starter fertilizer in a no-till system to get crops off to a vigorous start for several reasons other than yield. Broadcast P can perform well, but without creating much early growth effect.

The preference for P application method is largely based on crop type. Wheat or other fall-planted cereals respond very well to P fertilizer placed with the seed. These crops develop faster and often mature earlier compared to non-fertilized crops, which can be important in many climates. Corn also gives a very good early response to pop-up (seed-furrow) or "starter" P (separate band 2 – 3 inches to the side of the seed). The early growth sometimes translates to greater yield depending on the weather at pollination and during grain fill. Also, early growth shades the soil more quickly, reducing potential weed pressure and reducing evaporation of soil water. In some years this is a definite advantage.

Runoff will be greater with any soil disturbance that is done. Nutrient loss in runoff also increases when soil is disturbed.

So the best method of application is to place the P fertilizer with or near the seed to encourage early growth. Broadcast P fertilizer will give crop yield increase when

Photo by Matt Hagny.

Thiosulfate is extremely toxic to seeds and seedlings. Here, the stand of corn was wrecked by the addition of a small amount of ammonium thiosulfate to the pop-up fertilizer.

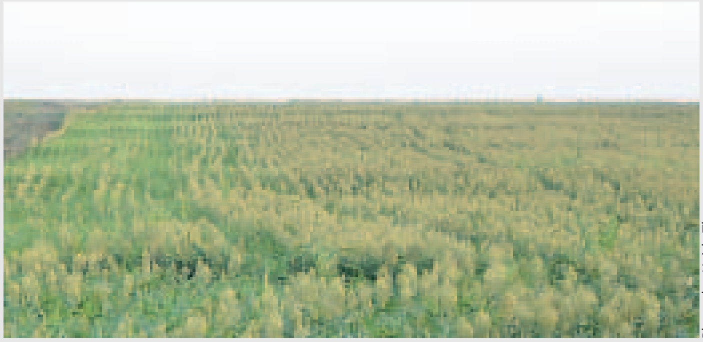


Photo by Keith Thompson.

No-till milo. The pass on the left had no pop-up fertilizer, and is noticeably delayed in maturity. Sometimes this delay adversely impacts yields, sometimes not.

soil levels are insufficient, although the early growth response to broadcast P will not be as visible as the pop-up or starter P. Some growers like the pop-up effect of seed-placed fertilizer, while others prefer to apply it exclusively in a separate band (which will significantly delay the early growth response). Of course, all combinations of these application methods can be used.

There are precautions to applying fertilizer in the seed furrow. Because of the chemistry of P in soil, phosphate fertilizer has a low "salt index" (a measurement of the strength of a compound's affinity for water, which is an indicator of potential to injure seeds or seedlings). However, other fertilizer nutrients do not react with the soil so strongly and consequently can be more damaging, so it is important to keep the rates very low. Nitrate (NO_3) and ammonium (NH_4) and potassium (K_2O) have a significant effect on seed germination and seedling emergence, so those nutrients should be limited in pop-up applications. Zinc and most trace elements are applied in small amounts and are normally safe in-furrow. However, ammonium thiosulfate (12-0-0-26) and potassium thiosulfate are highly toxic to seeds, so I recommend *not* applying *any* of these fertilizer sources with the seed.

The 'safe' rate of N and K_2O for seed-furrow application varies by crop (see table). If soil moisture is abundant at planting time, the rate shown in the table could be exceeded without problems, although the risk does go up at higher rates. The rates listed will be safe across a broad range of conditions that are suitable for planting, with the exception of extremely sandy soils.

So-called starter fertilizer is typically placed about 2 inches to the side of the seed at planting. If high rates of N are to be applied in this band, then it should be placed 3 – 4 inches to the side of the seed. A traditional starter is high in P with smaller rates of N, K_2O, S, and trace elements. Some no-tillers like to apply all or a large portion of the N at planting. I suggest up to 45 pounds of N, K_2O, and S no closer than 2 inches to the side of the seed. If the starter is set to apply 3 – 4 inches away from the seed, I am comfortable going up to 90 pounds of N, K_2O, and S. If early-season growth response is desired, a pop-up application in the seed furrow will be necessary, since the plant roots will not access the starter band for some time (for corn, at about 3- to 5-leaf stage, normally)[2]. The remainder of the nutrients can be applied at another time.

Maximum safe amount of N + K_2O applied in the seed furrow (direct seed contact):

Crop	30-inch rows Lbs of N + K_2O/Acre	7.5-inch rows Lbs of N + K_2O/Acre
Corn	6	24
Wheat	6	24
Grain Sorghum	3	12
Soybean	None	6
Sunflower	None	6

If the no-till rotation is wheat followed by corn or grain sorghum, it can be a good idea to apply most of the P needs for both crops to the wheat. As discussed, wheat yield is extremely responsive to P fertilizer. Therefore, the greatest economic advantage is to apply extra P to the wheat crop and then use the carryover to nourish the corn or sorghum crop.

Broadcast phosphate works reasonably well for no-till farmers because of the residue cover that holds moisture, allowing some of the plant roots to grow very near the soil surface to take up the broadcast nutrients. In all but the driest climates, the broadcast P will move into the soil quickly enough to supply the growing crop. Deep-banding (sometimes as part of the justification for a strip-till operation) of P fertilizers is sometimes advocated to ensure P will be available to roots in times of drought, typically involving placement to a depth of 5 to 10 inches. Obviously this will require considerable horsepower and soil disturbance. The benefits for plant uptake are minimal, especially in a system that has some residue cover. Crop demand for both water and nutrients follows a similar pattern, increasing rapidly during late vegetative growth. So if the soil is already dry from evapotranspiration at a 2-inch depth, it will very soon be dry at a 5- or 10-inch depth (within a few days). Conversely, a small rain shower might dampen the soil only to a depth of an inch or two, which enables the roots near the soil surface to take up nutrients again, while the slightly deeper zone remains dry (no uptake).

Benefits of deep-placed P for plant uptake are minimal, especially in a system with residue cover.

Ideally, some nutrients would be available at all rooting depths. However, it generally is not a large enough advantage to expend much effort or dollars to mechanically place P at significant depth. Some P redistribution in soil occurs naturally, moving downward with moisture at the rate of 0.5 to 1.0 inch per year for most of the Great Plains.

Photo by Keith Thompson.

Big corn yields in no-till are simply a matter of getting a few details right, including fertilization practices. Here, Craig Stehly seems to have it figured out for corn following stacked wheat (with cover-crop sunflowers after the 2d wheat). Craig and his brother, Gene, are longtime no-tillers at Mitchell, SD.

Summary

I often get questions on how is the best way to apply P fertilizer. It depends. There are several ways that P can be applied effectively. The choice is up to the grower and depends on the P status of their soils, as well as equipment, sources, etc. Phosphorus needs to be applied so that it is available for uptake when the crop needs it. Generally, the response to P application in-crop is much less than at planting time or before planting due to the processes described. Phosphorus fertilization might need to be increased to allow organic matter to build during the first few decades of no-till, and to accommodate the increased grain removal from intensified rotations. However, P losses by runoff and erosion are largely eliminated under well-managed no-till, so P fertilization is more efficiently stored in soil and converted to grain under no-till.

[2] *Editors' Note: Nodal root development in no-till corn appears to be slower to initiate and establish than for corn in tilled seedbeds [in relation to leaf stage], perhaps due to physiological reactions to cooler temperatures. This especially appears to be true for corn in wheat stubble (even if no sidewall compaction issues are involved).*

Pressure Relief

by Andy Holzwarth

TECHNIQUE

Andy Holzwarth is an agronomist with John Deere, previously for Guetterman Farms.

For years we have heard how detrimental soil compaction is to crop yields. While no perfect solution exists, minimizing this problem is less difficult than many people realize.

No-tillers have already begun the long process of reclaiming soil health and redeveloping soil structure. Many have noticed the soil changes under no-till, including the increased infiltration and becoming more firm. This firmness is a good thing: the beginning of soil structure redevelopment and future compaction management. Over time, no-till soils can continue developing firmness and structure that is more similar to an uncompacted native prairie. Crops grow well in these soil conditions.

First, we must understand what compaction is, and how it develops. An uncompacted silt loam soil would have roughly 25% air, 25% water, and 50% solids (mineral particles and OM).[1] The air and water are in the spaces or pores between the solids. Compaction occurs whenever a pressure is applied which causes soil particles to move closer together and reduces the pore space between the particles. So the density of the soil increases (i.e., more soil particles per given volume). This increased density constrains root growth, reduces air availability to the roots (they respire, or breathe, to oxidize sugars which fuels root growth), and decreases available water to the plant. We have all observed this scenario, especially near field entrances or on headlands, where the plants are always first to show water stress.

Once a soil is compacted, only relatively slow natural processes (root growth, mycorrhizae, earthworms, and other soil life) can truly eliminate the compaction by reassembling the soil particles into aggregates by binding them with organic compounds. Freeze/thaw and shrink/swell cycles can pry apart the compacted particles, but this improvement in pore space is quite temporary unless organic processes bind the new arrangement of particles into a more permanent aggregation.[2] As a related matter, the lower the organic matter or the higher the clay content, the more easily a soil will compact. This derives from the amount of organic 'glue' present in relation to number of soil particles to be stabilized.

Only natural processes (roots, mycorrhizae, earthworms, & other soil life) can truly eliminate compaction by reassembling soil particles into aggregates with organic 'glue.'

Likewise, mechanical tillage alters the soil particle arrangement but does nothing to stabilize it. Deep tillage is only useful to *redistribute* a horizontal plow pan (or other compacted layer). The compacted soil particles are still compacted, but the layer is redistributed. Since roots have difficulty with sudden density changes, the redistribution of the compacted layer may, for a short period of time, allow the plant roots to penetrate the compacted region and add organic material between the soil particles, thereby allowing a very small amount of true soil structure regeneration. Since soil OM is lost due to the tillage, any net benefit is tenuous at best. The key to all compaction remediation is that once soil particles have been redistributed by mechanical means or freeze/thaw cycles, *organic material must develop between the redistributed soil particles in order for the compaction to be reduced.* This occurs quite slowly over many years. The natural soil processes described will remove deep compaction even more slowly than shallow compaction.

Photo by Ralph Holzwarth.

Heavy loads should be carried properly to reduce soil damage. Choose tire sizes and inflations to spread pressure more uniformly across lugs.

[1] At "field capacity" moisture content.

[2] Ray Ward, personal communication.

Prevention

We already have several methods to prevent or minimize compaction, and we don't have to spend a fortune to implement them. We can stay off the soil when it is wet, we can assist the processes of nature by growing the best crops and keeping the residues (and not doing tillage), and we can set up our equipment to tread as lightly as possible when we drive across the soils.

Soils compact worse as moisture content increases, up to a point. If the soil is dry, the particles are bound tightly together (electrochemically). When the soil holds more moisture, the water films thicken around each soil particle. The additional water is weakly held and actually 'lubricates' particles to slip (compact) more easily. However, when soils are truly waterlogged and moisture completely fills the pore spaces, the water prevents the compression of the spaces (water is much less compressible than air), so very little compaction occurs.

While no-till fields do stay moist near the surface longer (due to residues slowing evaporation), the improved structure under long-term no-till will better support loads with less compaction. Think of driving across a pasture versus driving across tilled soils after a rain. However, some compaction still occurs.

Another tool is to grow the best crops possible, especially grass crops. High-yielding crops add far more residues and root mass than lower-yielding crops. Root mass is the primary contributor to increasing or maintaining soil OM, and helps sustain other soil life. Surface residues protect soil aggregation from damage by raindrops.

Soft Touch

Heavy ag machinery is a necessary evil, but it can be outfitted with proper footwear to reduce the potential for soil damage. One of the most economical options is the use of large tires (preferably radials) at low inflation pressures.

Besides enlarging the tire footprint, lower inflation pressure allows the lugs and casing to mold themselves to small undulations, ensuring that pressure is relatively uniform across all points of contact.

Not everyone realizes the value of reducing the inflation pressures. We developed the habit of over-inflating tires during the reign of bias-ply tire designs, which simply required more pressure than radial-belted designs. Also, we over-inflate in the hopes of reducing the potential for tire failure. Few realize the costs in terms of compaction (and lost tractive efficiency).

Why is inflation pressure important? It is a determinant of pressure applied to the soil. Especially for radials, lower pressures allow the tire to squat, so the load is spread over more lug area (the 'footprint' of lugs on the soil gets a little wider and much longer). Perhaps more importantly, the lower pressure allows the tire lugs and tire casing to mold themselves to small undulations of the soil surface in no-till, ensuring that pressure is relatively uniform across all points of contact. Also, the impact of the lug as it first strikes the soil surface is cushioned by lower inflation pressures. (Note, however, that reducing inflation for a given tire and load will shift the *peak* soil pressure from the centerline to the outer edges of the tire—some of this is a good thing, but don't over-do it.) In comparing large radials functioning normally at 6 – 14 psi inflation, the *average* applied soil pressure underneath the tire will often be 1 – 4 psi higher than the air pressure inside the tire. (Obviously this rule fails at extremes: if pressure is zero, you are riding on the rims. If inflation pressure is high, the *average* soil pressure can be no higher than total machine weight divided by *effective* contact area—plus a couple psi.)[3]

The capability for using lower pressures is determined by weight the tire must carry, and the size of the tire. Typically, larger tires can carry a given load at a lower pressure than smaller tires. Most radial tire manufacturers suggest inflation pressures in the 6 – 14 psi range for the larger sizes. When possible, try to select radial tires large enough to carry the load at the lower end of this range.

As an example, a large 4WD tractor (say you're pulling a wide no-till air drill) might have a load of nearly 19,000 lbs on each axle. The chart (p. 248) shows some possible tire configurations. For instance, if we assume that adding 2 psi to the inflation pressure will approximate the average pressure on the soil, the

[3] "To assess ground bearing pressure, the tire inflation pressure is the primary factor plus an additional amount that represents the tire casing stiffness when deflected." (http://www.goodyearag.com/pdf/tireHandbookSec4.pdf.) Note that this only holds true in a narrow range of inflation pressures and loads. Not surprisingly, a study has found the *average* applied pressure to actually be *less* than the 25 – 30 psi inflation pressures for some tires & loads. The surprise is that *peak* pressures applied by driven lugged tires (at 10 – 30 psi) are frequently 300 to 1000% higher than *average* pressures on a rigid road surface. (M. Gysi, V. Maeder & P. Weisskopf, 2001, Pressure Distribution Underneath Tires of Agricultural Vehicles, *Transactions of the ASAE*, 44(6): 1385-1389.) Apparently this occurs due to the dynamic of the lug edges engaging and scrunching as the casing deforms during the rotation of the wheel. While a rigid surface is likely a better approximation of no-till soil than loose tilled conditions, it probably doesn't quite capture what happens on a no-till soil either (the researchers duly note that the measured peak pressures don't reflect conditions on cropland). Virtually all of these types of studies are done either on rigid surfaces or in tilled conditions. No-till readers should beware the conclusions from compaction or tractive-efficiency studies conducted in tilled soils—those conditions are sufficiently different that the results in no-till could be quite the opposite.

20.8s apply 13 psi to the soil while the 710s apply only 8 psi, a reduction of 63%.

Keep in mind that this reduction in applied soil pressure comes at the expense of a 34% wider area trafficked by the 710 tires.[4] So do we prefer a wider area compacted to a lesser degree (and a more shallow depth), or a narrower area compacted more severely and more deeply? Because of natural processes previously described, the shallower, less-severe compaction is likely preferable. Additionally, the 710s will have better flotation and cause less deforming or bumpiness of the soil surface.

Tracks will compact a narrower area than most dual tires. However, with tracks, remember that as the tractor pulls an implement through the field, it experiences an increased load from how it was originally ballasted. The torque created by pulling the load causes the nose of the tractor to lift (by varying amounts), so the front of the tracks carries less weight (sometimes none). Now most of the weight is on the rear of the tracks, thereby applying far more pressure to the ground. A similar situation happens as the track passes over slightly uneven ground (or terraces), since the high spots will carry the load with minimal effective footprint. (*Editors' Note: These concerns apply primarily to tractors with only 2 tracks; tractors with 4 tracks that 'walk' in relation to the frame have significantly less problem in this regard.*) Higher cost of tracks is a reality, and sometimes the ride is rougher.

Recommended Tire Air Pressure (With Duals)

Tire	Weight	PSI
18.4-46 480/80R46	19,000	14
20.8-R42 520/80R42	19,000	**11**
620/70R42	19,000	9
710/70R42	19,000	6
800/70R38	19,000	**6**

Source: John Deere Ag Sales Manual, citing Goodyear and Firestone.

The most economical way to manage soil compaction is to be vigilant and try to prevent it. Once compaction is created, it is costly in terms of yield, and cannot be removed by tillage. Soil life repairs compaction, but at an extremely slow pace. Compaction may not 'make or break' your farm, but it does impact yield significantly and is not all that difficult to minimize. While the improvement of soil structure with good no-till practices certainly goes a long way toward solving the problem, some attention to a few other relatively simple items can be very worthwhile.

[4] To whatever extent the footprint grows in length (due to either more tire squat, or larger-diameter tires), it is pure gain in reduction of compaction.

Photo by Tracey Palen.

Lost Investments

Doug Palen of Glen Elder, KS collected these samples during a rainstorm in Aug. '05 from a brome waterway where runoff merged from 2 fields—one cropped with full tillage (neighbor's), the other with low-disturbance no-till for 11 years by Doug (yes, he still has some runoff). Keith Thompson, Joe Swanson, and other producers have collected similar comparisons of runoff, all of which validate what is shown so vividly with the rainfall simulator demos.

In the photo, the dark colored water in the jar on the right is due to soil particles suspended in the runoff. Farmland is a significant investment. Every ton of soil leaving the field diminishes its productivity and the value of that investment. Not only does the loss of topsoil reduce ability to grow crops, but the taxpayer gets nicked again when the road ditches, culverts, streams, and reservoirs silt up and require clean-out. Because a portion of the soil particles remains suspended for months or years, cities spend more money cleaning the water for domestic usage.

Tillage/Planting Method in Wheat Stubble	Residue Cover (percent)	Soil Loss (tons/acre)
Full tillage	9	4.2
Reduced tillage	29	1.2
No-till	86	0.2

Nebraska tests after tillage/planting on a silt loam soil with 4 percent slope, with 3 inches of water applied in 75 minutes. Full tillage was moldboard plow, harrow, rod weeder, drill. Reduced tillage was blade plow three times, rod weeder, drill. No-till was drill only. (Adapted from E. Dickey, D. Shelton & P. Jasa, 1986, Residue Management for Soil Erosion Control, *NebGuide G81-544-A*, U.Neb.-Lincoln.)

For crop production, both water and soil are limiting factors—keeping more of the water also lets you keep more of the soil. Both are accomplished by maintaining sufficient residue cover, along with not tilling the soil. Good reasons for both the farm operator and the landlord to insist on those methods. (See the Dec. '03 *Leading Edge*, where Rolf Derpsch describes the infiltration process.)

A Better Understanding

by Keith Thompson

Making no-till work properly has never been obvious—certainly not for the world's pioneers of the practice, and not for those who are first in an area to apply the principles to their local conditions. Even with a "brain transplant" for no-till, sometimes things like crop rotations, fertilizer application, and seeder functionality take awhile to decipher. For the poorly drained, high-clay soils of east-central Kansas—regarded by many experts as not suitable for no-till practices—the deciphering took a bit longer.

That's exactly what faced Chad Filbrun and his dad, Dwayne, who farm near Westphalia, KS (halfway between Ottawa and Chanute). They'd experimented with some no-till planted crops for many years in the '90s—doing min-till or 'skip-a-till' on the majority of their acres during that decade—before eliminating full-width tillage in '98. Since 2000, the Filbruns have used only true no-till practices. While some of the academics have concluded that no-till is impossible on those soils (Kenoma, Woodson), this 'fact' didn't deter the Filbruns in the least (or perhaps they were totally oblivious to the professional verdict on no-till for their area), and they appear to be migrating toward a successful system now. Not that the Filbruns are the least bit interested in slowing down the search for further improvements.

Photo by Keith Thompson.

Filbruns' double-crop soys thrive in heavy wheat stubble.

While the Filbruns won't claim to have invented much of anything at all, they have indeed successfully sorted out much of the grain from the chaff when it comes to making true no-till work in their conditions. They've either survived or dodged many of the untruths, half-truths, propaganda, fads, and other distractions that seem to dog the move to better cropping systems. They're a bit ahead of the pack in this regard, whether by dint of asking the right questions, skill at problem-solving, or just being lucky.

Like many who start down the no-till track, at first the Filbruns simply took out the tillage and didn't change much else—with rather predictable results. Luckily, they fixed the biggest deficits fairly quickly. Filbruns' rotation prior to no-till was essentially a crop split of about 2/3 soybeans with 1/6 corn and 1/6 wheat. "We're probably still paying the price for some of that today. We did a lot of damage to the soil," says Chad, referring to the mining of soil organic matter (OM) and erosion. No-till has allowed the Filbruns to increase the portion of wheat and corn in the rotation, while adding double-crops. "Wheat always goes in after soybean, then double-crop to soybeans after wheat, then to corn." After that, it gets more varied, usually with full-season soybeans following the corn. Sometimes another corn >>soy cycle follows that, stretching it out to a 5-year rotation. Occasionally corn is stacked, but not soybeans. "Rotations are what we're fiddling with right now. We don't have it all figured out." Chad's interested in doing more stacked corn, but frustrated by some aspects of corn following wheat/dc soy. (More on that later.)

On 2 years of strip-till: "We were fighting a losing battle."

The scheme for fertilizing needed an overhaul, too, so back in '98 the Filbruns bought into what was being pushed: a DMI strip-till rig. Touted as solving all those fertilizer placement issues, and various other seedbed problems of min-till or no-till, Filbruns soon had some experiences of their own. They gave strip-till a serious effort, and try as they might, strip-till ended up costing them money. Whatever was supposed to happen when strip-tilling, Filbruns found that if the soil was a little too wet, big clods would be brought to the surface that never went away—becoming so hard that the planter would hop around terribly. Or if it was too dry when strip-tilling, an even bigger crack would be left underground—not at all a good place to install seed. Strip-till was a bust even if they got it done in the fall as recommended by the machinery dealer—and in the spring, same problems only worse. "We were fighting a losing battle. . . . The second year ['99], the planting conditions were so rough we actually jumped over and started planting *between* the strip-till ['prepared' zones]. To our surprise, it actually planted quite nice. We said to ourselves, 'Good night! This works just fine [for a seedbed]. All we've got to do now is figure out another way to put fertilizer on.' " Chad notes that newer strip-till rigs are designed a bit better, but he further explains that most of the problems plague the concept itself. "When we were strip-tilling, we had more weed pressure in the row [where the shank disturbed the soil]. It took lots of horsepower to pull the thing. . . . We've found other ways to apply fertilizer."

Now, Filbruns' fertilizer for corn goes on as high-pressure streams of liquid squirting behind straight coulters, which run shallow on 15-inch spacing. They run the applicator up to a month or two before planting, and sometimes just ahead of planting. The applicator has an 800-gallon tank to allow them to cover the acres in a hurry, since they apply up to 130 units of N, plus some P and K. (Filbruns continue to ratchet up N, P, and K rates as their yields improve.) Chad mentions that one can hardly see where this unit runs, except on the first day when the blades are still rusty. If they do have to apply N after planting, they side-dress after the corn is up, using the same applicator but without the coulters engaging the soil. Some pop-up is applied with the planter, through the Keetons, which Filbruns like for the improved early growth.

Asking the Right Questions

From their strip-till experience, the Filbruns learned that a little bit of tillage in the wrong place caused more problems than it solved, and what they really needed to be concentrating on was the seeding operation. Their original Sunflower "no-till" drill just didn't have what it took to place seed properly, lacking any method to get good seed-to-soil contact in firm conditions. Chad says, "It was more a min-till drill than a no-till drill. We couldn't get enough down-pressure to cut. Our stands were suffering." That had to stop, so in '01 they purchased a used John Deere 1850 that had the required ability to penetrate residue and get the seed to depth. Good seed-to-soil contact was finally achieved when they installed (Case-IH) SDX firming wheels on the 1850, instead of the wider original ones. They saw improved stands, and soon discovered they didn't need to plant so much seed to get the stands they wanted—obviously a 'plus' for the bottom line.

Filbruns' 1850 drill was purchased without an air cart—they mounted a new 90-bushel Gandy box on the frame instead. The drill is plumbed for liquid fertilizer as pop-up, but they usually "get in a hurry" and broadcast dry N-P-K ahead of the drill for wheat. Their wheat gets most of the N in the spring, sprayed on with a floater.

The Filbruns' 12R New Idea (White) 6100 planter had its own deficiencies in firm no-till soils, which became quite apparent as they went along. Keetons were the first addition, for seed-to-soil contact. Another major problem with the planter was getting the seed trench closed, and after hearing a speaker at a No-till on the Plains conference describing them, Chad thought he'd try a row of Exapta's HCS brackets and Thompson spoked closing wheels in '04. When they started planting corn that spring, the difference was striking enough—and Filbruns' problem significant enough—that they hastily


Photo by Keith Thompson.

Chad is surprised at how quickly his residue disappears. Warm, wet climates will do that. More residue is definitely needed to cover this soil.

purchased and installed the remaining rows early in the planting season. Chad says furrow closing hasn't bothered them since. (Full disclosure: The author is co-inventor of the wheel named after him, and a shareholder of Exapta.)

The Filbruns also run row cleaners on the planter, but Chad is quick to point out that he makes sure no soil is moved, and only enough residue gets moved so that hairpinning is not a concern. At most, he moves 80% of the residue, and usually considerably less. (Their soil turns to bricks otherwise.) Having adequate down-pressure on the row units for proper seed placement is another skill Chad has mastered. He's still tinkering with improvements such as R-K seed tube guards, but overall he's quite happy with planter performance these days—"Best, and most consistent, stands we've ever had."

Much of what the Filbruns do revolves around their cattle, since they feed quite a large number. This means efficiency with field operations is mandated, as well as having feed for cattle. They now have an ethanol plant nearby, so the Filbruns feed wet distillers mash instead of their dry corn. Filbruns' cattle ration includes corn silage, a practice they've increased in recent years. When they take silage, Filbruns usually drill rye soon afterward. The rye is grazed heavily, but also helps control erosion. Soybeans are planted in the spring after the rye is killed. With the forage option, Chad is keen to try some things like turnips or radishes elsewhere in their rotation.


Photo by Keith Thompson.

Filbruns' 2005 corn harvest commences.

One problem that persists is Chad's observation of significant yield drag in corn into wheat/dc soybean stubble. Just why this occurs they haven't figured out. While corn planted into high-residue conditions works well in slightly drier regions, Chad suspects their poorly drained clay soils and wetter conditions create a different outcome for them. Because of this, he is thinking about a rotation of soy >>wht/dc milo >>soy >>corn >>corn, but so far they haven't taken much action for going down that path—Chad thinks milo is a weed, and they're not yet comfortable with stacked corn. The Filbruns' original plan for 2005 was to plant dc milo after wheat harvest, but high soybean prices lured them away. I suspect their intentions are to fix their corn-after-wheat problem with yet another soybean following the wht/dc soy. (*Editors' Note: Quite likely, much of the problem with Filbruns' yield drag is plain old denitrification, which is best remedied by applying a portion of the N fertilizer after the corn crop is established and drawing significant moisture from the soil—the N loss via denitrification occurs primarily when soils are waterlogged. Furthermore, N fertilization requirements are higher following a wide-C:N high-residue crop such as wheat or corn, as compared to following a low-residue narrow-C:N situation such as full-season soybean stubble. As for having a high percentage of soybeans in rotation, this creates major problems with soil degradation, and low yields in corn & wheat from lack of residue, while soybean health also declines.*)

The Journey (Thus Far)

Despite all the bumps in the road, Filbruns stuck with the no-till course through all the travails of strip-till, poor stands, etc. They had their sights set clearly on several management objectives—primarily, making the same or more profit while spending less time on field operations (remember the cattle), and not losing so much soil.

Being extremely industrious people, Filbruns weren't lazy when they desired to simplify cropping operations in the mid-'90s. "For us, the original motivation to go to no-till was definitely the reduced workload." Part of that was having more time for expanding the cattle operation, and for family, church, etc. But the Filbruns also knew that all those field operations were costly, and they were always itching to get more done with less. Also, some tasks were just not that much fun—"I hated cultivating row crops," Chad says emphatically. Moving from 30-inch beans to drilled beans simplified things as far as Chad was concerned. He explains that the next step seemed logical enough—stop doing tillage pre-plant on soybeans. But it was still "just a skip-a-till, not a true no-till system," says Chad, who is slightly annoyed with people who say they "no-till" when all they really do is occasionally omit tillage.

During the time Filbruns were moving to drilled beans and less tillage, they decided to go to Lessiter's 1997 "National No-Till Conference" in Des Moines. Previously, they hadn't taken in too many of those types of meetings, explains Chad, "It was a real eye-opener. I didn't know I was losing that much soil." Also in January of '97, a neighbor attended the first No-Till on the Plains conference in Salina, KS, and was similarly impressed—giving the Filbruns a full report. Filbruns started attending that conference regularly themselves, as well as taking in a couple no-till meetings in Lawrence, KS and more locally. Chad remembers the shock of hearing the possibilities of a system that was less destructive as well as involving fewer field operations.

Chad admits he still doesn't spend much time worrying about soil health, but he does acknowledge the undeniable benefit of keeping their soil on the hillsides. Both Chad and Dwayne remark on how much less silt is in their waterways with the elimination of tillage.

Photo by Keith Thompson.

Chad examines his '05 double-crop soybeans, which have good potential under his careful management.

The Filbruns also note the improved soil structure translating into being able to plant sooner. And they've been pleasantly surprised at how well the soil supports their combine. This, along with larger combine tires (front and rear), has eliminated rutting in the fields. Despite the third-wettest August on record, and rain a few days prior, Dwayne begins corn harvest in late August—with no sign of mud on the tires.

Efficiency and profitability are really what drive Chad's and Dwayne's thinking, and to find and implement better methods as rapidly as possible. Chad was a bit reluctant to be interviewed for this article, saying, "We're a long way from having it all figured out. We've only been at it six or seven years. Our views are very much from an amateur standpoint." Rookies, perhaps, but learning fast.

To Our Readers

For those who receive this magazine solely because of your 2005 Winter Conference registration, this is your last issue. The Dec. '05 *Leading Edge* will be mailed only to paid subscribers. The Dec. '05 issue will be included in the '06 conference materials, as the first installment of a year subscription for the '06 attendees. If your attendance is uncertain, please arrange payment to continue receiving *Leading Edge*.

Gratitude to the Experts

A hearty 'thank you' for reviewing articles and supplying information during the past 4 years of *Leading Edge* goes to: Randy Anderson (USDA–ARS), Dwayne Beck (SDSU: Dakota Lakes), Agustin Bianchini (AAPRESID), Ron Christensen (Monsanto), Bud Davis (NRCS), Rolf Derpsch (free-lance consultant), Patrick Dodson (formerly with Nitragin-LiphaTech), Dirceu Gassen (Cooplantio), Pat Geier (KSU), Paul Jasa (U.Neb.–Lincoln), Kassim Al-Khatib (KSU), Bob Klein (U.Neb.–N.Platte), Gerry Posler (KSU), Don Reicosky (USDA–ARS), Tom Schumacher (SDSU), Merle Vigil (USDA–ARS), Tom Wacek (formerly with Urbana), and Ray Ward (Ward Labs). Your efforts and diligence are commendable.

No·till On The Plains

P.O. Box 379
Wamego, KS 66547-0379

Non Profit Org.
U.S. Postage
PAID
Permit No. 69
Salina, KS