Leading Edge

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No·till On The Plains

Raising the Bar

by Roger Long

Just 50 miles south of Kingman, KS, where a faded sign curiously boasts: "Plow Capital of Kansas," sets an entrenched no-tiller who has no intention of joining his 'scorched earth' neighbors. Anyone who has driven through Kingman County in July has seen the horizon dotted with billowing plumes of smoke fueled by burning wheat stubble, followed by smaller puffs belched by 300-horsepower tractors pulling 12-bottom plows. Escape to the south and you will find Randy Lanie of Manchester, Oklahoma, who—with 10 years of no-till crop production under his belt—quietly searches for the next management breakthrough to take yields and profits to ever-higher levels.

Randy recalls some of the challenges he faced when he first started no-tilling: "I had a landlord that came around when I was no-till planting soybeans into wheat stubble. He was very cordial and pleasant, and then as they got in the car to leave I overheard him telling his son in an almost defeatist tone of voice, 'He ain't gonna grow anything.' [The landlord] netted $95 per acre on those soybeans that yielded 57 bu/a, and then we made 75 bu/a on the following wheat crop."

Lanie's other landlords have been easier to convince: "We had good wheat and milo crops in '97 which the landlords were happy with. We harvested an early field of milo while the price was still very good—I sent a check for $9,500 to a very good landlady. About a week later,

Photo by Roger Long.

Lanie's wheat thrives in cotton stubble.

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her daughter called and told me that I had made a mistake and forgot to take out my share of the grain. I told her, 'No, I already took my share out and that it was correct.' " Randy can still hear the shouts of jubilation booming through the phone. "It was by far the most they had ever made on that piece of ground."

Like so many new technologies, acceptance eventually snowballs. Randy now gains new ground and landlords due to the profitability and higher level of land stewardship no-till affords. Lanie now works with over 30 different landlords, so public relations and communication are very important. "Most all my landlords now have e-mail so I try to send them some type of communication pretty regularly, letting them know how their crops are doing, how much rain we got and other things like that." He readily encourages landlords to ask questions, and if they don't understand something to have him explain it to them. Lanie many times provides written explanations of why particular inputs are used and the expected return on those expenses.

Returning to the farm in 1971, well-trained in financial analysis: "I could see that straight wheat farming wasn't going to cut it."

A Road Less Traveled

No-till has allowed Lanie to diversify his cropping choices and made double-cropping feasible. Even before no-till, Lanie was instituting greater diversity than many of his continuous-wheat neighbors. After completing his Bachelor's in Finance at Oklahoma State University, he started a graduate degree in accounting but left early to come home and farm. The year was 1971 and Randy was embarking on what would eventually become a successful farming venture, but it wasn't particularly profitable during the early '80s and early '90s, and Randy knew he couldn't just do "what everyone else was doing." He explains, "I could see that straight wheat farming wasn't going to cut it. Even where the soil was very good, we just weren't getting the stands of wheat that we needed. We started growing alfalfa and made some very good profits." It was this quest for diversity that enticed Lanie to no-till.

After Randy began to grow the operation by adding more acres, he soon saw the burden that heavy tillage was taking on time and profits. "We didn't just scratch around out there; we worked it deep and often. And, we had so much to get over, we had to go all the time. If it was wet . . . we worked it wet! One year, we put 1,800 hours on a tractor." So, in 1980, they enrolled 40 acres in a Soil Conservation Service program that had them commit to 3 years of no-till on it. Randy saw potential and some of the opportunities lying ahead, but as many no-tillers know, no-till in the '80s provided even more challenges than today's no-tillers encounter. The rotations that so many no-tillers today deem standard and absolutely necessary were not as well-known back then—for instance, Lanie planted the enrolled field to wheat all three years, with declining grain yields and more 'cheatgrass' and disease problems each year. And Lanie says, "The planting equipment was very poor. The stands were no good. We've made tremendous advances in no-till seeding equipment since then." Not to mention, "Roundup was really expensive at that time," at $70/gallon. Many other herbicides hadn't been invented yet, and there were certainly no glyphosate-resistant crops. Other miscues

Leading Edge

No·till On The Plains

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

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

like not evenly spreading straw and chaff behind the combine further slowed no-till adoption.

But the journey had begun, and while there were bumps in the road, those little nuggets of success kept Lanie looking down a no-till path. He was still doing a fair amount of tillage in the early '90s, but he was developing a more intense rotation and gaining experience with no-till planting of various crops. In the spring of '96, he planted milo into failed wheat (due to drought) in what turned out to be a wet summer, with one field averaging 135 bu/a. Lanie was gaining confidence in no-till, and in 1997 he bought a no-till drill and a no-till planter and put a sizeable chunk of the farm into no-till that has continued to this day.

'97 was also the first year for cotton for Lanie, so he and some neighboring farmers teamed up to buy a stripper. Together they grew about 800 acres of cotton that year: "We would harvest about 20 acres a day—it took us all winter to harvest it!" The burgeoning crop diversity and better seeding tools gave Lanie the confidence he needed for going complete no-till, although one landlord continued to forbid the practice for awhile. Also, Lanie was doing some tillage yet to smooth up some fields, and attempting to disperse some plowpans by ripping (more on that in a moment). By 2000, Lanie was all no-till.

1980s forays into no-till were frustrating due to lack of knowledge on crop rotations, plus, "The planting equipment was very poor. We've made tremendous advances in no-till seeding equipment since then."

Crops & Soils

Rotation to some farmers in the area means switching from Jagger to Overley (or from graze-out wheat to harvesting grain), but for Lanie it means trying at least 10 different crops over the years. Some have fallen by the wayside, such as canola that had unacceptable winterkill and a shaky-at-best market, and sunflowers that had too much trouble with headmoth and too much risk (high cash outlay, inadequate insurance) for Lanie's taste. A few hundred acres of alfalfa can still be found on Lanie's farm, and an occasional field of Lanie's barley or triticale break up the northern Oklahoma landscape (his barley and triticale are grown for seed for Johnston's, although some of the triticale is grazed out).

With many years of trial and error, Lanie now has some general principles he follows in his rotations that flex with markets and weather. With the current price of milo, Lanie will be replacing many of his acres that would 'normally' be planted to cotton with milo. While his rotation decisions would be better illustrated with a flow chart, the following explanation summarizes his procedures: Wheat is immediately followed by double-crop (dc) milo or soybeans (they plant dc soybeans until June 20th and then switch to milo after that). If dc milo, the field usually goes to cotton (or sometimes milo) the next year, and if the cotton is harvested soon enough it is seeded to wheat. If dc soybean, the field goes to milo (or corn) the next spring, and these are followed by wheat again. And while he obviously likes to really mix things up, he admits that on some of his poorer soils he has some acres in their 3d consecutive year of wheat right now. He has not found a good consistent broadleaf crop to grow on the poorer soils.

Randy knows the concerns that many growers have regarding wheat following milo, although he notes that they have had pretty good success, which Randy attributes to their early milo harvest. They generally plant their full-season milo from May 1st to May 15th and harvest mid-August to early October. Directly after harvest, they kill their milo with glyphosate—so it no longer uses precious moisture—and apply plenty of nitrogen. These practices accelerate the decomposition of the milo and likely shorten the time when the milo residues are allelopathic to wheat. In years of normal moisture, he has not seen

Photo by Roger Long.

Just a reminder.

Low overhead: "If I was still doing tillage, I'd have to own 5 four-wheel-drive tractors and then all the tillage equipment, not to mention all the labor."

a yield drag compared to 2d-year wheat.

Lanie has come full circle with cattle in his operation. When he first came back to the farm, they had cattle which worked well with wheat (grazed) and alfalfa, but Randy's meticulous bookkeeping showed they were only a break-even enterprise. Thus, away went the cattle, and the time and money were put towards crop production. But as time passed, his kids needed projects for a source of revenue and character-building, so back came the bovines. Now, most of the kids are gone, but Randy likes cattle being back in the mix. "I don't think cattle

"Ripping to improve infiltration—that was a waste . . . I can't see where it's helped root penetration or crop yield either."

would be good on 'new' no-till—it takes about 3 years for the soil to 'solid-up.' "

Randy is reminded of how far his soils have come anytime he takes over a new piece of ground. Like many other no-tillers, Randy is quick to point out the difference between 'firmness' and 'compaction.' No-till soils more easily support hooves and wheel traffic, but allow for ample root growth which is so apparent when a spade reveals what is happening below the surface. Compaction may also support traffic, but has no forgiveness for roots. Randy points out the improved stand initiation he has compared to neighboring tilled fields: "We just don't have very many problems getting stands anymore."

Interestingly, despite the frequent usage of plowing in the recent history of some of his cropland, including plowing while wet, Randy notes little if any response to ripping in any field where he's tried it. "Ripping to improve infiltration—that was a waste . . . I can't see where it's helped root penetration or crop yield either."

Planning for Profits

As his degree would suggest, Lanie is also a careful financial manager, which fits hand in hand with his no-till system. "If I was still doing tillage, I'd have to own 5 four-wheel-drive tractors and then all the tillage equipment to go along with it, not to mention all the labor." Even though he farms a substantial amount of acres, his equipment inventory will come closer to fitting on a business card as opposed to filling up a sheet of paper. He does own 2 combines (and generally leases another), one 40-ft 1890 JD air drill, a 12-row planter, and—instead of an entire stable of green ponies—Lanie has one 9200 JD (with auto-steer) that supplies all of his horsepower for planting. Throw in a 4910 JD self-propelled sprayer and a hooded sprayer, and you have the complete picture of his equipment line-up. Randy is particularly proud of his sprayer and what it has done for his bottom line. "In '98 we hired all our spraying done. And that was with $40 glyphosate!" He bought a Spra-Coupe in '01 and then upgraded to the John Deere 4910 in 2004. Even with the hefty price tag of $160,000, Lanie figures it paid for itself in less than two years, "And I still have it!" He continues, "It's the most expensive tool I ever bought, and I probably paid for it more quickly than anything else."

Of course the reduction in spraying costs is more the exception than the rule. He notes that when he started raising cotton, his break-even was around a half a bale (250 lbs) per acre. Now, with increased seed costs (Roundup Ready, seed treatments, etc.) and custom-harvesting costs (he had all the fun he could stand with owning a stripper) he now figures his break-even at around 450 lbs of lint per acre.

As with many growers this year, profitability of milo and corn looks promising. Lanie's break-evens on milo from a couple of years ago ($2.00/bu grain price) had full-season coming in at 70 bu/a (with land rent included) and double-crop at 27 bu/a (Randy figures a "cost of fallow"—leaving wheat stubble idle—at $18/a). Better grain prices today decrease those break-evens considerably despite the higher fertilizer cost.

Lanie's actual yields on no-till milo have been "very inconsistent," often only "40 – 50 bu/a on marginal land," but with 80 – 90 bu/a being typical yields "on better ground." About every third year is a good milo year, he says. Even in bad years, "We always have at least one good field of milo, depending mostly on planting date. Unfortunately, we never know which planting date will be the right one until harvest." His double-crop milo generally runs 20 – 80 bu/a, although some years it is a complete bust. But in '06, all his full-season milo failed due to drought, while his two fields of double-crop milo yielded 23 and 51 bu/a.

The Plan in Action

With 40% of Lanie's acres in wheat at any given time, he pays special attention to its management from beginning to end. He starts planting in late September (25th) at rates of 60 to 70 lbs per acre, after October 10th he bumps the seeding rate by 10 pounds, and then increases his rate by 10 pounds for every 10 days thereafter (up to 120 lbs) and tries to be done planting wheat by early November. "We used to replant 1/4 to 1/3 of our wheat every year due to poor stands. Since we have gone to no-till, we haven't had to replant wheat." His fertility program is even more regimented. Twenty-five to thirty pounds of N and around 20 lbs of P go on at planting; then if there is good moisture, another 60 lbs of N is streamed on in either December or January. Finally, a third shot of N of approximately 20 – 30 lbs goes on with herbicide in February or March.

All Randy's milo, both full-season and double-crop, get seeded with his air drill in 30-inch rows. He suspects some yield drag from using the drill instead of his planter; however, "The air seeder is less costly to operate [than the planter]. And it's faster—40 feet versus 30; plus, faster ground speeds, it's easier to fill, and you don't have to fill as often." Randy says his planter doesn't see much action anymore—generally, the only crop it plants is corn.

Randy is bullish on corn, saying that it has been fairly consistent for him, except in '98 when he had some serious problems with 2 weeks of extremely hot weather at pollination. He says that on good land, such as what is suitable for alfalfa, his corn generally averages 90 to 115 bu/a, while on poor land it is closer to 40 or 50. Lanie initially decided not to plant any corn in '07 due to lack of subsoil moisture, but substantial rains in late March and early April had him put it back in the plan—if he can get it planted in time! He plans on quite a bit of corn in '08.

Lanie's cotton also goes in with the air drill, on 30-inch spacing. In recent years, he's gone to Cruiser or Gaucho seed treatments, which has dramatically reduced thrips problems and improved his early square load. He typically applies a growth regulator during the season, and occasionally sprays for fleahoppers, largely deferring to his crop consultant in those decisions. Due to better technologies and improved knowledge, his cotton yields have continued to climb (750+ lbs/a isn't uncommon for him)—until a 2005 hailstorm and the 2006 drought. However, the increased expenses now give him pause: "If the crop fails, it's a big loss—unless proven yield is high for crop insurance," and he has reduced his cotton acreage somewhat because of this. His biggest problem with cotton is control of summer weeds. Despite owning a hooded sprayer, it is a task that doesn't get quite the attention it should, mainly because it conflicts with wheat harvest and double-crop planting.

"We used to replant 1/4 to 1/3 of our wheat every year due to poor stands. Since we have gone to no-till, we haven't had to replant wheat."

Photo by Andy Holzwarth.

No-till corn that Lanie custom-planted for a neighbor in '99. Most soils in the Manchester/Wakita area are quite low in organic matter from decades of severe tillage, and were none too wonderful originally—ranging from blow-sand to nasty red clay, sometimes all in the same field. Not exactly Iowa . . . .

Nitrogen fertilizer for Lanie's cotton, corn, and full-season milo gets applied in the spring, either as broadcast urea (hired) or as UAN streams through his sprayer. Double-crop milo gets 40 lbs of N as urea applied 7.5 inches to the side of the milo row (his air drill is on that spacing). For corn, he applies 11-52-0 fertilizer about 2 inches over from the seed row, while milo gets 11-52-0 in the row with the drill.

Lofty Goals

His "Plow Capital" neighbors may be big on tillage, but Randy isn't the only no-tiller in his corner of the world. "There is actually quite a bit of no-till in this area. There were two other growers who started no-tilling about the same time I did, and we all just keep getting bigger. Now, quite a few more farmers locally are going to no-till." When asked what advice he would have for beginning no-tillers, Lanie was quick to reply: go to the No-Till on the Plains Winter Conference; talk to other experienced no-tillers; get a consultant, a no-till drill, and a sprayer. Ready, set, GO!

After visiting with Lanie for an afternoon, it's fairly obvious that he is adept at setting specific objectives and then achieving those goals. Lanie has also been involved in many activities off the farm, including getting the Anthony gin started, and serving on the local telephone board. He attended OSU on a full-ride track scholarship after winning a state high-jump championship in high school. Championships take hard work and determination. That same work ethic and drive has now been capitalized in a farming venture that began with the vision to improve the status quo. Set a goal—reach it—then set the bar even higher.

Air Drill Rx

by Roger Long

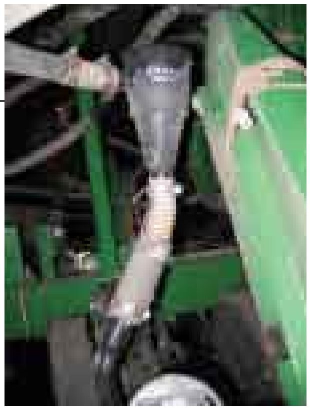


Photo by Doug Palen.

Seed placement with many disc-opener (or narrow knife point) air drills has long been a problem. The velocity of the seed in the air stream can cause far too much bounce at the opener, often with seeds ending up somewhere other than the bottom of the furrow. Producers have attempted to alleviate the problem by seeding deeper, by upping their seeding rates, and so forth—none of which are good agronomically or economically. Fortunately, a better remedy has come to market in North America.

The D-Cup Diffuser is a venturi that mounts into the air line above the opener, venting the air pressure and slowing the seed as it spirals through the chamber. Grooves inside the chamber improve seed flow and dispersal, reducing clumping or bunching of seed in the row. The Diffuser is made of durable abrasion- and impact-resistant plastic that won't corrode, providing many years of service. Made in Australia, the Diffusers are distributed in North America by Exapta Solutions: exapta.com/products/airdiffus.html or phone 785-820-8000.

Highlights: 2007 Winter Conference & AIM Symposium

Wayne Smith stirred (shook?) those in attendance by asking why our yields were so low (wheat grain yields, beef produced per inch of rainfall, etc.), and *why we set our sights so low*. Many minds were opened to the possibility that vastly more potential exists than we ever dreamed. Even if our potentials are somewhat less than Smith proposes (for whatever reason), it is still almost certain that our potential is far higher than we currently imagine. Indeed, why *do* we set our sights so low?

Smith provided many excellent ideas for pursuing better production and higher profits, for both crops and pastures, and it was easy to see that Smith was zealous in going after *all* advantages to be had. For cropping, he was adamant that stubble retention and no-till were cornerstones, and that inadequate plant nutrition was likely holding us back from achieving better crop yields.

For pasture production, Smith was focused on rotational grazing, supplying necessary nutrients (especially trace elements) *to the pasture plants*, and using introduced pasture species that yielded more livestock gain. He was also shocked to learn that virtually no one in the U.S. was using Bud Williams-type techniques to reduce stress on stock. We were all a bit ashamed of our shortcomings after hearing Smith!

John Grove of the U.Ky. presented results of studies—many of which were 20+ years in duration—demonstrating excellent yields under long-term no-till, and generally outpacing yields of the tilled plots. Most of his work was on N, P, and K management under no-till systems, including nutrient distribution within the soil profile, with the conclusion that under long-term no-till: "Stratification is not your enemy." In other words, nutrient stratification did not impair yield or require special measures to address.

Photo by Jana Lindley.

The '07 Winter Conference was a brilliant success, owing to superb presenters and attendees keen to learn. Here, Wayne Smith pushes us to get rid of our excuses.

Rolf Derpsch drove home many important points, especially on the value of mulch in the no-tillage system, for which he presented many research results from around the world. Many other thought-provoking presentations and conversations were to be had, which we cannot hope to capture in a few paragraphs.

Stay informed of upcoming events (including summer tours) at www.notill.org, and check out the online store, which includes past issues of *Leading Edge* (CDs, and a limited supply of hardcopies) as well as some past conference proceedings ('07 WC proceedings are sold out, but some related materials are available yet; call 888-330-5142 to inquire). Also, '07 AIM Symposium materials are available for purchase, which include a trove of information from Wayne Smith on plant language (diagnosing and correcting nutrient deficiencies) with many color photos, as well as Rolf Derpsch's presentation on long-term no-till effects—including research on the importance of mulch, and insights as to the lagging adoption of no-tillage in North America as compared to South America.

Plant Language:

Diagnosing Trace Element Deficiencies

by Wayne Smith

TECHNIQUE

Wayne Smith is an agronomy consultant (and beef farmer) based in Albany, Western Australia.

Prompted by Smith, we are finding micronutrient deficiencies are alarmingly common in Kansas wheat and other crops. We would do well to heed Smith's 'language' lessons.

Does No-till Make Trace Element Deficiencies Worse?

When you start no-till after years of degrading the soil structure (cultivation and erosion), your plant's roots will grow more slowly in the no-tilled soil than in the cultivated soil because the soil is more compacted and less structured. It takes time for stubble retention and undisturbed underground biology to do their repair work to the soil. Therefore your plants will be more prone to root diseases and trace element deficiencies in the first few years of no-till.

Another phenomenon is also at work. Initially, the mulch and soil organic matter that build under no-till will be 'sinks' for nitrogen and trace elements held in those materials until they once again cycle into forms available to your plants. This nutrient cycling is done by biological processes, and the increased mass of these organisms per land unit must be 'fed' also, since their bodies are composed primarily of the same nutrients needed for plants. It is a common observation that a little extra nitrogen is needed in the first few years of no-till because of this. Later on though, it is a common result that less fertiliser is needed as the now bigger volume of organic material releases its nutrients to the crops, i.e., fertiliser inputs needed (per unit of grain produced) become less than they were under cultivation.

Photo by Wayne Smith.

Photo 1. Leaf tipping on oats due to copper deficiency. (Freezes weren't involved.) Note the twisting of the dead tissue.

Having been through this with my clients on soils that are deficient in everything except sand,☺ my strong advice is to be pedantic on trace element nutrition and root diseases in the first few years of no-till. Also, never cultivate the soil again because that will just take you back to ground zero. Get past those first few years with well-fertilised plants and you will quickly start gaining the extra profits that are waiting for you.

Learning Plant Language

I consider it crucial to know what your plant is saying it needs. For plant nutrition, usually we just think about supplying nitrogen and phosphate. However, the biggest 'bang for your buck' is from trace elements. You can be 20% out (low) in the phosphate and nitrogen application rates without affecting yields significantly, but you can lose 20% of yield with no visual symptoms if the crop is lacking in a trace element like copper, molybdenum, zinc, or manganese.

My strong advice is to be pedantic on trace element nutrition in the first few years of no-till. Also, never cultivate the soil again because that will just take you back to ground zero.

On my trip to Kansas in April 2006, every wheat paddock I was shown had clear symptoms of copper and/or zinc deficiency. (*Editors: To our knowledge, Ray Ward was the first to propose copper deficiency in Kansas wheat in '04, although those were severe cases of deficiency. Smith is skilled at detecting the less-obvious cases.*) Numerous plant tissue tests and subsequent observations by Matt Hagny confirmed the deficiencies.

So what do you look for in a cereal crop? Firstly, unless a crop is droughted or has endured extreme sub-freezing temperatures, the plant should be green from top to bottom when the heads begin to emerge. There should be no dead spots on leaves, no dead leaf tips, and definitely no dead leaves. Any symptoms like that when the crop is not droughted should be seen as a sign you do not have things right yet.

As an agronomist when I was fresh out of university and wet behind the ears, I would refer to textbooks on nutrition and plant tissue tests to work out if a plant was deficient. However, my experience has shown me that the usual plant symptoms of trace element deficiencies are rarely 'textbook' in appearance or severity. There are degrees of the symptoms and they can express themselves differently in various varieties. Some varieties are also more susceptible than other varieties to a given nutrient deficiency. We have many such cases in Australia.

You can lose 20% of yield with no visual symptoms if the crop is lacking in a trace element.

But, there are clues to look for. I call it learning plant language because you need to be able to see what the plant is telling you it needs. Being from Western Australia where most of our crops are grown on sand and lack every nutrient a plant needs, by necessity we have become good at identifying all the deficiency symptoms.

Photo by Wayne Smith.

Photo 2. Triticale head with deformities due to copper deficiency.

However, the big impetus for us improving our yields and profitability was knowing what the potential yields were (see my article on potentials in the last *Leading Edge*). That showed we were nowhere near the yields that we could be achieving, and that made us investigate everything that was stopping us from reaching the potential.

Symptoms: Copper Deficiency

So what should you look for? If your cereal crop suffers from a hot wind and the tips burn (go black and then die), your crop is copper deficient. Molybdenum deficiency can also be involved, but nearly always it is copper deficiency.

If the top leaf has a dead tip, but the next leaf down is green to the tip, that is clear copper deficiency (see Photo 1). The dead tips often have a characteristic 'pig-tail' in which the dead material bends back down the leaf, and twists or rolls tightly. You would be losing at least 20 – 30% of your yield before you even see that symptom.

Other nutrients tip from the bottom (oldest) leaves first. Copper, however, tips from the newest leaf first and then down to the older leaves. If the youngest (newest) leaf has a dead tip and the next leaf down is green to the end, nothing else causes that except copper deficiency. (*Editors: A severe freeze can also cause this. Smith has frequently emphasized that copper deficiency will make the crop more susceptible to freeze damage, but low copper isn't always involved with leaf tipping.*)

Another copper-deficiency symptom is deformities of the head including sterile spikelets and twisted awns (see Photos 2 & 3), which occur in wheat, triticale, rye, and barley. Oats is the most sensitive cereal to copper deficiency and will have many blanks (no seed) in the head if deficient.

Photo by Robert Bosch of South Africa.

Photo 3. Wheat heads getting caught in the sheath is often due to copper deficiency, although late application of growth-regulator herbicides can cause similar effects. Note the bending and kinking of the awns on the emerged heads. Freezes during 2d-node or boot-stage wheat may produce vaguely similar symptoms, while freezes occurring after heading will turn awns white but without the kinking.

Zinc Deficiency

If you spray a 'fop' or 'dim' herbicide and it scorches or bleaches your crop, and if that damage is on the middle of the leaves and they are bent in the middle from dead lesions, that is a sign of zinc deficiency. These chemicals induce temporary zinc and copper deficiency, but it is also a sign your crop nutrition is too close to being marginal. (Remember that you can suffer 20% yield loss with a trace element deficiency without any visible symptoms in the plant.)

Have a look at Photo 9 on p. 354. This wheat plant was sprayed with a herbicide that can cause temporary bleaching. Have a close look. What do you see? Anything strange? I'll give you a hint. Every leaf was sprayed with the herbicide. Now do you see something strange?☺ See how the middle of the middle leaf is showing dead lesions. That is zinc deficiency. Nothing else causes that. Do not blame winter injury or herbicides for that damage. It is zinc deficiency.

Classic field examples of severe zinc deficiency in Australian wheat, where leaf disease has invaded the tissue weakened by the deficiency.

Photos by Wayne Smith.

One consistent symptom with zinc deficiency in cereals is dead lesions in the middle of the middle leaves. Not the top leaves and not the bottom leaves, but in the middle of the middle leaves. In severe zinc-deficiency situations, all leaves will start showing symptoms and it will look very droughted. It will also suffer more from any stress from root diseases and nematodes, and from moisture and heat stress. The crops will also be more susceptible to damage from many herbicides.

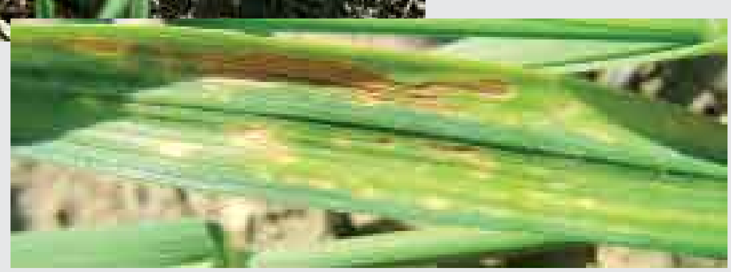
Photo by Wayne Smith.

'Textbook' zinc deficiency with broad whitish bands running along the length of the leaf on either side of the midrib. Trace element deficiencies are rarely 'textbook' in appearance or severity.

Too many times in Australia, people would look at a zinc-deficient crop and see leaf diseases and spray it with fungicide, only to see little or no yield response. "Must have been too dry," they'll say. Not necessarily. When you get good at plant language, you will be able to tell if the leaf markings are leaf disease or are zinc deficiency, or if the leaf disease is there because the tissues were weakened by zinc deficiency.

My experience has shown me that when we concentrate on making sure trace elements are never deficient, our crops

Acute zinc deficiency in Kansas wheat in early April '06. These symptoms almost never appear so distinctly, even in acutely deficient plants.



Photos by Wayne Smith.

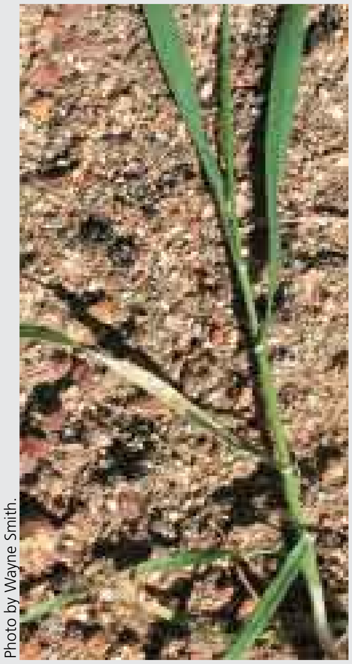


Photo by Wayne Smith.

Photo 9. Wheat plant injured by herbicide—or did the herbicide merely make manifest some other problem?

start tolerating the most amazing stresses and still yield as if they had 5 inches of extra rainfall. The crops also get less leaf diseases. Rusts are the exception: I have never seen the nutrient status of a cereal affect how badly it is attacked by rusts.

Molybdenum Deficiency

With molybdenum deficiency, the textbooks will say it is only a problem on acidic sandy soils. Not true. I have seen areas in eastern Australia (alkaline clay soils) and in South Africa (alkaline clay and loamy soils) where molybdenum deficiency is a problem. To me this is just another case of why you must learn plant language. You must let the plant do the talking and know what it is saying.

Things to look for with molybdenum deficiency are: the plant not responding to nitrogen as quickly as you would expect; the crop suffers frost damage (aborted grains, including in canola); and in legumes, some or all nodules on the roots will be less than blood red. If any nodule inside is white or green, that is definite molybdenum deficiency. If they are pale pink, that does not necessarily mean it is molybdenum deficient, but it is a warning sign that it might be marginal. If legumes do not perform on some paddocks or soil types, even though the pH and nutrition levels in the soil look okay, check the nodules.

Photo by Wayne Smith.

Photo 10. The sunflower on the left is normal, while the two on the right are molybdenum deficient. Note the upward cupping and distortions on the leaf margins.

Sunflowers are excellent indicator plants if there is a molybdenum deficiency in your paddocks since they are extremely sensitive to molybdenum shortages (see Photo 10). Deficient plants will be paler, stunted, and the leaves are cupped upwards with scorching around the edges of the leaves.

Manganese

Manganese deficiency is the easy one. Severe symptoms are the whole plant is pale and floppy. The trick is to pick up the deficiency before it gets to that stage. Like all trace elements, you can get large responses to manganese even with no visual symptoms.

Early signs of manganese deficiency are hard to pick in cereals. In barley it is very difficult to see until the problem is severe, and there are also varietal differences in oats and wheat that only experience can show you. What I do is look at the plants every week on a known manganese-deficient area so that you can see what the first symptoms are before the whole plant goes pale and floppy. Usually the early signs to look for are the bottom half of newest leaves being paler than the top half and the beginnings of yellow or pale stripes between the leaf veins on the newest leaf.

When trace elements are never deficient, our crops start tolerating the most amazing stresses and still yield as if they had 5 inches of extra rainfall. The crops also get less leaf diseases.

One very important lesson on manganese deficiency is something I learnt many years ago in England and Scotland. There, they sprayed manganese at the flag-leaf stage on what looked to me like perfectly healthy plants (they were shooting for 150 – 180 bu/a yields). When I asked why, they told me they learnt that the plant still responds to the late manganese spray if it needed (and got) an earlier manganese spray, even though it no longer shows any sign of being deficient.

In Western Australia, we suffer manganese deficiency on many of our soils but I had only been recommending one spray of manganese on deficient crops, usually around the mid- to late-tillering stage. That next season, I asked clients to spray a second manganese application around the flag-leaf stage (some one leaf earlier) to 'look-see.' By then, the plants looked fine and had responded beautifully to the earlier manganese spray. They did not look like they needed more manganese.

I was shocked at the yield response to that second spray. It was at least a 15-bu/a response in nearly all paddocks. So if you have manganese deficiency in your crop, plan on a second spray at or just before flag leaf emergence.

A Digression

There is a lot to go into about learning plant language, but I want to dispel one false-science view going around. The view you need to dismiss is that calcium-to-magnesium ratios matter: They do not, except at the extremities. We have grossly imbalanced nutrition in our soils of Australia, and not one single trial has ever shown a yield response to adjusting the Ca:Mg ratio in the soil, except at the extremities (extremely high calcium levels and very low magnesium or vice versa, e.g., more than 30:1 or vice versa).

Let the plant do the talking.

Australia even had a research team investigate every trial around the world they could find on Ca:Mg ratios, and again, not one single independent trial showed that the ratio matters, except at the extremities. My experience has also shown the theory is nonsense. Do not waste your money on this wrong nutritional philosophy.

Other Diagnostic Tools

Back to learning plant language. A tissue test is a snapshot in time. You may test the plants today and the result showed they were fine for zinc. But two weeks later, after cold cloudy weather, the crop can become zinc deficient. Just because your tissue test two weeks before said it was okay, does not mean it is still okay.

You can get errors with contamination from your hands and from other nutrients being a problem. For example, suppose your tissue test shows it is very high in nitrate nitrogen. Your plant looks sick and you probably shrug your shoulders and wonder why your crop is looking so sick. It can't be nitrogen deficiency because the plant test showed it was high in nitrogen.

But this is where learning plant language is so critical. If your plant is showing nitrogen-deficiency symptoms, guess what, your plant *is* nitrogen deficient. You would need to look at your plants and say, well, you are showing that you are nitrogen deficient, but the test shows you are high in nitrogen, and you are definitely not healthy, therefore you are probably molybdenum deficient, and/or copper deficient.

That conclusion should make you look closer at the plant to see if you see any copper- or molybdenum-deficiency symptoms. These two nutrients are involved in converting nitrate into proteins and if deficient, the plants can have excess nitrate in their sap but are unable to use it. This is why the plant can still look nitrogen deficient, especially with molybdenum deficiency.

This is also why the newest leaf tip 'burns' in a hot wind with copper deficiency. Nitrogen is moved up a plant to the growing point, but if it is copper deficient, it cannot convert all of the nitrogen into proteins and other compounds it needs. Therefore, the nitrate nitrogen accumulates at the end of the top (newest) leaf. Along comes a hot wind sucking the water out of the plant quicker than it can replace it, and this concentrates nitrate in the leaf tip even more to the point of it being toxic to the plant. That causes the blackening, and then death, of the tip.

Oats is the most sensitive cereal to copper deficiency. Oats should yield more than wheat and barley, unless you have crappy oats varieties.☺ If oats yields significantly less than wheat (in *weight* of grain per land unit), I would suspect that you have a copper-deficiency problem in your paddocks. Conversely, canola rarely exhibits copper deficiency (i.e., it is very tolerant of low copper levels).

And as for soil tests, I have no faith in them at all for trace elements. I deal with South African farmers who have soil tests that show their soil is high in copper (and other trace elements), but the plants show they are deficient. Vice versa happens too, where the soil test says it is very low in copper (for example), but the plant says, no, it is fine with the amount of copper it has.

Australia had a research team investigate every trial around the world they could find on Ca:Mg ratios, and not one single independent trial showed that the ratio matters, except at the extremities, e.g., more than 30:1 or vice-versa. The theory is nonsense.

So, remember to know what the potential is. It is not what the best farmer has achieved. It will be higher, and probably much higher. When you know what the potential is, you can then work out why you are not reaching it. Secondly, learn plant language. It will tell you how it is going. And, never let trace elements be deficient at any stage of the plant's life.

Diagnosing Multiple Deficiencies

It can be difficult to diagnose one nutrient deficiency while learning plant language, but it gets more difficult when two or more nutrients are deficient. If root diseases, soil acidity, or compaction are also problems, these can make it more confusing to know what to fix first.

Photos 11 & 12. Multiple nutrient deficiencies discussed in the article.

Photos by Wayne Smith.

In the courses I run on learning plant language, I emphasise that farmers are actually very good at observing problems with their plants, but usually don't know what to do about them. You need to start with this premise: that you can see the plant is not "as it could or should be." You can tell when it is not tillering as much as you think it should, that there are dead lesions or leaves on the plant and where those dead areas are, that there is a dead tip or two on the plant, that the plant is looking rather pale all over or at the top or at the bottom, that it suffers badly from a hot wind when other areas of the field didn't, etc. . . .

These are observations you make. You just need to stop there for a moment and take in these observations. Go over what you are seeing, and go through information on nutrient deficiencies such as in Table 4 on p. 361. Check the roots: Are they long, white, fibrous and matted with lots of tiny hairlike roots; or are there few roots, bunchy with no fine roots; or are they fatter than normal roots, etc.? This will give clues to what is wrong. You will be right more often than you think when working out what is wrong with your plants.

A tissue test is a snapshot in time.

The following photos I think are very good at showing you how to pick what to fix first with a crop when it is showing multiple deficiency symptoms. Photos 11 & 12 are of the same field. It is in a low-rainfall environment (~ 12 inches/year if we are lucky☺), is a hard-setting soil (poorly structured), and has a history of very little fertiliser being applied. The farmer was using a fully compounded fertiliser that was prilled from a slurry of MAP + ammonium sulphate + 1% copper, 2% zinc, and 3% manganese. Remember that a compounded fertiliser has every granule identical: all nutrients are in every granule.

When the farmer was sowing, this fertiliser was placed with the seed in the same furrow—what you call pop-up fertiliser. This is standard practice for us in Australia. However, the farmer had a few blockage problems in the heads of the air seeder and so had these groups of rows being seeded without any pop-up fertiliser.

So what you do see in Photo 11? There are three things you should notice. One, where there was no fertiliser, the crop is shorter and paler. Second, where it did get the fertiliser, the plants still are not perfect. Though it is hard to see, you should be able to discern some yellowing on the bottom leaves—i.e., they are not lush and green to the tip of every leaf, and the top leaves are too erect and are not lush. That is an important observation. It is usually one you only notice when pointed out, but you still can see it.

Thirdly, look again at the rows without pop-up fertiliser. Notice that there are variations in the colour: None of it is healthy, and there are some paler areas with still less growth. You should be able to see this, and it means that there is more than one thing wrong in those rows without pop-up fertiliser. If it was all one colour, it means only one thing is wrong.

Now look at Photo 12. The rows in the front are the rows without pop-up fertiliser. The back rows did have fertiliser. In the front rows, you might be able to see some middle leaves kinked over, some floppiness throughout, and dead leaves at the bottom of the plant. It is a combination of zinc and manganese deficiency.

If you stood in that field and looked at the different coloured areas in the rows without pop-up fertiliser, some areas would be mainly all pale and floppy (manganese deficiency), and other not-so-pale areas would have dead lesions in the middle of the middle leaves causing the leaves to bend at those lesions (zinc deficiency). Some areas have a mixture of both.

If a plant is showing a deficiency symptom, but does not respond greatly to that nutrient (properly applied), there is always something else wrong that is holding it back.

But the lesson does not stop there. Have a look at the base of the stems in the rows that missed out on pop-up fertiliser, compared to the row behind with pop-up fertiliser. Can you see a difference? The rows without the pop-up fertiliser are pale on the stems, but plants in the row behind (with the fertiliser) are red at the base.

This is where the 'second' observation comes into play—i.e., the plants *with* the fertiliser do not look lush and there are some dead leaves at the bottom of the plant. If you were really good, you might have also noticed that those plants have leaves a little shorter and a little too erect for normal plants. A completely healthy plant would have no dead leaves, and the leaves would be long and lush and at the usual angle ('relaxed,' but not floppy).

Take notice of all your observations so far. Now let's decipher what is happening. The plants *without* fertiliser are showing zinc and manganese deficiency but not phosphate deficiency, and the plants *with* the pop-up fertiliser are showing phosphate deficiency. This speaks loudly what the main problems are.

The *main* problems in this paddock are zinc and manganese deficiency. They need to be fixed first. But, once that has been attended to, the plants now show what the next most-limiting nutrient is: phosphate. The plants were so deficient in zinc and manganese that low phosphate wasn't hindering their growth, but when zinc and manganese were applied as well as phosphate, the plant was showing that it needed more phosphate and that it would have grown better if there was more.

Although initially you may look at a field and have no idea where to start to work out what is wrong, you can actually decipher it with just pausing a little to chew over what you are seeing.

Multiple Deficiencies, Another Example

Now have a look at Photos 13 & 14. These are not the greatest photos, so my apologies for this, but I think you will gain confidence in your abilities despite the low quality of the photos.

Both photos are from fields showing chronic sulphur and zinc deficiencies. However, in each photo, you can probably see only one symptom. But that is a good observation! Photo 13 is showing dead lesions and the leaves are bending over at those lesions. The plants in Photo 14 are not showing dead lesions in the middle of the middle leaves, but the top leaves are quite pale and yellow, and are short and erect.

Photos 13 & 14. Multiple deficiencies discussed in the article.

Photos by Wayne Smith

I know both fields are chronically deficient in zinc and sulphur because I have walked through both fields and seen the results but did not take photos of plants showing both symptoms mainly because there was only one major nutrient deficiency showing in each field. However, having told you both nutrients are chronically deficient, what does that mean to your observations in the two photos? In Photo 13, the *main* problem is zinc deficiency, and in Photo 14, the *main* problem is sulphur deficiency.

Plant roots need hundreds of sites of a trace element in the soil.

Where sulphur deficiency is the main problem (Photo 14), it is so bad that most plants are too sick to show zinc deficiency, but if sulphur had been added, then the plants would be showing chronic zinc-deficiency symptoms. Adding just zinc or sulphur in either situation may not give much or any yield increase because both are needed. Be aware that if a plant is showing a deficiency symptom, but does not respond greatly to that nutrient (properly applied), there is always something else wrong that is holding it back.

Hopefully you can see these symptoms, draw the correct conclusions, and gain some confidence in your observation abilities. You are good at noticing things. You usually just need to ponder on those for a few minutes and you will come up with what is the main problem, what is second and third, etc. . . .

Photo by Wayne Smith.

Peas shouldn't be more pale at the top than the bottom. This is sulfur deficiency.

Addressing Trace Element Deficiencies

Some quick basics: Plant roots need hundreds of sites of a trace element in the soil. Access to only two or three sites will not fix a deficiency. Each set of tillers has its own roots and so if a plant has access to zinc on one set of tillers only, all the other sets of tillers will still be deficient.[1]

This is why blends of granular fertilisers do not work (blends are where each granule is different, e.g., pure DAP granules mixed with pure zinc sulphate granules). A compound fertiliser is much better for correcting a trace element deficiency. A compound fertiliser is where each granule is identical, e.g., DAP and zinc sulphate are slurried together and *then* granulated. This makes every granule have the same amount of nitrogen, phosphorus, and zinc. When using a compound fertiliser, there are many more sites of zinc for the plant to access. Roots also proliferate around compound fertiliser granules and take up the nutrients more efficiently as compared to accessing phosphorus at point A and zinc from point B. (*Editors: Sources of compound granules with zinc and/or copper in North America include Cargill/Mosaic and Agrium; compounded granules have been on the market for 40 years, but remain obscure*.)

Foliar sprays work reasonably well, but placing nutrients in the soil at seeding will always be the better method.

Some fertiliser suppliers apply coatings of trace elements onto DAP or MAP granules. This is much better than blends, and almost as good as a compound fertiliser, unless the coating flakes or dusts off before being placed into the soil (with trace element liquids applied to dry prills, this really isn't a concern). Some coatings are also very expensive per unit of nutrient supplied. (*Editors: Since most North American soils have relatively high CECs, this provides opportunity to build soil nutrient levels in a way that may not be practical in Western Australia. For instance, some knowledgeable soil scientists in the central U.S. would contend that the best way to address zinc deficiency is to apply 30 lbs/a of zinc sulfate and then not worry about it for 5 – 10 years.*)

[1] *Editors: This is common knowledge in Australia, and taught in their textbooks decades ago.*

In no-till, my experience has shown that the most efficient way of preventing a trace element deficiency is to use a liquid at seeding and have the trace elements in that liquid stream close to the seed. A rule of thumb we have concluded from our observations so far is that you need a quarter to a tenth of the trace element in a liquid stream as you need in a compound dry fertiliser to prevent a deficiency. This is because there are millions of sites of trace elements for the plant to access when in a liquid stream. (*Editors: Considerable research demonstrating the advantage of liquid streams over dry prills in the seed furrow has been done in Western Australia and South Australia, in soils ranging from highly acidic sand to alkaline clays. However, experiments in the Great Plains region of North America generally haven't shown a major advantage to liquid streams over dry prills. Perhaps the differing results have to do with the highly weathered properties of Australian soils.*)

Pre-no-till trials with trace elements showed calcareous and high-iron soils can 'fix' zinc and manganese so tightly to soil particles that they become unavailable to the plants. All pre-no-till trials also showed we needed to mix the trace elements into the soil and the more it was mixed in, the better the uptake by the plants, but over time, zinc and manganese would become unavailable.

When adding trace elements to a liquid stream at seeding, go for the cheapest per-unit source of the actual nutrient as long as it is compatible with anything else you have in the stream.

This was a concern when we started no-tilling in that if we put all the fertiliser in the furrow with the seed, there would not be enough sites of trace elements throughout the soil for the plant to find. However, the reverse occurs in that having the nutrients in a narrow band/stream near the seed actually results in more efficient uptake of the nutrients. So far, we have not experienced soils fixing the trace elements in the year of application when applied in a liquid stream.

You will need to gain experience with rates for your environment, but perhaps as a starting guide, Table 1 shows the current rates we use on fields where we know or expect to have a trace element deficiency. These are the rates used as liquids when placed in a continual stream in the furrow with the seed. (*Editors: For example, if you had a fluid zinc source that was 20% actual zinc by weight, and weighed 11.1 lbs/gallon, you would need to apply 10.4 fluid ounces of that product per acre to achieve the 0.18 lb. of elemental zinc per acre (0.18 / [0.2 x 11.1 / 128]). It is the same calculation as for actual N/acre by applying some quantity of 32% UAN solution, with the added wrinkle of dividing into fluid ounces.*)

Table 1. Seed-Furrow Application in Fluid Stream for Winter Cereals in Western Australia

	Actual Nutrient/Acre	In Metric
Copper	0.045 lb/a	50 g/ha
Zinc	0.18 lb/a	200 g/ha
Manganese	0.31 lb/a	350 g/ha
Molybdenum	0.0018 lb/a	2 g/ha

Editors: These rates are for acidic sandy soils. Much higher rates (5x or 10x) of zinc and manganese may be needed on high-clay or high-pH soils to have the same nutrient-supplying power for a cereal crop. Molybdenum is more available in high-pH soils, so less is needed—the opposite of zinc and manganese. Smith has not experienced copper rates needing to be changed according to soil pH, although he emphasizes they are still learning about this new technique.

Foliar sprays are a good quick-fix and your only option once the crop is already in the ground (foliar sprays work reasonably well, but placing the nutrients in the soil at seeding will always be the better method). For foliar sprays, sulphate forms (e.g., zinc sulphate, manganese sulphate) are quicker for the plant to respond, but also are quicker to run out and become deficient again.

For foliar sprays, oxide forms are good as long as the particle size is extremely small: The smaller the better. The best foliar products I have found are the ones from Phosyn (a.k.a. Yara) as they give a longer response to the plants and are compatible with most things we would like to spray with them at the same time (e.g., herbicides). (*Editors: Phosyn has distributors in the central U.S., including Helena Chemical.*) Chelates for us are too expensive, but if they are a similar price to other 'good' products (per unit of actual), they are an option too.

Table 2. Foliar Application

	Actual Nutrient/Acre
Copper	0.1 – 0.2 lb/a
Zinc	0.2 – 0.3 lb/a
Manganese	0.2 lb/a
Molybdenum	0.017 lb/a

Manganese Nutrition & Herbicide Effects on Wheat Yield (t/ha)

Metsulfuron-methyl (e.g., Ally), 60% active (product g/ha)	Manganese applied (kg/ha): 0	1	3	7	12	Mean
0	3.0	3.3	3.6	3.9	4.1	**3.6**
3	2.9	3.3	3.3	3.6	3.6	**3.3**
6	2.2	2.5	3.1	3.3	3.6	**3.0**
9	2.1	2.4	2.6	2.9	3.3	**2.7**
Mean	**2.6**	**2.9**	**3.1**	**3.4**	**3.6**	

Conducted in South Australia by Peter O'Keeffe & Nigel Wilhelm (SARDI). The results occurred with Mn leaf tissue levels of 14 to 56 ppm at early tillering (the metsulfuron had been applied earlier), the lower levels of which are considered 'marginal' since the critical level is assumed to be about 10 – 15 ppm. Wilhelm & O'Keeffe have conducted similar trials with metsulfuron and zinc; no yield reductions were found if soil zinc levels were high, while large yield losses were found on soils with low/moderate zinc levels. Many herbicides such as metsulfuron reduce root growth, which exacerbates the nutrient-deficiency problem (similar studies in South Australia on wheat and barley have found significant interactions between marginal micronutrient status and various herbicides, including many sulfonylureas, imidazolinones, growth regulators, and triazines). The 3 g/ha rate would equal 0.043 oz/a (product) of Ally 60XP, well below the U.S. labelled rate of 0.1 oz/a, and is the same amount of metsulfuron included in 0.20 oz/a (product) of Finesse. Sources: O'Keeffe, 1993, The Hidden Costs of Sulfonylurea Herbicide Use on Micronutrient-Poor Soils, in Proceedings: 7th Australia Agronomy Conference (1993). Nigel Wilhelm, personal communication Apr. 2007.

With these foliar rates (see Table 2), we would normally spray twice if a deficiency was visible early in the plant's life. The first spray of zinc would be at the 2-leaf stage to early tillering, and the second at the mid-/late-tillering stage. Copper and manganese would have their first spray at the mid-/late-tillering stage, and again ~ 4 weeks later.

When adding trace elements to a liquid stream at seeding, go for the cheapest per-unit source of the actual nutrient as long as it is compatible with anything else you have in the stream. We often have UAN and triadimefon (a fungicide) in the stream and there are no compatibility problems with these. (*Editors: The Western Australia farmers generally do not have ammonium polyphosphate [10-34-0] in the stream, since they are instead using MAP or DAP with their air drills. Oxide formulations of trace elements are not compatible with 10-34-0 in pressurized manifold systems [however, this mix isn't too problematic with Greendrop-type systems]. For compatibility with 10-34-0 in pressurized manifolds, use chelates or the carboxylic forms from Yara/Phosyn under their 'Pholex' tradename; ammoniated zinc chloride is also compatible.*) If you needed sulphur in the paddock, I would definitely prefer sulphate formulations in the liquid stream over oxides, or you can add a little ammonium sulphate to get 6 – 8 lbs S/acre. (*Editors: Acid-forming fertilizers can improve Zn and Mn uptake on most soils. Conversely, liming can induce Zn deficiency on soils that are borderline.*) Unless sulphur is adequate, attempting to apply copper or zinc will be rather useless. (*Editors: See Ray Ward's article on sulfur management in the Sept. '06* Leading Edge.)

Sources such as prilled zinc sulphate or manganese sulphate can be dissolved in water and mixed with most other liquid fertilisers (a jar test for compatibility is always prudent). However, copper sulphate is rarely used in a liquid form due to its highly corrosive properties. (*Editors: When mixing with 10-34-0, non-chelated zinc sources can only go in at about 1.8% concentration, maximum—this is approx 1 quart of 20% ammoniated zinc chloride in 3.5 gallons of 10-34-0. And orthophosphate, such as 9-18-3, cannot hold any zinc.*) And don't get caught up in the idea of putting zinc and copper treatments onto the seed; they are a waste of money (the rates are too little to have much effect). Molybdenum on the seed is a good practice, however, since the rate needed is so low.

Best regards, and happy farming!

Photo by Wayne Smith.

Listening to the plants can have a big payoff. Here, the crop nutrition and other agronomy were spot-on. The 570-acre paddock of canola yielded 2.7 t/ha (2400 lbs/a).

Table 4. Nutrient Deficiencies in Wheat, Barley, Oats

Nutrient	Visual Symptoms	Comments	Usual Time of Problem
Phosphorus (P)	Plants shorter. Bottom leaves dying back from tip. Top leaves darker green. Poor tillering and slow growth. Reddish/purplish tinge often seen in the dead leaf areas and base of stems.	Can only be fixed from 0 to 2-leaf stage. Dead tips are brown to slightly reddish tinge. Similar to K deficiency except K-def leaf dies back along the edges from the tip ('green arrow').	At the beginning, from germination to 1 – 2 leaves. Deficiency must be prevented (using fertiliser with the seed) since post-emerge fertilisers are too inefficient.
Nitrogen (N)	Bottom leaves dying from tip in a straight line, or dying first along midrib, and the dying area is white to yellow. Top leaves green.	The white to yellow ends of bottom leaves do not die (turn brown) initially as do most other deficiencies.	Any stage after 2d leaf.
Potassium (K)	Bottom leaves dying back from tip and along the edges of the leaf (green arrow effect). Has a reddish tinge on the dead leaf. Plants more prone to diseases and moisture stress.	Look for the green arrow on bottom leaves and reddish to orange tinge on the dead leaf areas.	Any stage after 2d leaf but rarely economic to fix after mid-tillering. Broadcast dry fertiliser to correct problem.
Sulphur (S)	Plants stunted and top leaves erect. Top leaves pale green to yellowish, bottom leaves darker green.	Hard to pick if other nutrients are also deficient. Some other deficiencies cause pale new leaves.	Any stage after 2d leaf. Gypsum or ammonium sulphate the best products.
Magnesium (Mg)	Deficiency is rare. Newest leaves can remain rolled and vertical. Some interveinal mottling of older leaves usually present.	Very rare to find this as an economic problem.	After mid-tillering.
Copper (Cu)	Top leaf tip dead and next leaf down is green to the end. Wilts easily. Dead tips are usually twisted. More prone to ergot and frost damage. Heads get stuck in the boot more often, awns twisted. Worse in high nitrogen situations.	Except for hard freezes, nothing else causes the top leaf to die and the next leaf down to be green to the end (early deficiency). Oats is the most sensitive cereal.	Best foliar responses will be at mid- to late-tillering. Plants must not be deficient from mid-tillering on, and especially at 2d-node and flowering stages.
Zinc (Zn)	Slow growing and poor tillering. Affected easily by herbicides and root diseases. Symptoms vary, but the common feature is dead lesions in the middle of the middle leaves.	Rarely textbook of two parallel dead lesions in the middle leaves. Varies between varieties, but look for dead spots in the middle of the middle leaves.	From sowing to tillering, but can still be a problem up to the flag-leaf stage and respond to a spray.
Manganese (Mn)	Severe: whole plants pale and floppy. Shortened internodes. Top leaf paler on its lower half than upper half, with some interveinal striping.	Plants will die in severe deficiencies.	Mid-tillering on. If you need to spray Mn by the tillering stage, you should spray again about 4 weeks later, even if no more symptoms are visible.
Molybdenum (Mo)	Very hard to pick. Look for slow response to N applications and grain not filling as well as expected (often confused with frost damage). Severe deficiencies show no response to nitrogen but look very nitrogen deficient. Top leaf tips can scorch similar to copper, but without the twisting.	Overdose of Mo will induce copper deficiency. Sunflowers are the best indicator plants if there is a Mo-def problem. *Can easily become toxic; do not apply unless you are certain this is the problem.*	Once thought to be vital only from germination to first few leaves, but has since been shown to be vital right up to grain-filling stage.
Boron (B)	Saw-tooth effect on edge of leaves. Poor grain filling. Brittle leaves.	Overrated deficiency. Very rare. Broadleaf species more likely to show deficiency than grasses. *Can easily become toxic; do not apply unless you are certain this is the problem.*	Mid-tillering on.

Author's Note: If you would like me to run some workshops on learning plant language techniques, please let me know. The next time I am in your neighbourhood, I would be more than happy to teach you. Also, I'm writing a book on plant language for winter and summer grain crops, and some general pasture species.

Editors' Note: Smith discusses crops grown in W. Australia, which don't include corn or soybeans, and very little sorghum. These crops also experience micronutrient deficiencies.

Observations:

Nutrient Deficiencies in Kansas Wheat

by Matt Hagny & Ray Ward

TECHNIQUE

Hagny is a consulting agronomist for no-till. Ward is a laboratory manager & soil scientist.

Our crop nutrition program has numerous problems, to say the least. We have been complacent, and (to some extent) led astray by the often-stated 'fact' that wheat is less likely to be responsive to some of the micronutrients than are the summer crops. One suspicion is that no-till possibly changes this in our climate, especially in certain crop sequences, due to those soils not having enough warmth (and time) to mineralize appreciable amounts of these nutrients from soil organic matter. This would be particularly true, for instance, for wheat following soybeans.

A related issue is the building of soil organic matter under well-managed no-till, which is itself a 'sink' for many nutrients (you get them back, just not right away—it is similar to having a retirement account with penalties for withdrawing early: the money is there, just not available to you at the moment unless you are willing to suffer losses to get it). Meanwhile, all these nutrients are being exported from the land as grain (or animal product) without replenishment, unless they are part of your fertilizer program. Eventually the soil cannot supply enough nutrients for the crop, and this happens regardless of tillage regime—converting long-tilled land to no-till simply advances the timeline a bit.

The article by Wayne Smith (see page 351) is an excellent primer for learning to diagnose plant nutritional deficiencies. As he has noted, symptoms vary in their expression due to climate and crop genetics, etc., so here we present a few photos to show Kansas wheat being afflicted by nutritional disorders. We would strongly encourage plant tissue analyses to confirm visual symptoms

Copper-deficient wheat in Kansas. The uppermost leaf is tipped, and rolls tightly. In the other photo, the head is distorted by copper deficiency. These occur over a wide area in Kansas. Freezes may get the blame, but weren't involved in either case.

Photos by Matt Hagny.

Photos by Matt Hagny.

Zinc-deficient wheat in Kansas (variety: Santa Fe) despite applications of zinc both in-furrow and broadcast pre-plant. The Kansas climate produces very slow-growing wheat as dormancy breaks in early spring, which may be the cause of Zn-deficiency symptoms a bit different than Smith describes. Note the overall paleness of the plant, that the leaves are less than half of normal size, and the leaves have a slight upward bending or abnormal curling (spiraling). A few leaves do have the classic dead band across the leaf (margin to margin) with the outer half of the leaf still alive and green, although probably not over one in 300 leaves in this area exhibits that symptom despite acute Zn deficiency (and no other deficiencies present). Later in the season, the plants are thin-stemmed and have narrower-than-normal leaves, with the pale green persisting. The classic dead bands mid-leaf become more prevalent by 2d-node and boot stages.

you may find in your crop, and that all information be taken together to arrive at an accurate diagnosis. Of course, the debate is ended when a nutrient is applied and the crop responds (either visually or in yield), although we must emphasize that lack of a response doesn't necessarily mean that the diagnosis was wrong (although that is certainly a possibility) but only that something else was preventing the plants from responding, such as other nutrient deficiencies, climate, diseases, and so forth.

In Kansas wheat, severe Cu deficiency early in the spring creates pale plants, often with unusual patterns across the field. Many of these symptoms are difficult to sort out in winter wheat in early spring; as the plants get more growth, the symptoms become more distinctive.

Cover Crop After Wheat

by Matt Hagny

No-till producers in the Plains region have long sought a cover crop to fill the lengthy non-crop period between harvest of wheat and the planting of the following milo or corn crop. A promising 'cocktail' of species for this use is canola + black (Indianhead) lentil. A similar ploy would be to use *winter* lentils (Indianhead lentils are a spring type), which have been developed with substantial winter-hardiness (they survive in northern S. Dakota typically). For instance, 'Morton' is a winter-hardy red lentil variety developed by USDA-ARS in Idaho and Washington.

Photo by Dan Forgey.

A canola + lentil cover-crop cocktail doing nicely in South Dakota.

In Kansas, lentils or lentil mixes for cover crop would be seeded in late August or early September, using a pea/lentil inoculant. (Seeding dates would be several weeks earlier in the Dakotas.) A few pounds per acre of canola (or turnip or radish) in the mix dramatically improves the canopy and weed suppression of the slow-growing lentil. Note that canola (and turnip and radish) require substantial sulfur nutrition for vigorous growth.

While cover crops improve nutrient cycling in general (see 'Field Ecosystems' in the March '06 *Leading Edge*), there is some initial delay while this material decomposes. Therefore, it is of extra importance that good fertilizer management be used in the following cash crop—any nutrient already marginally low can be exacerbated into a deficiency by adding cover crops or otherwise increasing the cropping intensity. But getting the plant nutrition right for the cash crops is something that needs to be done anyway to maximize profit.

Photo by Doug Palen.

A similar cocktail in Kansas, seeded after wheat harvest in preparation for the next year's milo.

Still More Opportunity

by Matt Hagny

The original story on Kodesh appeared in the March '02 issue.

Central Oklahoma no-tiller Tony Kodesh claims not to be doing anything new, yet his operation has morphed considerably in five years. One big addition is corn. Tony first tried corn on 130 acres in '02, which he hired planted. That went well enough that he kept adding acres—to 2,500 in corn in '06, and 3,300 in '07 (including 500 acres of irrigation). He bought a 12-row planter in '04, but still hires half his corn planted—his friend Gerald Boyer has an identical 12-row, and they run both planters together to get Tony's corn planted. Kodesh's dryland corn formula is a seeding rate of 19,000 using 98- to 110-day hybrids, with all the N streamed on during late winter, and a low rate of liquid fertilizer through the planter Keetons.

The '06 drought knocked Tony's corn yields (yet he had some that made 40 bu/a on 0.6 inches of in-season rain), but Kodesh has seen enough good years that his enthusiasm for the crop hasn't waned. Plus, he points to the strong price and improved insurance for corn in his county. Kodesh likes corn because he can get it in earlier than milo, which he hasn't grown since '02 (and very little in '02 & '01). Kodesh also likes the simplicity of weed control in RR corn, that birds don't bother it as with milo, and the insect control is largely done with *Bt* (on 80% of his acres) and seed treatments. He hasn't had any problem with aflatoxin in the grain, either. Kodesh has even done well with 2d-year corn, which held up in the '06 drought, and he has many acres of it in '07. On his big switch to corn: "I just kinda roll along with whatever is working," —but those who know Kodesh realize he puts some savvy thinking into those plans.

Meanwhile, Kodesh has cast aside cotton, and drastically reduced his full-season soybean program. "I have nothing against cotton," he says, "We did have one really good cotton crop a few years back." However, Kodesh likes to be on top of his harvesting, and hiring the cotton stripping wasn't satisfactory: "I guess I'm too particular about certain things," alluding that the job wasn't up to his expectations. Nor does owning cotton-harvesting equipment have much allure for Tony.

Kodesh explains the emphasis on corn while decreasing soybeans: "We needed corn to build up our residue levels, and to anchor it. I went from not having a warm-season grass in my rotation to having too much." He grows good wheat following corn, so all-in-all, corn fits his system fairly well, although he is looking to return to more full-season soybeans in the niche between corn and wheat. Currently, his primary rotation is wht /dc soys >>corn >>corn, but that is overly simplified, since he still has quite a bit of alfalfa.

A deluge of 10 inches of rain overnight on a field he just planted: "We didn't lose any soil."

One reason Kodesh is heavy on corn this year is that his wheat plantings in the fall of '06 were curtailed by dry weather. And since it was too dry to double-crop last summer, this gave him the opportunity to do more stacked wheat, which, he says, "Looks awesome." He further comments on how much better the no-till wheat in his area looks compared to the tilled fields: "The no-till held onto the scant moisture last fall." Kodesh even planted some wheat into live alfalfa late last fall, which proceeded to astonish him: "I don't know how it survived. But it's the most beautiful wheat I have right now."

In general though, Kodesh's intensive management of wheat has changed little: He uses Gaucho on all the seed, and the high rate where he predicts Hessian fly. Most of his wheat acres get fungicide at flag-leaf, depending on the year. One change he did make was going to 10-inch spacing when he traded his 1850 on an 1890 a couple years ago, and he's happy with the results: "There's less maintenance, and I have more weight per blade. I haven't seen any drop-off in yields . . . and no increase in weeds coming through the canopy."

Kodesh is pleased with advances in the condition of his no-till soils. A recent deluge dropped 10 inches of rain overnight on a field he had just planted to corn: "We didn't lose any soil," further explaining that he didn't move any residue with his row cleaners. He isn't sure the corn will make a stand in such soggy conditions, but breathes relief that at least his soil is intact—unlike some neighboring tilled fields. Kodesh keeps gaining rented land due to his care for the soil: "People are seeking us out because we're no-tilling." Healthy soils, healthy profits—Kodesh never stops his quest, commenting in his humble matter-of-fact style, "I just keep trying to improve."

Friendship & Synergy

by Matt Hagny

'Better together' is the message from Phillip Nelson and Randall Kaufman, whose skills and machinery lines complement each other's farming operations near Windom, KS. Indeed, the daily operations seem so fluid and seamless that an outside observer might have trouble accurately guessing who owns what. As Randall explains it, "We're comfortable with everyone working on each other's equipment. We're goal-oriented."

The businesses are separate—Nelson's 2,200 acres are distinct from Kaufman's 750 acres, and all the equipment is owned by either one operation or the other. Inputs are carefully tracked and assigned to the proper crop owner. Yet that's the extent of the worry about the ledger balance—field operations aren't billed to each other, nor does anyone track their time in working on anyone else's machinery or crops. Phillip notes, "We don't spend a lot of time counting the nickels [between us]." Phillip's dad, Verlyn, comments, "If everyone's content, well . . . good enough." Randall adds, "The family friendships are valuable," and have spanned decades.

Phillip explains the synergy further: "We each make our own management decisions, but we bounce a lot of ideas off one another. We work well together, and are very fortunate in that regard." He continues, "We've talked so many times about how lonely it would be doing a job by yourself." On which Randall reflects, "When you break down and you're by yourself, it's a downer." By pooling their labor, they're much more efficient and better able to cope with those issues.

Photo by Matt Hagny.

Nelson's milo stalks, with the previous wheat stubble visible. A reasonable mulch, but Nelsons and Kaufman get concerned if residue gets sparse.

A lot of the teamwork got started because Verlyn was best friends with Randall's older brother, and they did a lot of things together (Randall was just a kid at the time). Randall's older brother died young, but when Randall returned to the community in 1975 (after college, and work in Haiti and Mexico), he and Verlyn became close friends and did many things together, including their farming activities. Randall had an off-farm job during much of this time, and the late-'90s found him doing engineering work in Nebraska and subleasing his farmland to Phillip. They each bring different strengths to the table, with Randall's engineering and mechanical background, Phillip's logistical and managerial skills, and Verlyn's self-described (with a playful grin) "maturity and wisdom."

On going 100% no-till: "We wish we woulda done it ten years earlier."

No-Till, and New Vigor

Nelsons and Kaufman have a long history with no-till. Verlyn recalls no-tilling milo back into milo stubble in the early '70s with an IH runner planter—although the planting job wasn't pretty, Verlyn says the milo yielded alright. Randall also did some no-till milo for five consecutive years in the early '80s, initially with a Buffalo planter, and later an Allis-Chalmers planter. However, that field "had more intrusive weeds every year [under that monoculture]." Randall recollects, "Those were very good milo crops. And the soil in that field was by far the most mellow of any on the farm [due to 5 years of no-till]." Always one to push the limits, Randall later had the first cotton grown in McPherson County (at least since FSA record-keeping began, anyway).

Despite those early ventures, Kaufman & Nelsons didn't get all the pieces together for continuous no-till until

Photo by Jalane Nelson.

Another milo harvest for the Nelson & Kaufman team.

some years later. Randall says, "We just didn't have the machinery [effective no-till seeding equipment]," while Verlyn points out that Roundup was nearly $80/gallon in those days. As more tools became available, they watched as Randy Schwartz of Great Bend and a nearby neighbor, Joe Swanson, went 100% no-till—including selling off their tillage implements and big tractors. (See the stories on Schwartz and Swanson in the Dec. '01 and March '02 issues, respectively.) Phillip points out, "It was Dad who got this switch to no-till going. He said, 'I'm watching what Joe is doing, and it's working.' " They talked more to Joe, and Randy (they knew him from growing cotton, since he was also an early producer of the crop), to learn what they could. By '99, Randall was 100% no-till, and Nelsons by 2000.

On the conversion to continuous no-till, Randall comments: "We decided to go, and never went back [to revisit that decision]. We wish we woulda done it ten years earlier." Phillip sold his 350-hp tractor and assorted tillage implements in 2000, and that was that. Phillip bought a 15-ft JD 1560 drill that year, and off they went. Verlyn reflects, "The first 3 to 5 years were tough—the planting window was small. [The heavy stubble] was too wet," although he knew they were on the right track, and everyone was supportive of their direction, including his wife, Wanda. However, at least one of them has relished the adventure—Randall, engineer and problem-solver at heart, remarks simply, "It's been a fun challenge."

Crop Diversity Overload

Nelsons and Kaufman were already growing wheat, milo, and soybeans in rotation prior to going completely no-till, so no major changes were required there. However, given some of Swanson's crops at that time, in combination with more abundant rainfall in the late-'90s, they pushed into growing corn as well as extensive double-cropping, including with sunflowers. Phillip remarks, "If I had to do it over, I would not be so ambitious on crop rotations. I wouldn't have added corn as a 4th crop, and wouldn't have done double-crop sunflowers. This made it harder than it had to have been—learning new crops *and* new ways of doing things [under no-till]."

Kaufman and Nelsons soon dropped the corn as the drought progressed, and the dc sunflowers. They quit trying to double-crop every acre of wheat stubble, noting the workload crunch of needing to harvest every cropland acre in the fall, as well as seeding wheat. Phillip says, "We were overloading ourselves." Half the double-cropping went by the wayside as a natural consequence of doing second-year wheat. The other eligible acres for double-cropping after wheat harvest still may go to milo or soybeans, depending on the moisture—"It depends on the opportunities," says Phillip, referring to soil moisture and timeliness of wheat harvest. Phillip is leery of using too much moisture with the double-crop and affecting the next year's crop, which is a valid concern in recent dry years. On the other hand, Randall notes that double-cropping helps with timeliness of field operations the next year by extracting some extra moisture.

"Our disciplined or set rotation has evolved into something more fluid."

For Nelsons and Kaufman, the general crop series is now wheat >>wheat /(dc milo or soys) >>milo >>soybeans. They have considerable history with stacked milo; however, due to problems controlling ALS- and triazine-resistant Palmer pigweeds, they're dropping way back on milo acres (Phillip isn't convinced Lumax is sufficiently crop-safe to be the answer). They've done some stacked soybeans too, but are quick to point out the deficit of residue in that scenario—they have trouble keeping enough mulch anyway. Randall describes the change in their thinking on rotations: "Our disciplined or set rotation has evolved into something more fluid. Now, we feel free to change it to address, for instance, a weed problem."

Get It Done

When it comes to working together, Nelsons and Kaufman have a good system. Phillip's 15-ft drill does all the wheat (although they did lease a second 15-ft drill in the fall of '06), and Randall's 12-row White planter does all the milo. For soybeans, they run both the planter and the drill in the same field at the same time, although they block off runs on the drill to achieve 30-inch spacing with it. They prefer the wide rows primarily to get the pods up higher for harvesting, and to get tall enough plants to feed into the flex head. At one time, they drilled all their beans in 15-inch rows, and Phillip muses that going to all 30-inch spacing "might be a knee-jerk reaction to the beans being too short in the drought years." Phillip notes that newer flex heads may have enough improvements to solve the problems associated with gathering the 'vertically impaired' 15-inch droughted beans, but for now, this is what they're running, although Randall does see slightly more weeds in the 30-inch rows. Having done a number of tests to determine optimum plant populations, they now strive for a soybean seed drop of 100,000 for both the planter and drill (with final stands of about 80,000), and milo at 34,000 seeds/a.

"With no-till, we're stopping the destruction of the soil."

Randall and Phillip each have their own combine and grain cart, but they run them together. Randall explains that the efficiency of harvesting together was what got them teamed up 20 years ago: "When you run two combines together, then you can use a semi [to haul]." Phillip's sister, Cheri, supplies additional help at harvest time.

Good maintenance allows them to stay lean on their machinery, running older C-IH combines and harvesting all their crops with a pair of 25-ft flex heads. Randall's planter is now 12 years old, too, although they all agree that it's a better machine now than when they bought it, due to frame reinforcements and a variety of other improvements, such as Keetons with Mojo Wires, and spoked closing wheels. However, they don't run any row cleaners.

Nelsons and Kaufman each own a spray rig as well, although again with complementary attributes. Phillip's Lor-Al floater handles high volume easily, such as streaming N on wheat in March, although they use it for low-gallonage glyphosate work as well. For some tasks, it covers both Phillip's and Randall's acres of that crop. Randall's sprayer is better suited to post-emerge work, and so it gets more of those jobs. "We talk to each other before we trade equipment," says Randall, "We try not to duplicate."

A gallonage meter on the planter lets Kaufman and Nelson keep track of fertilizer usage precisely, and properly allot it to the crop owner (all fertilizer for the milo is put down with the planter via 3x0 openers). Diesel, seed, and other inputs are all accounted, but for labor and field operations, Randall says, "We're close enough." As far as which fields get done first, he says, "When we lay out our planting and harvesting sequence, we try to be fair to landlords and to each other." With a 30-mile spread, some give-and-take is certainly necessary to keep the jockeying to a minimum. Phillip also cites the value of getting a tract all into one crop, or two at the most, commenting that landlords aren't so nervous about that after seeing better yield stability with no-till.

Furthering their efficiency, the Kaufman and Nelson operations use a CropQuest consultant on their milo and wheat, and Cheri checks the soybeans (she worked for Collingwood's agronomy dept. at one time). Phillip remarks, "When we're not planting or harvesting, we're doing something else. There aren't enough hours in the day to scout everything and do everything else." He cites examples of benefits of timely scouting that he wouldn't have accomplished himself, and Randall concurs.

Photo by Matt Hagny.

A bit of added crop diversity for Nelsons is alfalfa. Here, the alfalfa has been terminated (mostly) and a vigorous wheat crop coming on.

Photo by Randall Kaufman.

Phillip drilling soybeans into Randall's killed pasture sod.

The Payoffs

Results? Randall says, "There are years when we've really seen the value of moisture savings. . . . There are instances where we've had crops and the conventional-tiller across the fence didn't get anything. Just last year, we had a milo field that made 78 bu/a, and a tillage field just a half-mile away only made 7." Verlyn interjects, "And they were the same hybrid! —I know, because I sold them the seed."

Continuing the discussion of results, Randall comments, "Occasionally the conventional-tillage guys outyield us in wheat. But I don't know that they out-bottom-line us." Wanda remarks, "The conventional-tillage wheat may look better early, but the no-till wheat [yields just as well]." Phillip observes, "There's probably more benefit [to no-till] in rougher land. The yields aren't so far apart anymore [between good soils and thinner ones]."

Verlyn enthuses that no-till put an end to their bindweed problem, and several other troublesome species. Phillip and Randall are amazed at their soil structure, and that they never make a track with the combine anymore, even if the tillage neighbors can't even run on account of mud.

Phillip comments that what's great about no-till is taking care of the land, and "making it better for the next generation," which includes Phillip's three sons, eager to be a part of the farming operation—at ages 4, 6, and 11. Phillip continues, "With no-till, we're stopping the destruction of the soil." Verlyn, reflecting from the vantage of the previous generation, says unequivocally, "No question—we would never go back to tillage."

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