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No·till On The Plains

Rising to the Challenge

by Andy Holzwarth

Today, in driving through the Gettysburg, SD area, you would have to drive a long time to find a field that is left uncovered with crop residue. However, back in the Eighties, burying residue was the norm. What pushed a couple of counties in north-central S. Dakota to 80 or 90% no-till? —some creative farm operators taking things into their own hands, challenging each other's minds, and, of course, competing for land.

One of those well-managed farms is owned by Mike & Monte Cronin, whose good business sense opened the way for the flourishing of the skills of Dan Forgey, manager of Cronin Farms west of Gettysburg, SD. Thirty years ago, Forgey was 'merely' a hired man on the grain and cattle operation run by Mike & Monte's dad, who at that time also owned a feed mill / grain elevator in Gettysburg. Profits from these eventually gave rise to investments in John Deere dealerships in the early '90s. As you can imagine, Mike and Monte had their hands full with the various business activities vying for their attention, so they decided to reallocate personnel and appointed Forgey as their farm manager. Dan is charged with seeing to it that the farm is a profitable enterprise, and he gets paid a portion of the profits, so he really pays attention!

The last 15 years have been a whirlwind of change for Forgey. They went from being 25% summerfallow to having none. And from using 4 people and 3 tractors (totaling 525 hp) to farm about 5,600 acres, to needing only 2 people and one 250-hp tractor to crop over 8,600 acres (and adding another 600 for '06). While cropped acres shot up, labor and capital being used were shrinking, and field operations were becoming much more precise. The

Photo by Dan Forgey.

Dan Forgey raves about field peas in his rotation.

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efficiencies are primarily due to the time gained from not doing tillage, and also from the extra seeding and harvesting windows provided by crop diversity, now at 11 crops. And Dan acts like it's much more pleasant with their current system of farming.

> **"When we got that 4-year rotation, we thought we had it made—we could do this forever." Well, not quite.**

Not Obvious at the Time

Where did this change come from? Dan explains, "It's all from Beck. He just keeps feeding us these ideas—he's that far ahead." It all started in 1990, at a District 6 Irrigators' meeting at Bob's Steakhouse: "Beck gave a presentation, and said how we could be doing everything with no-till. Everyone at the meeting was chuckling—except Ralph [Holzwarth]. I'll never forget, a few days later I was talking with [another prominent local farmer who] said it was pretty unbelievable that you could sell your chisels and discs and just own a no-till drill." (*Editors: Ralph Holzwarth's story was the cover of the Sept. '04 issue.*)

Mike & Monte's dad had known Beck for over a decade already at that point (Beck actually taught at Gettysburg High School at one time), and thought enough of the research Beck had done on their farm that he didn't discard the idea. Cronins tried some dryland no-till corn into wheat stubble in '91, and things really accelerated after that. They were 100% no-till by '93.

In 1990, Cronin Farms was about 50% wheat and some mix of corn and sunflowers on another 25% of their acres, for a pattern of w.wht >>s.wht >>summer crop >>summerfallow, although: "We didn't really have a rotation." Forgey describes their first steps trying to figure out the rotation for no-till: "We were planting spring wheat into corn stalks. We did some silly things back then. Scab got us. We didn't know what we were doing. I just shudder when I think about those years." In '94, they put sunflowers into corn stalks for the first time. "We didn't think two long-season [summer] crops in a row would work. We were really struggling." By '96, all their flowers went behind corn, for a s.wht >>w.wht >>corn >>flower rotation with no summerfallow. Dan says, "Eighty percent of Potter and Sully counties are now in this rotation." He further notes his own mistake, "When we got that 4-year rotation, we thought we had it made—we could do this forever. We didn't have to listen to Beck anymore."

That was short-lived. Forgey explains, "The cheatgrass blew up. By '99, we knew that rotation wasn't going to work.

Photo by Dan Forgey

Quite a bit of 'cheatgrass' seed can survive two years of lying on top of the soil in the Dakotas. Here, the cheatgrass (downy brome) has emerged in one of Cronins' fields that's been in corn two years already. Neither the weed seeds nor the crop residue decompose as quickly in the Dakotas as they do in Kansas or Oklahoma. Forgey designs his rotations accordingly.

Leading Edge

No·till On The Plains

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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.

So we went to three years out [of wheat].” Which they accomplished by stacking the corn (second-year corn), a method that had them really nervous since they thought they didn’t have enough moisture (it’s been working out, with stacked corn within 8 – 10 bu/a of corn after w.wht). They’d also been doing some soybeans instead of sunflowers in the rotation, and they sometimes stacked those as well, but Forgey doesn’t like what two broadleaf crops in a row do to the soil. In fact, while Dan considers soybeans to be “more enjoyable to grow” than flowers, soybeans have not been as profitable for them. The three years out of wheat did let them get a handle on cheatgrass, and also breaks up root disease cycles.

“I make rotational decisions in July, based on weed pressure.”

Forgey has been working with field peas for the last 4 years, and raves about how well they fit in the rotation: “Any crop I grow does well after field peas.” The peas stop using moisture at about the same time wheat does, while fixing some N and making the soil mellow for planting the next crop. Improved pea varieties have really opened up possibilities for them, and Forgey describes how well the peas are working in their feedlot and stock-cow rations. With peas, Forgey added several more rotations, including s.wheat >>pea >>corn >>flowers, as well as w.wht >>corn >>corn >>pea. Another one that excites Dan is a simple w.wht >>corn >>pea. These are designed to “clean up the cheatgrass” since they’re only 1/3 to 1/4 wheat.


Photo by Dan Forgey.

Big spring wheat yields demand stand density and vigor such as Forgey has achieved here in sunflower stalks, a common crop sequence for them. Note the abundance of corn stalks from crops prior to the sunflowers.

Isn’t this going backwards, to shorter rotations? Perhaps, although Forgey explains, “A field isn’t going to be in a rotation forever. I make rotational decisions in July, mostly based on weed pressure—with some consideration of residue levels and fertility, but mostly weed pressure. A lot of people think they’ve got this [cheatgrass] problem solved with Olympus. We tried to do that with Maverick, and it didn’t solve the problem. Cheatgrass is a huge issue for us—we don’t want to be consistent with our rotations, or the cheatgrass will figure it out.” During the 2 or 3 years out of wheat, they work diligently to keep the cheatgrass from going to seed, and have stopped using in-crop herbicides to control it in the wheat—Dan dislikes the rotational inflexibility that comes with long-residual herbicides.

The Fire of Ingenuity

Rotations weren’t the only thing to evolve rapidly during the last 15 years on Cronin Farms. They’ve also been challenging long-held concepts about seeding and fertilizing methods.


Photo by Dan Forgey.

Timely spraying is one of Forgey’s ‘standard operating procedures.’

In ’94, Forgey decided they needed to put all their N fertilizer in the ground. They built an anhydrous rig from an old duckfoot (chisel plow) frame, and this NH_3 rig was used till 2000. “I didn’t like the anhydrous opener—it was moving too much dirt.” While they seriously considered low-disturbance methods for NH_3, ultimately they decided to go to urea applied with their air cart. “By that point, we only had one tractor. I couldn’t afford to make a $5 – 6/a pass just to apply anhydrous. Rotations and cattle got in the way—we just never had time to apply it in the fall, and in the spring you should be planting.” Efficiency dictated the outcome.

Several things allowed Forgey to move to putting all the N on at planting. First was the decision to pull the air cart behind the planter, which a number of Dakota producers are now doing. “We took a $68,000 cart and put it behind *two* pieces of machinery [the planter and the drill]. That’s huge.” The second piece of the puzzle came with Deere’s introduction of the 1895 air drill in ’02, with its separate rank of mid-row banding openers to place urea between every other row of wheat (seed openers on 10-inch spacing, and fertilizer openers on 20-inch). Cronins bought one that year.

Cronin Farms traded planters for '05, and again had to do some engineering to put low-disturbance single-disc dry fertilizer openers under a narrow-fold 30-inch 1770 CCS planter. Now all their neighbors are doing the same. For corn, the air cart supplies a light rate of pop-up fertilizer in-furrow, and also the total urea needs through the openers 3 inches away from the row, at the same depth as the seed (3x0). Sunflowers are seeded the same way.

Forgey has also been pushing the management for wheat, starting with fertility. In '99, they began extensive soil sampling (every field every year, tracking the sampling locations with GPS), and made the decision to build soil test P levels into the medium range. It took 6 years to build the soil test P levels. The P (11-52-0) was placed with the wheat seed with the drill, in an attempt to get the P into the ground and into bands instead of broadcast. They elected to build with the 10-inch bands with the drill versus the 30-inch with the planter so that P would be more dispersed horizontally in the soil for seedling root access by all crop types. During these years, Cronins chose to build soil P levels instead of spending extra cash on land purchases.

Photo by Dan Forgey.

Winter wheat survivability is improved by standing stubble, a known trick of Dakota no-till producers.

For both spring and winter wheat, 80 – 100% of the N is applied at planting.

"The organic matter is working for you."

Forgey has done lots of testing with N placement and timing on wheat, including working with several SDSU researchers. Forgey strives to keep protein up on both winter and spring wheat to capture premiums, and this often requires some stream-bar applications of liquid N at boot stage. However, they aren't able to do all the acres, and are wondering if poly-coated urea at planting might do the same thing for them. More research.

Wheat goes in at around 1.5 million seeds/acre, and Forgey uses N rates based on 2.2 lbs of N per bushel, with yield goals of 60 bu/a for winter wheat and 50 bu/a for spring wheat (actual 5-year averages for them are 58 and 49 for those crops). With favorable weather and good management, winter wheat in their area can yield up to 100+ bu/a, which is enough of a mystery for Forgey to comment: "It's the soil doing it. Hard to explain—the organic matter is working for you." Wheat yields are up 24% compared to their "pre-no-till" era.

Long-term no-till, good rotations, and heavy residue also led to phenomenal corn yields, averaging 116 bu/a over the last 5 years, and most of those years were actually drier than normal. Forgey is amazed at the yields, never having dreamed it possible in the tillage days. And he's really puzzled at the drought tolerance. In 2005, their last rain for the summer was the 3d of July on 14-inch-tall corn, and by August, "We thought we'd lost the crop. But it ended up making 117 bu/a. Even the second-year corn averaged 106, and sunflowers following two corn crops made 2100 lbs/a." (Their 5-year average on flowers is 2400 lbs/a, up 25% from the "pre-no-till" years.) Something similar happened in 2003, and the whole thing has Forgey perplexed. Apparently they've made some real progress in soil condition and general plant health.

Forward-looking Strategies

When asked about the future direction of the farm, Dan directs his comments towards figuring out how to use various cover crops efficiently in an attempt to manage soil water, and to increase plant health and soil organic matter. That they've gone from 25% summerfallow in the tillage days, to 50% summer crops with zero fallow, to even *thinking* about using cover crops is a testament to what they've accomplished with their soils. He acts a bit sheepish about not having done anything with cover crops, but who would have ever thought it possible in his area without irrigation?

"Sure, it looks like a no-brainer now, but the first 4 or 5 years of no-till, you really wonder."

Dan is contemplating mixing in hairy vetch when planting field peas, and would then chop the peas for forage and let the vetch come back. (Their cow/calf operation and 500-head feedlot make use of plenty of feed.) He also would like to try an oats + vetch mix, taking the oats for hay. Forgey wonders about Indianhead lentils behind wheat that would go to corn the next year, thinking he has more water than he needs (and his area averages only 17 inches of precipitation annually!).

Cronins also have some pivots by the river (Oahe Reservoir), which were in a corn >>soybean rotation for a long time. When the water levels got too low to irrigate, Forgey had the idea to plant wheat there, which really yielded well due to the complete absence of wheat in those fields for decades. This taught him something about long rotations, and now he says there's "no question" they'll have small grains in the rotation under the pivots even when they resume being able to actually irrigate. When they are able to irrigate again, Dan thinks flying radishes into the corn is a must-try.

Just as Dan finishes speaking about cover crops, he launches a discussion on variable-rate fertilizer applications that he's been doing, including various in-crop sensing technologies. As you can see, the decision about no-tilling has been made and there is no going back. Dan has moved on towards improving soils with cover crops and into reducing inputs with variable-rate applications.

Other experiments had Forgey trying what "the Hefty boys" (Hefty Seed Co.) were pushing—a Brillion zone-till operation. Forgey tried it in a couple fields on 10 acres each: "It cost us 3 bu/a in our corn. And it really tore up the soil. *No way* would you want to do that to your land," Forgey comments, shocked that he or anyone else would do such a thing.

Photo by Dan Forgey.

Cronin Farms' abundant stubble from 2 years of corn, ready for sunflowers the next season. Forgey is quite the rotational architect.

Forgey again marvels at the progress in their own capabilities: "Sure, it looks like a no-brainer now, but the first 4 or 5 years of no-till, you really wonder what you're doing. When we started no-till, we didn't know anything about spraying—we hired all of it done." He got up to speed rather quickly, and now is quite knowledgeable in many areas of agronomy. Dan is excellent at observing his crops, understanding the soil and rotations, and how to make a profit from them. Upon speaking with Dan, you cannot help but be overcome with his passion for farming efficiency and for sustainable land management. Dan is the type of person who is always learning. When you walk through a field with him, he is always looking, learning, and asking intelligent questions. When querying Dan on the reasons for something, both agronomics and economics are always driving his answer. Decisions are both detail-oriented but strategic in scope, making it an incredibly woven-together operation. And Forgey has such respect for the land: "I'm just excited at what the soil can do for us," although he doesn't expect most people to understand—it took him 15 years of study to get his mind wrapped around rotations for plant health, and how the soils behaved when managed to this degree.

On zone-till: "*No way* would you want to do that to your land."

Photo by Dan Forgey.

This corn crop is ready for harvest, and was planted into pea stubble—the wheat stubble visible is from prior to the peas. The visible pieces of corn stalks are older yet, creating a wonderful duff layer to feed the soil. Of his gains in soil organic matter test levels, Forgey says, "I'm just tickled."

It has often been said that necessity is the root of all ingenuity. Historically speaking, ingenuity drives success and profits. Creativity, foresight, and diligence are paying off for Dan Forgey and Cronin Farms. When questioned on the subject of profitability of their current system over the last decade as compared to their past tillage history, Forgey pauses for a moment, then says, "Our returns have been easily 30% higher." Forgey cautions against chasing short-term profits by altering rotations in response to fluctuations of grain markets, preferring a look-ahead strategy, and taking care of the land—"In the end, it all works out."

Roots: The 'Foundation' of Crop Plants

by Richard Waldren

SCIENCE

Richard (Rick) Waldren is an agronomist and professor at Univ. Neb.-Lincoln.

Roots are one of the main organs of the crop plant, but are the least conspicuous and often do not receive the attention they deserve. Much less effort has been directed toward the study of growth and physiology of roots than to the stems and leaves above the ground. This is partly because conducting studies of roots in the soil is difficult and awkward. To remove all or even a part of the root system for observation or measurement destroys some of the root system and alters the soil environment. However, crop producers and researchers are becoming increasingly aware of the importance of the root system and the root environment as primary factors controlling crop growth and subsequent yield.

The physiological functions of roots are most commonly studied in water or sand cultures in a greenhouse or growth chamber. Although these studies are carefully conducted, the results must be applied to soil and field conditions with caution.

Photo by Dirceu Gassen, Cooplantio.

A corn seedling developing normally in a no-till soil. By the time you see the shoot, the roots have already spread considerably. Note the 'crown' (nodal) roots beginning to develop from the stem tissue above the seed, which will become the dominant portion of the root system in a few weeks.

Root Structure & Growth

In any explanation of root growth, the structure most commonly shown and discussed is the root tip. The root tip and its structure are emphasized because root growth originates in this area and nearly all of the absorption activity occurs at the root tip region, which extends from the tip itself through the region of root hairs. Although this region probably represents less than one percent of the total root mass, there are hundreds of thousands of root tips in the total root system and the metabolic activity that occurs in this region determines the growth and development of the entire plant.

Roots do not sense the location of favorable temperatures or moisture and grow to it. Instead, during the course of normal growth patterns, roots encounter favorable environments and respond by proliferating in those zones.

The root structure develops in the following manner. An apical (as in 'apex,' or outermost point) meristem is at the tip of the root. In this meristematic region, cells divide rapidly. Forward of this meristematic region is the root cap that is continually regenerated by new cells from the meristematic region. The root cap protects the rest of the root tip as it grows through the soil. The cells of the root cap are continually sloughed off as the root tip is pushed through the soil by the cell division and elongation immediately behind the cap. This sloughing of root cap cells deposits a microscopically thin gelatinous coating on the adjacent soil particles, which eases root growth through the soil. It is estimated that this sloughing of root cap cells plus other root secretions (exudates) may use 20 to 30% of the plant's carbohydrates (sugars) produced during photosynthesis.

Other cells produced in the meristematic region develop into other root tissues. The root grows some by cell division, but the primary region of root extension, that is, increases in length, occurs directly behind the meristematic region in the elongation zone. In this region, cells enlarge, primarily lengthwise, to push the root tip through the soil. This region of elongation varies in length from about 1 mm in timothy to 10 mm (0.39 inch) in corn. Although some absorption of water and nutrients occurs in this region, the primary function is root elongation, as roots increase in length only in this region.

Behind the zone of elongation, the root gradually changes into a differentiation zone where the cells begin to develop into various tissues. In this region, many epidermal (outer) cells produce lateral extensions called root hairs. The root hairs do not form until the cells in that part of the root have ceased elongation. Any further elongation in that region would shear off the fragile root hairs.

Root growth is opportunistic, taking the path of least resistance, meandering in response to the small-scale arrangement of soil components.

The number of root hairs is enormous, with as many as 200 root hairs per square millimeter of root. These root hairs grow rapidly and reach full size in a few hours. It is estimated that root hairs increase the absorption surface area of roots by 20 to 30 times. Crop plants could not absorb adequate amounts of water and nutrients for rapid growth if root hairs did not exist.

In the maturation zone, cells become more specialized in function, and tissue formation is completed. The outermost row of cells develops into the epidermis that protects the root. Once the epidermis matures it no longer absorbs water and nutrients. Inside the epidermis, the cells differentiate into vascular (transport) tissues, with the xylem conducting water and nutrients up to the stems and leaves, and phloem moving materials (mostly sugars from photosynthesis) downward and out to the root tips.

Root Systems

The type of root system, classified as either 'taproot' or 'fibrous,' is determined genetically. When a seedling's primary root continues to grow and develop and becomes the central part of the root system, the plant is said to have a taproot system. This large central root may exhibit considerable branching as with soybean and alfalfa, or only a slight amount as with sugarbeet or turnip. Taproots can grow very deep in the soil, especially with perennial crops such as alfalfa. Most legumes and other non-grass crop plants have taproots.


Photo by Steve Groff

Example of a taproot, in this case Steve Groff's forage radish. Here, the thick part of the taproot is over 30 inches deep, and finer roots go far deeper. Root growth and absorption occur only in tiny areas at the root tips. Microscopic root hairs (extensions of single cells) increase the absorption surface of roots by 20 to 30 times.

A fibrous root system has no main central root from which all other roots originate. Instead, there are many roots originating from the plant, all of which are about the same size. A fibrous root system develops when the primary root is supplemented by many adventitious (from stem tissue) roots, which originate from the mesocotyl or 'crown' region that forms above the seed. All grasses have a fibrous root system. Fibrous roots do not usually grow as deep as taproots, but are often more thoroughly distributed in the soil. Taproot systems generally can absorb water and nutrients from deeper in the soil, but fibrous root systems can often absorb more water and nutrients within the root zone. Thus, each system has its advantages.

Besides the species differences in rooting patterns and root surface area, there are also great varietal differences within species. For instance, plant breeders have developed corn hybrids with rapid root growth to overcome corn rootworm feeding. Varieties selected for drought tolerance are highly branched and develop a large root volume.

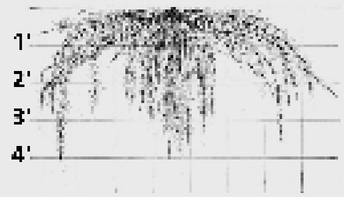
Functions of Roots

Although the patterns of root growth vary from crop to crop, the major functions of roots are the same for all plants. Roots primarily function to absorb water and nutrients from the soil and to support and anchor the plant. However, roots also have other important roles such as carbohydrate storage for regrowth.

Roots are the plant's contact with the soil and must absorb the water and nutrients necessary for plant growth. Since practically all of the absorption occurs at the root tip (primarily through the root hairs), roots must continually grow into new soil areas to contact soil water and plant nutrients. When the topsoil is moistened from rain or irrigation, new roots must grow into the moistened zone. The old roots existing in this zone cannot absorb the water or nutrients but instead send out new branches with new root tips. When the soil water is depleted in the newly moistened zone, the plant will allow those branch roots to die, only to be replaced the next time the topsoil is moistened.

Typical corn root system at V6, approximately when ear size is being determined. Note the extensive root exploration.

Roots do not grow toward water and nutrients. Instead, as roots grow, they encounter these materials. Water is held in very small pores in the soil. Nutrients are dissolved in the soil water in very low concentrations, which roots can absorb. As this occurs, more nutrients dissolve into the soil water from the surface of soil particles and organic matter, where the nutrients were *ad*sorbed (held). These nutrients are not accessible by roots until dissolved in the soil water.



Corn at 4-foot height (~ V10), during maximum growth and nutrient uptake. With this much root exploration, why would we think that nutrients must be placed in a certain location for efficient uptake?

The actual mechanism by which nutrients enter the root is complex and not well understood. A nutrient molecule must pass through the cell membrane of the root hair (remember, the root hair is an extension of a *single cell*), which involves both physical and chemical processes. It involves a combination of ion exchange with attachment of the nutrient molecule to a carrier that moves it across the membrane. In this way, the plant controls uptake of various nutrients.

Crop	Type of Root System	Maximum Depth of Roots (ft)	Lateral Spread (radius, inches)
Winter Wheat	Fibrous	7	8
Spring Oats	Fibrous	6	8
Spring Wheat	Fibrous	5	6
Corn	Fibrous	7	40
Sorghum	Fibrous	7	36
Cotton	Tap	10	38
Soybean	Tap	6	24
Sunflower	Tap	10	60
Blue grama	Fibrous	6	18
Big bluestem	Fibrous	9	14
Alfalfa	Tap	25	24

Table 1. Typical distribution of roots of common crop plants grown without substantial competition from nearby plants, and without root-restrictive soils. Environment and variety can cause significant departures from these values.

Nutrients meet the root surface for absorption by one of three mechanisms (or some combination). Although some examples are given for each mechanism, any nutrient can come into contact with the root using any of the three ways. All three processes are continually active in the soil during nutrient uptake. "Mass flow" accounts for about 80% of the contact between roots and nutrients. Roots exert a tension on the soil water to draw it out of the soil pores. With mass flow, the nutrients are dissolved in the soil water and move with the water as it is drawn to the roots. Most of the plant's nitrogen and sulfur are absorbed in this manner.

The second mechanism by which roots contact soil nutrients is diffusion. Diffusion is a natural process in which molecules will move from an area of higher concentration to an area of lower concentration. As the roots preferentially absorb a nutrient and remove it from the soil solution, the concentration of that nutrient will become lower. More molecules of the nutrient will then move or diffuse toward the root surface. Much of the phosphorus and potassium, which are attached to soil clays and organic matter, move toward the root by diffusion.

Looseness to our eyes can be very misleading as to what is encountered by microscopic root tips. Likewise, penetrometers generally do not provide accurate representations of factors affecting root development.

Root interception is the third mechanism that enables roots to contact nutrients. In this method, the roots simply encounter the nutrients as they grow through the soil pores. Most of the calcium, magnesium, and molybdenum are taken up in this way.

Nutrient uptake, especially phosphorus and micronutrients, is enhanced in many crops by the symbiotic relationship between roots and mycorrhizal fungi living on the root surface. This occurs to a greater extent when nutrient levels are low. The mycorrhizae colonize the root and grow filaments, called hyphae, into the surrounding soil that absorb nutrients and make them available to the root. Mycorrhizae obtain sugars from the plant root to sustain themselves. Mycorrhizae populations diminish considerably in the absence of plants for long periods of time (e.g., fallow), or if tillage is done. Not all plant species or varieties are hosts to mycorrhizae.

Extent of Root Growth

The root system of annual crop plants totals at least one-third to one-fourth of the total dry weight produced. Some researchers estimate that the belowground dry weight production is actually equal to the aboveground portion but is not measured accurately in root studies since many small branch roots and root hairs are lost during removal from the soil. The root *surface area* is 20 to 30 times greater than the leaf and stem surface area, and if total root hair area could be included, the surface area is probably 100 times greater. The total root system represents a large surface area in intimate contact with the soil environment.

Knowledge of the root growth pattern and area of penetration at various growth stages can be useful in managing the crop. In some instances, it can be important to place the fertilizer where root growth occurs, especially if insufficient time is available to allow movement of surface-applied nutrients into the soil. Root growth patterns can also be enlightening when deciding crop adaptation to soil depth, rotations, etc.

Root growth is both downward and horizontal, and is influenced primarily by crop species, soil water, soil temperature, soil aeration, and soil depth. Crops with a taproot system usually penetrate deeper but have less lateral spread than crops with a fibrous root system. Crops grown under light and frequent irrigations (not a recommended production practice) will have a higher percentage of their roots in the upper root zone. Rain-fed crop roots may penetrate deeper into the soil as water near the surface is exhausted, although overall root growth will ultimately be curtailed by lack of photosynthate (sugars) as water becomes limiting.

Fall-seeded small grains penetrate 30 to 40% deeper into the soil than spring-seeded small grains. Although this is partially a genetic influence, it is also due to the longer growing season available to winter annuals. Sorghum and corn appear to have the same general pattern of root growth, but sorghum produces smaller diameter roots and the total number of roots in a given soil volume is greater. This undoubtedly contributes to the greater drought tolerance of sorghum compared to corn, and the ability of sorghum to produce equivalent yields with less applied nitrogen fertilizer. (*Editors' Note: The apparent drought tolerance of sorghum compared to corn is also due to heat tolerance, and ability of the plant to slow its life cycle under dry conditions.*)

Deep tillage to fracture clay pans or previous tillage layers has not resulted in lasting improvement of root growth in most agricultural soils.


Photo by Dirceu Gassen, Cooplantio.

Residue must cover the soil to preserve the structure, but this mulch also allows roots to grow in the favorable zone created very near the surface. When crops are established, if soil cover is good, one can often peel back the thatch and duff to reveal roots at the soil surface. Roots grow wherever moisture and other conditions allow.

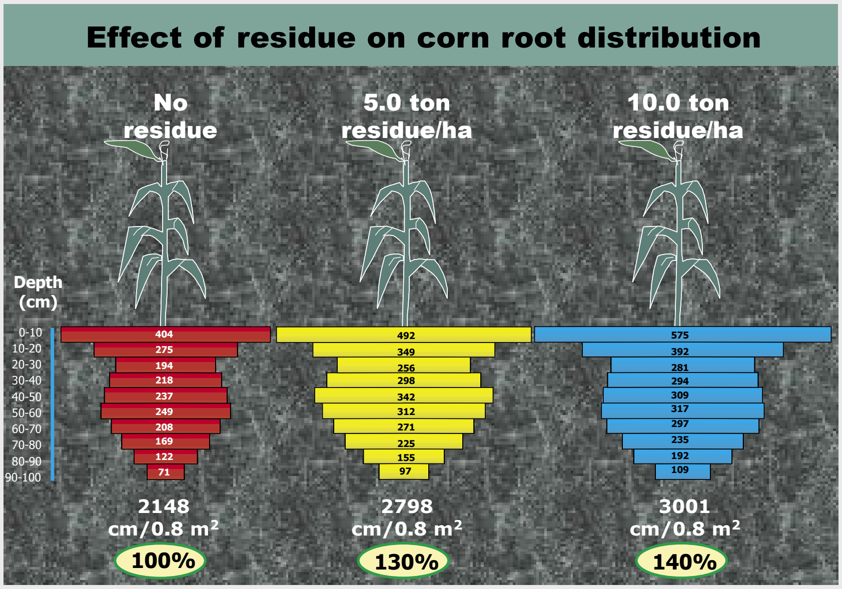
Root Responses to Environment

Root growth is directly influenced by the root/soil environment and indirectly by the factors which influence the growth of the entire plant. Energy for seedling root growth is initially derived from the seed. However, the energy source for expanded and continued root growth is the sugar produced by photosynthesis in the leaves and translocated to the roots.

Root growth responds to certain environmental conditions and these responses have been labeled tropisms. Experiments show that roots grow toward the pull of gravity and away from light, and these responses are caused by redistributions of plant growth hormones. Roots will grow more rapidly and proliferate in favorable temperature environments. Roots also grow more rapidly in a favorable moisture environment. Roots do *not* sense the location of a favorable temperature and/or moisture environment and grow to it. Instead, during the course of their normal growth patterns, roots encounter favorable environments and respond by increasing their growth rate and proliferating in the favorable zones.

Most crop roots can grow in soils within the range of -1/3 bar (wet) to -15 bars (dry) of “soil water potential” (moisture content).[1] One bar is equal to 14.5 psi. At potentials less than -15 bars, the soil is too dry for root growth. In water-saturated soil (<-1/3 bar), soil aeration is too low for root growth, since the roots ‘breathe’ in oxygen (required for deriving energy from the carbohydrates) and excrete CO_2 as a waste product. Poorly drained soils with a high water table or which otherwise contain excessive water will restrict root growth due to limitations on root respiration. Conversely, excessively drained soils can limit root growth because soil water is lacking.

Crop roots will not grow into or through dry soil to reach moist soil because there is no water to elongate the cells in the root tip. Root tips must continually grow into moist soil zones to absorb the water needed for cell elongation and metabolic processes. Once the water in a given soil volume has been depleted, it must be replenished by precipitation or irrigation before renewed root growth occurs in that area.



High residue levels can improve root growth. The site had been no-till for 6 years prior to this study, and the soil cover variable was created by removing the straw (5 t/ha) from plots (now 0 t/ha) and placing it onto others to create 10 t/ha of cover. So all plots were no-tillage, only the residue level varied. Results are averages from 13 hybrids. Soil is in an area originally a subtropical prairie, near Ponta Grossa, Paraná, Brazil, with soil classified as an oxisol (Dark Red Latosol) with clayey texture and considered to have good structure. Conducted by João Carlos (Juca) Sá.

Water availability (amount of infiltrated water, minus evaporation) greatly influences rooting patterns. As Table 2 shows, when moisture is limiting, rooting depth decreases and the lateral spread of roots increases. Roots spread farther laterally to absorb all of the limited water supply (until nearby plants begin affecting root growth by having already extracted most of the soil water). They do not penetrate as deeply because the soil does not get moistened very deep, and because photosynthate often becomes limiting in these conditions.

Since water and nutrients are absorbed from the areas where they occur, the zone of greatest root activity and greatest absorption is usually in the upper layers of the soil. An annual crop with an effective rooting depth of 6 feet generally would have about 70% of its root mass in the top 3 feet of the soil. Although only 30% of the absorption might occur below 3 feet, this extra supply of water and nutrients can be very important to the plant if conditions are favorable for root growth at that depth.

Precipitation	Rooting Depth (inches)	Lateral Spread (radius, inches)	Plant Height (inches)
High	60	12	40
Medium	48	20	36
Low	24	24	26

Table 2. Influence of precipitation on root growth of winter wheat. Shallower rooting in drier conditions is due to soil not being moistened at depth. Again, this is with relatively little competition from nearby vegetation.

Management of the water in the soil and other soil properties can affect the zone of maximum root activity. However, deep fertilizer placement does not encourage roots to grow deeper since water supply is the overriding factor that determines rooting depth. For example, 90% of the total roots of irrigated corn are frequently found in the upper 3 feet of soil because of the constant supply of water in the top of

Attempts to place nutrients in certain locations to encourage (for instance) deeper root growth have not succeeded in altering inherent plant rooting characteristics and abilities. Water supply is the overriding factor that determines rooting depth.

[1] “Soil water potential” is a measurement of how much energy must be expended to extract the moisture. The primary factors are how tightly the water is held on the soil matrix (as water films decrease in thickness, they are more tightly held by electro-chemical forces), and the elevation (the atmosphere exerts more pressure at sea level than at higher altitudes).

the soil. A common myth among irrigators is that delaying the first irrigation will increase the rooting depth of the crop. While delaying irrigation will stimulate the plant to send its roots deeper, once irrigation begins, root growth will occur mostly in the wetted soil zones. The newly applied water stored in the upper soil profile is likely at a lower "soil water potential" than water stored deeper, meaning it is easier for the roots to extract. So maximum root depth occurs when soil water in the upper profile is substantially less than plant demand, yet the deeper profile has sufficient soil water to accommodate root growth and maintain high rates of photosynthesis.

Physical Hindrances to Root Growth

Root growth can be limited by such physical barriers as impervious rock, gravel subsoil, clay pan, or a compacted soil layer from tillage or heavy traffic. Root growth is opportunistic, taking the path of least resistance, and meandering in response to the small-scale arrangement of soil components. Roots will follow channels left by old roots and earthworms. Again, they take the path of least resistance. In both of these cases, however, roots tend not to follow the larger channels as these do not hold enough water to support growth.

Soil looseness, such as resulting from tillage, does *not* benefit roots. In fact, loose soil will likely dry out, especially the larger voids. Roots need a firm soil with good structure to hold moisture and nutrients and allow easy penetration. Tillage destroys structure, so the observation of looseness to our eyes can be very misleading as to what is encountered by microscopic root tips. Similarly, penetrometers and soil probes generally do not provide accurate representations of factors affecting root development, except to indicate dry soil zones. When using these instruments, dry soil zones can easily be mistaken for compaction layers, and must be carefully evaluated by other methods (usually involving a spade) to determine the cause of the perceived restriction and determine whether roots are growing through it.

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Roots can penetrate physical barriers only if the barrier strength is less than the root pressure. Root pressures vary with the crop species, but can reach maximums of 9 to 13 bars (130 – 190 psi). If roots cannot penetrate a physical barrier, growth will be horizontal along the face of the barrier. Deep tillage to fracture clay pans or previous tillage layers has not resulted in lasting improvement of root growth in most agricultural soils in the U.S. Plains region or Corn Belt.

Photo by Dirceu Gassen, Cooplantio.

Soils generally have good structure and aggregation under natural conditions, which allow for maximum root growth. Tillage by implements destroys structure. Here, the upper part of the soil profile has suffered tillage aplenty, resulting in no structure and no passageways for the movement of air or water, or for roots to penetrate easily. Below the tillage zone, where implements have never reached, the soil structure is fine.

Nutrients, pH, & Aeration

Root growth is more extensive and branched in a fertile soil than in an infertile soil. Roots will proliferate extensively around a lump of animal manure or fertilizer band in the soil. However, roots will not grow directly into the zone of high nutrient concentration, and often will show some inhibited growth and deformities at the point of first contact with the concentrated supply. This is due to the "salt effect" of the concentrated fertilizer. The zone of concentrated nutrients affects the level of chemical salts in the soil water near the supply, and roots cannot grow into this until sufficiently diluted.

While adequate nutrition is certainly necessary for plant growth, uniform nutrient distribution within the soil is generally not important. Roots will grow in the soil profile as determined by factors previously described. So long as conditions are favorable for new root growth in a zone, uptake of nutrients will occur and these will be translocated within the plant. Attempts to place nutrients at certain depths or locations to encourage (for instance) deeper root growth have not succeeded in altering the inherent rooting characteristics and abilities of the crop plants. So long as nutrients are placed (or have moved with infiltrating water) into the soil in locations where root growth will occur early in the season, total nutrient uptake is generally not affected by placement. For example, it makes little or no difference for plant uptake whether nutrients are placed 6 inches below the seed, 3 inches beside the seed, or somewhere else a few inches from the seed. Recall that plant roots only take up nutrients that are dissolved in water, so if nutrients from a particular fertilizer source cannot move in the soil with infiltrating water, they will never be available to the plant anyway.

Both high and low soil pH decrease root growth. At pH levels above 7.5, the solubility of phosphorus and the micronutrients iron, manganese, zinc, copper, and cobalt is reduced. However, fertilization can overcome this, and yields of many crop species generally are not limited up to soil pH of 8.3. Additional complications occur if the high soil pH is caused by an accumulation of sodium salts that may be toxic and/or interfere with water absorption by roots. At pH levels below 5.5, the increased solubility of iron and aluminum can cause these elements to reach toxic levels or reduce the availability of phosphorus and other nutrients.

Uniform nutrient distribution within the soil is generally not important. It makes little or no difference for plant uptake whether nutrients are placed 6 inches below the seed, 3 inches beside, or somewhere else nearby.

About 20 – 25% of the volume of a typical soil is gas-filled voids, and about 20% of this soil gaseous mix is oxygen. Oxygen is essential for root respiration, which provides the energy needed for continual cell growth and maintenance, as well as nutrient uptake. In some circumstances, energy is required for water absorption. Under anaerobic conditions (without adequate oxygen), roots and soil organisms may produce toxic substances that further inhibit growth. During rapid growth, roots will consume up to 9 times their weight in oxygen in 24 hours.

Crops vary in the optimum level of oxygen for satisfactory root growth. For example, rice and buckwheat can tolerate low soil oxygen levels while corn and field pea require higher oxygen levels than most other crops. However, the root growth of most crops is retarded when the soil's gas mix is less than 10% oxygen. Elongation of cotton and soybean roots is reduced at oxygen levels of less than 10% of the soil gas mix, but exhibits the same rate of growth from 10% up to 21%.

Soil 'air' is about ten times higher in carbon dioxide and slightly lower in oxygen than the atmosphere, although the composition will vary with soil type, soil organic matter level, crops grown, and atmospheric conditions. The roots and most soil organisms use oxygen and produce carbon dioxide. Many soil pores are not contiguous with the atmosphere, which reduces the exchange of gases between the soil and the atmosphere. Coarse-textured soils have larger pores and are more aerated than fine-textured soils. Gas movement in soils is directly related to water content (water displaces gases in the voids), so soils with good structure will more readily diffuse oxygen to roots.

Roots only take up nutrients dissolved in water, so if nutrients from a particular fertilizer source cannot move in the soil with infiltrating water, they will never be available to the plant anyway.

Effects of Temperature

Optimum soil temperatures for root growth vary between crops as shown in Table 3, but are usually similar to optimal temperatures for stem and leaf

Crop	Temperatures for Maximum Growth Rates			
	Roots		Shoot	
	°C	°F	°C	°F
Alfalfa	20 – 28	68 – 82	20 – 30	68 – 86
Barley	13 – 16	55 – 61	15 – 20	59 – 68
Corn	20 – 30	68 – 86	25 – 30	77 – 86
Cotton	28 – 30	82 – 86	28 – 30	82 – 86
Oats	15 – 20	59 – 68	15 – 25	59 – 77
Wheat	18 – 20	64 – 68	18 – 22	64 – 72

Table 3. Temperatures reportedly producing maximum growth rates of roots and shoots of various crops, if no other factors are limiting. (Note that 'optimum' nighttime temperatures will often be lower, if "dark respiration" begins to exceed daytime photosynthetic production—i.e., if the plant's nighttime consumption of sugars for maintenance and growth exceeds its ability to produce those sugars during daytime.)

growth, even though the soil is usually cooler than the air above it. However, during the growing season, variations in the root environment temperature are usually much less than variations of air temperature.

In a favorable soil environment, root growth rate will increase as temperature increases, up to the optimum. Cooler temperatures reduce the rate of biochemical reactions and membrane permeability, and increase the viscosity of cell fluids. Although this varies by species, generally roots respond to cooler soil temperatures by becoming larger in diameter and less branched. At cooler temperatures, the rate of mineralization of plant nutrients from the organic (unavailable) to the inorganic form (available) is reduced, and mycorrhizae are relatively inactive at temperatures below about 50º F. These phenomena can make nutrient uptake more problematic for plants at cooler soil temperatures.

Water warms and cools 5 times more slowly than other soil components, so a moist soil buffers against temperature change.

Soil temperatures are influenced by soil water content, with wetter soils usually cooler than drier soils. Water warms and cools about five times more slowly than the other soil components, so a moist soil buffers against (slows) temperature change, whether cooling in the fall or warming in the spring. Soil color also influences soil temperatures. Soils inherently darker in color (due to parent material) or darker due to soil organic matter content will absorb more solar radiation (become warmer) to whatever extent they are exposed. A bare soil will warm more quickly than a soil covered with crop residue. Any factors that affect soil temperature also influence root growth.

Summary

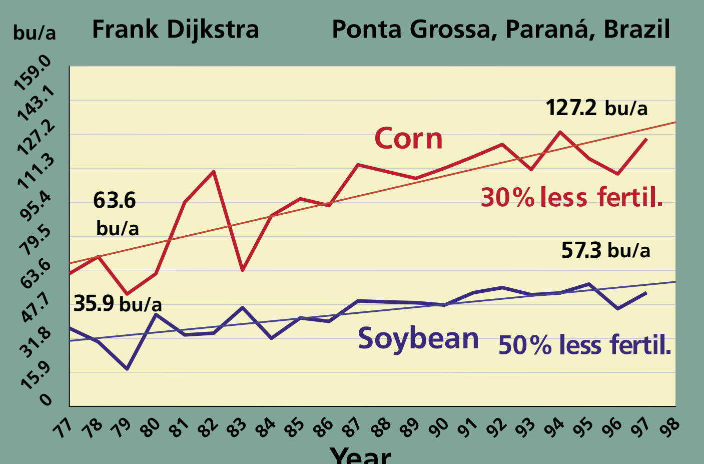
While plant roots certainly have physiological limitations, roots can adjust their growth to accommodate their surroundings within substantial ranges of conditions. Most soils of the world, including those of the U.S. Plains, are well-suited to root growth in their natural untilled condition. Root growth is not improved by any type of tillage in these soils. The producer can provide a better environment for root growth only by ensuring the soil is adequately covered with stubble, supplying sufficient nutrients, managing pH, rotating crops, and observing other agronomic practices to allow normal crop development.

Conference Snapshot

The 2006 Winter Conference was a smashing success, with record attendance of 1,500 eagerly learning to better manage production. Gabe Brown blew away many of our previous notions with his creative and highly profitable approaches to integrating livestock grazing with cropping. Alan Mindemann brought forth his results from 2005—"It was a great year to be in farming"—despite below-normal precipitation and aggressive cover-crop usage. Alan States, as usual, challenged us to push the boundaries of farm management. Gary Maskus ratcheted up the cropping intensity, as did Dan Forgey. Mike Hubbs did an excellent job of tying together soil/water/air relations and crop performance.

One of the most powerful slides was during Ademir Calegari's presentation, showing Frank Dijkstra's farm results. Dijkstra's farm in southern Brazil has had yields trending upward substantially (see graph) in continuous no-till with cover crops since the late 1970s, while fertilizer use has diminished. Herbert Bartz's farm in Brazil has had similar results with continuous no-till and cover crops since the early 1970s. As Calegari and Dirceu Gassen both take pains to point out, it has little to do with whether cover crops *per se* are used, but that the soil be covered and crop diversity is high. They further emphasize that the fertilizer efficiency is mostly due to nutrient recycling (less 'leakage'), while legume fixation is minor.

Long-Term No-Till Results



Source: R. Dijkstra, 1997.

Disturbance Favors Weeds

In December '03, *Leading Edge* published an article by Randy Anderson on reducing weed pressure with low-disturbance no-till. A four-year study in Saskatchewan supports Anderson's conclusions. Eric Oliver, an SSCA agronomist, compared four drill opener designs that vary considerably in amount of soil disturbance during operation, *with each opener type used on the same plots for the duration of the study.*[1] Openers were the Barton Gen.-I disc, 0.75-inch knife, 2.25-inch spoon, and a 12-inch sweep. All were on 9-inch row spacing. Four crop species were grown in each of the four years, with four replications of each.

Over all four years, the angle disc resulted in the highest percentage of crop establishment in all crops. However, the high-disturbance openers *were* successful in planting more weed seeds. Burndown and in-crop herbicide programs were used. Because occasional weed escapes produced seed that remained in the plot, weed pressure changes were ongoing much like on an actual farm. The graph presents weed pressures averaged over the last 2 years of the study. Yields in the final two years tended to be slightly lower for the higher-disturbance openers, due to both weed pressure and residue destruction.

Photos by Matt Hagny.

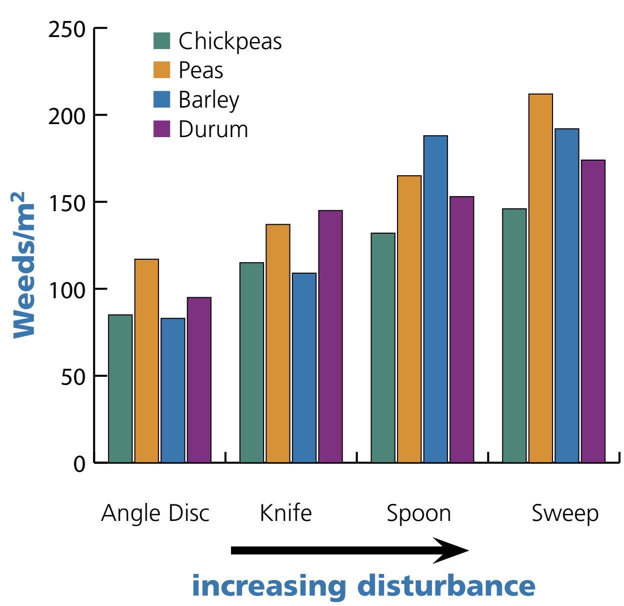
Soil disturbance 'plants' weed seeds. Here, a field had been in no-till a few years when a gas pipeline was dug across it. The greenish-yellow vegetation in the disturbed streak was sprayed with herbicide about a week before the photo was taken. The close-up shows the weed population was probably more than 100 times greater in the disturbed area.

Photo by Ken Flower, WANTFA

This photo, from Western Australia, shows wheat that was seeded with a low-disturbance disc opener. Ryegrass—a terrible weed problem in Australia—has emerged in the perpendicular 'stripes' where a shank opener had run the previous season. Disturbance 'banks' weed seeds.

Obviously, increased weed germination results in reduced crop yield or requires more herbicide (or both). Anderson's article provides solid evidence that even quite shallow disturbance preserves more weed seeds for future years. Why give weeds these advantages?

2000-2001 Weed Densities



[1] This study had technical oversight by Doug Derksen, a scientist with Agri-Food Canada, and others.

Field Ecosystems:
Principles & Practice

by Matt Hagny

TECHNIQUE

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

While we are often oblivious to it, some basic relationships govern vegetative patterns and water/nutrient cycling in the soil. Whether we want to admit it or not, our fields certainly are subject to the laws of chemistry, physics, and biology. Understanding these principles can guide our management as we progress to more efficient cropping systems.

Brazilian agronomist Dirceu Gassen has often prodded us to better understand: "Think like a plant. Think like a bug—what does it need to grow?" We might ask the same thing of the field ecosystem: where do losses occur? Where must we intervene repeatedly to keep it from doing something we don't want? Where does it *not* behave like a native grassland or forest?

Photo by Doug Palen.

Long periods of stubble maintenance are costly. Meanwhile, the residue disappears and nutrients escape from the system.

In many regions of the world, winter is relatively warm, and snow cover or frozen soils are encountered only a few days of the winter (if at all). Summer frost-free periods span quite a number of days, and average temperatures relatively high. In many of these areas, significant precipitation can occur in every month of the year. Consequently, adapted plants can grow in most (or all) of those months. Surface residues and soil OM decompose year-round. Nutrients 'leak' from the system in all months. Essentially, the biological and chemical processes comprising the ecosystem are fairly active all during the year, in contrast with cooler regions where those slow to a snail's pace during several months of frozen winter. This can and should influence our management choices.

Yet so many producers in these warm regions only have a crop growing during a few months of any given year. *We spend the remaining months battling weeds and watching the soil cover disappear.* The more astute agriculturalists might realize that nutrients are also being lost from the system, since nothing is recapturing them (mineralization exceeds uptake by plants + microbes).

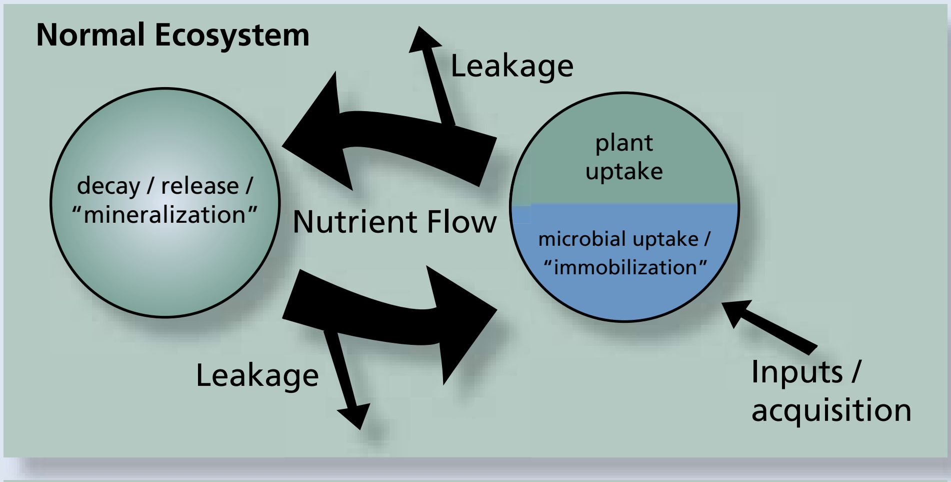
For example, take the rotations used at Gettysburg, SD: often something like s.wheat >>w.wheat >>corn >>soybean. Sometimes corn is stacked, sometimes sunflowers substitute for soybeans, but you get the idea. Now look at common rotations for no-till producers at Great Bend KS, 600 miles to the south: perhaps w.wheat >>w.wheat >>milo >>soybean. Maybe sunflower is substituted for soybean, but essentially it is the same rotation, yet with 45% more precip during the year and 17º F warmer during winter. The warmth partly offsets the moisture, since evaporation is higher, so cropping intensity might not be as far off the mark in terms of balancing soil moisture as the moisture figures indicate. Yet the decomposition rate will be quite high, which worsens the moisture inefficiencies (less mulch) and creates the opportunity for soil degradation. Long non-crop periods also drive up weed control costs. The situation gets worse farther south and east, into still warmer and wetter climes. What can be done? We must understand the problem, first.

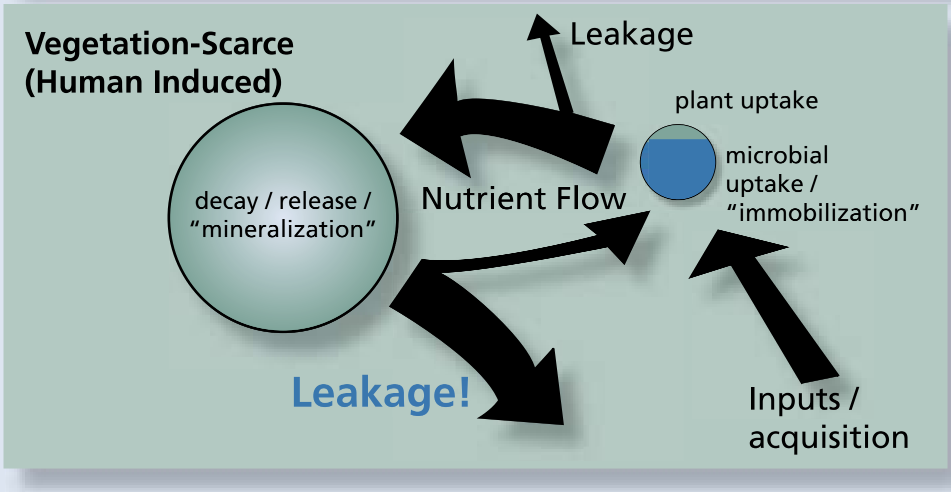
Problems are created by too long a time with little or no vegetation, and by too little plant diversity over time.

Four Problems, or One?

Cropping systems in warmer climates often have 1) difficulty with weed control over extended periods without crops (and with rapid weed growth due to warmth and moisture, 2) difficulty maintaining surface residues and soil OM due to high decomposition rates, 3) more nutrients 'leaking' from the system because few living organisms are absorbing them, and 4) inadequate diversity of plants over time. Actually, the problems are all different aspects of the same thing, as will be explained.

Long non-crop intervals have more weeds, if moisture and temperature are accommodating. For instance, stacked wheat (w.wheat into wheat stubble) has a length of time from harvest to seeding of the next crop of only 6 weeks in the Dakotas, but 14 weeks in central KS, and even longer in Oklahoma. This necessitates at least one additional herbicide application. Similarly, the transition from wheat to corn or milo is often 10+ months, but the higher temperatures and precip amounts in KS or Oklahoma can again require more weed control expenditures. Nature abhors a vacuum, and the weeds are opportunists.





Nutrients are released during the decomposition process, the final stage of which is called "mineralization," in which the nutrients are again in a form that can be taken up by plants. Various microbes can also acquire those nutrients, which we term "immobilization." But it is nutrient uptake by living organisms nonetheless. These microbial populations ramp up when plant roots are present, and begin to die off if no plants have grown in that location for awhile. If not enough uptake is occurring (either by microbes or plants), the nutrients can easily 'leak' from the system. You must then replace the lost nutrients to maintain yield potential.

Warmer conditions also result in lower soil OM levels. No great revelation. Biological and chemical processes continue to degrade OM year-round, and both processes go faster with higher temperatures and adequate moisture. Less widely appreciated is the fact that surface residues also decompose more quickly. This is of great concern since the soil cover is essential for maintaining soil structure and for soil/water/plant relations.

Having the soil moisture profile full can cause serious nitrogen losses.

Nutrient Leakage

'Leakage' applies to any loss of nutrients from the ecosystem. It can be deep leaching with water percolation, surface runoff carrying dissolved nutrients (or residue) away, or gaseous losses (denitrification, volatilization, and ammonia losses by well-fertilized plants through their leaves).

Crop tissues are composed of C, N, K, Ca, Mg, S, P, and various other elements acquired from their surroundings—the soil and atmosphere. Bacteria, fungi, and other soil organisms are comprised of the same elements. Many of these soil organisms feed upon root exudates (sugars, lipids, etc. that ooze from roots), decaying roots, and other plant residues in various stages of decomposition. Many of these populations ramp up when plants are growing in the soil, and decline if no plants have been present for a long period. In contrast, chemical decay processes are more constantly active. Consequently, when soil organism

Photo by Alan Mindemann

Hybrid sorghum x sudan gives Alan Mindemann a tremendous amount of soil cover in a short time, which is rejuvenating his southwestern Oklahoma soils.

populations rapidly decline, the elements are no longer being acquired by the various living organisms as fast as they are being relinquished. The soil has limited capacity to bind these elements, which subjects many of them to leaching or other losses. Leaching can begin to occur long before soil moisture becomes fully recharged. Once nutrients are at depth, it is essentially a race between root growth/uptake and further movement of the nutrients downward with each rain.

Precipitation that is not infiltrated will runoff, carrying dissolved nutrients away. Again, this is well known. Less widely appreciated is the influence of surface residues—including growing plants—on infiltration. (See Derpsch's 'Understanding Water Infiltration,' *Leading Edge*, Dec. '03.) Long periods of fallow make runoff worse due to loss of residues. Further, as the soil profile becomes saturated, runoff is more certain.

Gaseous losses such as denitrification are ongoing in most soils, essentially happening during microbial 'blooms' (population explosions) when soils become saturated at the surface for even a few hours. In a low-oxygen environment (saturated soil), these particular microbes use the oxygen atoms from nitrate molecules, converting them to nitrous oxide or to N_2 which both escape into the atmosphere. Soils with poor structure, shallow depth, etc., have considerably more denitrification, although it definitely occurs in all soils to some degree. Attempts to have the soil moisture profile full at certain times during a rotation can cause serious denitrification in some soils.

Adequate Diversity

Another frequent issue is achieving sufficient diversity of plant species in fields. In the absence of having 4 or 5 different cash crops in rotation, and 'stacking' most of those, you will not be optimizing crop health and biological suppression of pests. And, to whatever extent the rotations are consistently followed, you are applying selection pressure to soil-borne diseases as well as insects.

Cover crops provide another opportunity to add diversity and keep pest populations 'off-balance.' Choose cover crops more distantly related to cash crops already grown.

Cover crops provide another opportunity to add diversity and keep pest populations 'off-balance' by changing the selection pressures. In other words, to whatever extent the cover crop is a host (even a weak one) to a pest, it alleviates some selection pressure exerted by doing only the main host (cash crop) in rotation—in other words, it causes the pest population to 'drift' away from better adaptedness to a particular cash crop and rotational scheme, because the pest reproduces in the weak-host cover crop (assuming the cover crop is a different species than the main-host cash crop). For example, if you're worried about soybean cyst nematode, and a certain clover species is a weak host, by adding it to the rotation you would increase cyst nematode populations slightly, but those nematodes reproducing on the clover would be better adapted to clover than to soybean. So long as soybean doesn't immediately follow the clover, the net effect over the long term might be to make the field's cyst nematode population less adapted to soybeans and therefore less damaging.[1] Further, cover crop presence can enhance direct chemical and (active) biological suppression of the pest.

Commonalities??

What do all these concerns have in common? Essentially, all of the problems are created by too long of an interval with little or no vegetative growth and/or by too little vegetative diversity over time. True, the leakage situation (and perhaps loss of surface residues and soil OM) could be handled by allowing weeds to proliferate, but this can have repercussions for subsequent crop

[1] This will only work in the intermediate-term, since it's still a selection pressure. Given enough cycles (dozens), the pest could become rather well-adapted to both. But if you occasionally switch cover-crop species to others that are also weak hosts, the mechanism could continue to disrupt the adaptedness of the pest to the cash crop.

Cover-crop Effects on Milo at Hesston, KS

	N rate lbs/a	Sorghum Yield bu/a 2003*	Sorghum Yield bu/a 2005
Wht stubble check (no cover crop)	0	49.2	49.2
	30	48.2	74.0
	60	48.8	84.5
	90	45.8	96.9
Group 8 soybean	0	47.9	73.4
	30	48.3	81.3
	60	56.2	92.8
	90	50.7	96.3
Sunn hemp	0	58.8	71.7
	30	53.0	87.2
	60	59.9	92.7
	90	62.6	106.7
LSD .05		10.0	9.7

*Low yields due to severe drought. Cover crops also failed in '03, so yield data from '04 milo wasn't collected.

Under no-till, milo tended to benefit from the previous wheat stubble being planted to cover crops, especially to sunn hemp. Due to inoculation failure of the sunn hemp in '02, no nodulation was observed—so the improved efficiency of N fertilization in the '03 milo crop was likely due to the sunn hemp's scavenging available soil N and releasing it during the milo crop's growth, and/or by improving milo plant health in some other way. Whatever it is, there does appear to be a benefit to having something growing, regardless of actual N fixation by *Rhizobia*. (Nutrient leakage happens—prevent it!) Interestingly, the '02 cover crops also provided benefits to '04 wheat planted into the '03 milo stubble, although this sequence isn't a recommended practice. This study is a continuation of an earlier study testing hairy vetch, for which the Group-8 soys & sunn hemp were substituted on the plots previously including vetch, and the N subplots remained the same, so some residual effects of those treatments might be influencing results yet. But the conclusion is still that cover crops are an economic benefit. Conducted by Mark Claassen, KSU. Sources: M. Claassen, personal communication Feb. 2006. KSU, 2005, *Agronomy Field Research 2005*, KSU Agric. Exp. Stn. & Ext. Svc.

production—especially since the weed density would need to be relatively high, so you'd have to let the weed seed bank build up in years prior to the fallow niche you desire to fill. More economically beneficial approaches might be to crop more intensively, and/or add cover crops.

The cropping intensity aspect has been covered previously (see, for example, Beck's 'Cropping Strategies in Semi-Arid Climates,' Dec. '04). Experimentation to fill summerfallow niches is ongoing. I am still optimistic on the ability of forages to fill the summerfallow niche in southwestern KS as well as the panhandles of Texas and Oklahoma. With improved genetics, some early-season low-risk grain crops such as field peas could yet become important. Chickpeas, mustard, proso, oats, etc. are more ready-made solutions, depending on a producer's capabilities and access to markets.

Cover Crops & Seeding Methods

Which ones? Where in the rotation? Again, we would be wise to consider Gassen's (or Beck's) approach: What *would* the ideal seedbed for the next crop look like? Do we need to add lots of residue, or is it already abundant? How much water is available, and when should the cover crop be using water? Will we get enough growth to justify the cost of establishing the cover? All of these are important considerations.

The general idea is to select cover crops that are not closely related to the cash crops already being grown. For instance, rye is very closely related to wheat (close enough that they can be crossed, creating triticale), so if wheat is already in the rotation, rye might not be the best choice. Same goes for barley (it's not quite as closely related to wheat as is rye, but it's still quite close—they host many of the same foliar and root diseases). Sudangrass (*Sorghum bicolor* var. *sudanese*) is actually the same species as what we call 'grain sorghum' or 'milo,' so it will carry the same diseases. Most peas, beans, vetches, and clovers are not too distantly related to each another. The point is not to be afraid of any of these, but to know what they are doing to the rotational break that is your primary tool for controlling root diseases (and nematodes) and promoting plant health in the cash crops.

Craig Stehly on cover crops: "I don't think I've ever hurt my yield the following year. Everyone worries about using too much water, but they never think about how much yield they lose to excess water."

Here's my take on directions for experimentation in the central U.S. Plains, although I'd strongly encourage even broader forays into cover crop uses:

Photo by Jim Millar.

Canola, a cruciferous crop. Here, it produced tremendous growth for Max Williams at Redfield, SD, when planted after wheat harvest to prepare the field for corn the next season. Herbicide savings more than paid the seed cost.

Mustard (Crucifer) Family

Turnips, canola, mustard, kale, and radish are all closely related species, although with differing habits of growth (some are more cold tolerant, some with bulbous roots instead of slender taproots, some are leafy forage types, etc.). These belong to a group called 'cruciferous' crops (the family was called Cruciferae, now Brassicaceae). They are not legumes. The family includes the genera *Brassica*, *Raphanus, Camelina,* and many others.

Several things make crucifers attractive for cover crop use. One is the diversification from most current crops (unless you're a canola grower already). Crucifers are quite unrelated to other broadleaf crops such as soybeans or sunflowers or cotton. So the risk of carrying many diseases is reduced. Cruciferous roots produce substances that kill nematodes, reducing these pests for cotton and soybeans. Crucifers grow rather quickly as a rule, and also decompose rapidly. Because of this, they can acquire many nutrients from the soil and supply them to the next cash crop.

Crucifers are also extremely affordable to plant, often with seed costs in the $1 to $5/a range (forage & oilseed radish are a bit more, but why not grow your own seed?). Because of the small seed size, they are well-suited to surface broadcasting of the seed for establishing a stand, especially in high-rainfall areas, or during fall or winter. This family of plants includes wild mustard, etc., so there is a minor potential for these cover crops to become weeds. Generally, they are easy to kill with herbicides, and should pose no problem unless allowed to seed themselves frequently. However, to make control easier, it might be best to stay away from RR or imi-tolerant (Clearfield) canola varieties.[2]

Most crucifers are somewhat heat-tolerant and can be established in August or September in Kansas. They are also cold-tolerant to some extent, although most varieties kill with a sufficiently hard freeze (10 – 15º F, except winter canola). Oilseed radish is the least frost-tolerant, since it was selected for tropical usage. Producers wanting rapid growth and a less bulbous taproot should consider 'Pasja' forage turnip, the forage radish, or the oilseed radish.

Where do the crucifers fit in the rotation? In central KS and Oklahoma, as well as on into eastern NE & SD, they fit quite well following wheat in fields going to corn or milo the next year. Ray Ward has been doing this on his farm near Beatrice, NE for several years, with favorable results. Ward's nephew used a drill to establish the turnips, and grazed them later in the fall. Jerry Burger, near Washington KS, had good success broadcasting turnip seed into wheat stubble in 2005. Rains germinated enough of the seed to create a dense stand of turnips that was reasonably effective at keeping volunteer wheat suppressed. The turnips produced excellent vegetative growth, and the Pasja in particular had nice roots.

For central & eastern KS, we need to try aerially seeding crucifers into corn several weeks before harvest (or any time after blister-stage corn, when corn's water use begins to

Photo by Jerry Burger.

The bulbs of Purple-Top turnips are almost entirely above the soil line, whereas the Pasja forage variety has a more slender taproot. Forage radish & oilseed radish will often have still deeper taproots. Canola is a more slender taproot.

[2] Be aware that even with conventional canola varieties, there is a chance of contamination of seed supplies with herbicide-resistant seeds, due to cross pollination, and/or physical mixing during harvest or seed conditioning. This risk can be managed with herbicide tankmixes to terminate the canola. For those who want to be extra cautious, radish or turnip should have still less chance of contamination.

diminish).[3] A rain would bring the crucifers up, frequently gaining several critical weeks of growth for the cover crop as compared to seeding after corn harvest. The goal would be to have the cover crop up and going when the corn leaves begin to dry up, which lets sunlight down to ground and causes weeds to flourish. We would like to have as much cover-crop growth in the fall as possible. Seeding cover crops by airplane is a longtime practice for some producers, such as Pat Sheridan of lower Michigan, who has used oilseed radish for 6 years with excellent results. In Brazil, tens of thousands of acres of cover crops are aerially seeded.

Seeding cover crops by airplane is a longtime practice for some producers.

Photo by Matt Hagny.

Double-crop sunflowers in north-central KS. In some regions, carrying wheat stubble for 10+ months can make for soggy planting in the spring, especially on soils with considerable clay. Excessively wet conditions cause problems with the planting operation, slow soil warming, increase disease potential, reduce aeration, and cause leaching and denitrification. Sunflowers—either for grain or strictly as a cover crop—will use some of that excess water.

It is also possible to use crucifers ahead of cotton with direct benefit to that crop, as pointed out by Ademir Calegari, a Brazilian no-till researcher. Producer Alan Mindemann has been using Pasja turnips in his rotations near Lawton, OK, primarily ahead of cotton. Producers in cooler regions with white mold (*Sclerotinia*) concerns will want to be cautious with crucifers if sunflowers or dry beans are already in the rotation.[4]

Cover-crop Sunflowers

Some producers are taking *bin-run* oilseed sunflowers and drilling them on 15-inch spacing in several rotational niches. Sunflowers have the advantage of being exceptionally inexpensive to plant ($1/a for bin-run seed at 10 lbs/a), and grow rapidly even in relatively cool temperatures, including withstanding mild frosts. Both wheat and corn do well as subsequent crops (no allelopathic issues). Sunflowers can dry the subsoil extensively, which can be either beneficial or detrimental depending on the subsequent crop and precip probabilities (and how big the flowers get).

Craig & Gene Stehly of Mitchell, SD are using cover-crop sunflowers put in with their 1850 air drill after the second wheat crop—these fields then go to corn the following spring. The drought in their area in ’05 prevented them from seeing much benefit in the corn from the ’04 cover-crop flowers, but Craig is still optimistic: “It definitely planted better. Some years it might be the difference between getting it planted or not . . . . We sure don’t have it all figured out yet. But in all my messing around with cover crops, I don’t think I’ve ever hurt my yield the following year. Everyone worries about using too much water, but they never think about how much yield they lose to excess water.” (The Stehlys farm in a “prairie pothole” region without many natural waterways. They’ve been 100%

Photo by Jim Millar.

A cover-crop mix of canola + black lentil + sweetclover tested by Max Williams following wheat harvest. This particular area is dominated by the lentil and canola.

You do not need the moisture profile full at planting if you are efficient enough in terms of water storage and usage while the crop is growing.

[3] Might not work at high latitudes; radish doesn't like shade.

[4] Even though these broadleaf crops aren’t closely related, they all host white mold, much like *Fusarium* lives on wheat, corn, sorghum, and many other grasses. See earlier discussion of diseases. Note that if you add a broadleaf cover crop in one niche of the rotation, and a grass in another niche, you are probably no worse off at all in terms of these diseases, since they ‘fake out.’ See Craig Grau’s work discussed in ‘Leveraging Biology,’ Dec. ’02.

Photo by Steve Groff.

No-till vegetable and grain producer Steve Groff of Pennsylvania uses Daikon (Japanese) forage radish planted in alternate rows with other species. Here, the radishes have frozen off, and will eventually die during the winter. The rye and vetch survives.

low-disturbance no-till since 1990.) Sunflowers have an advantage for this niche in the Dakotas, since they can be seeded relatively late and still produce lots of growth in cool fall weather (it takes ~ 20º F to kill them). The Dec. '05 *Leading Edge* reported on Roger Oplinger's use of sunflowers after his second wheat crop, and ahead of milo, although in his case he has been harvesting the flowers for grain.

Lewis Unruh of Peabody, KS and Jerry Burger are experimenting with sunflowers *between* wheat crops to use extra moisture and recycle nutrients. These producers have previously used sunn hemp (*Crotalaria juncea*) for this purpose, but the extremely low cost of bin-run sunflowers has them looking at this alternative. Like sunn hemp, sunflowers grow quickly and extract lots of deep water, which can be an advantage for doing stacked wheat in a climate that otherwise is a bit too wet (on average) for this sequence.

If you're contemplating this cover crop, plan ahead—beware long-residual herbicides that could kill or stunt sunflowers (Finesse, Rave, Amber, Peak, Maverick, Tordon) or post-harvest applications containing dicamba or substantial rates of 2,4-D amine.

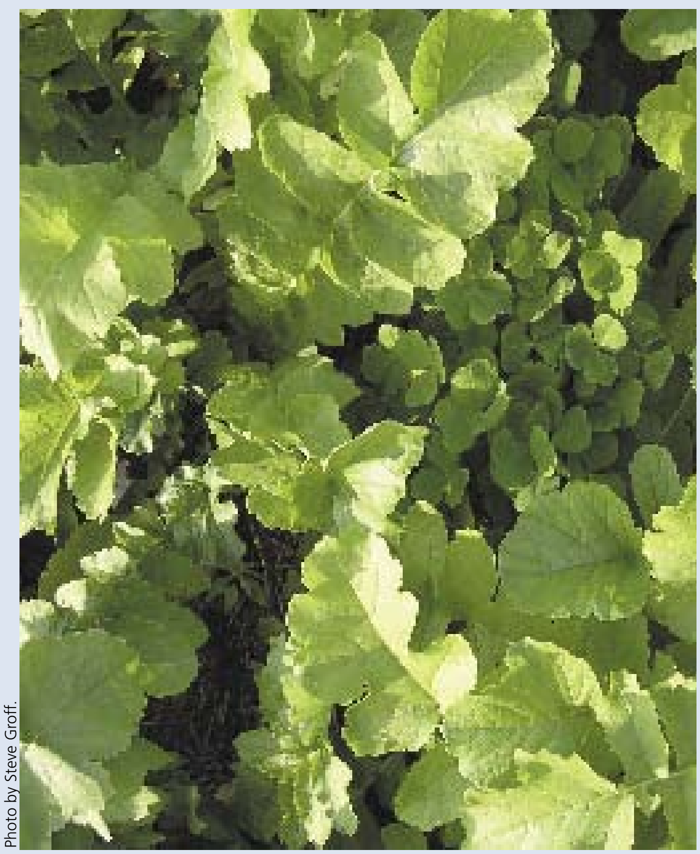


Photo by Steve Groff.

Steve Groff's radish and crimson clover in alternate rows. Dirceu Gassen offers expert advice: "Do not rest the soil. Give it plant cover and biological activity."

Cocktails

Calegari and no-till vegetable producer Steve Groff of Pennsylvania are fond of cocktails. We're still talking about *cover crops!* They see the advantages of mixing two or more species, which can enhance the overall performance of the cover. This can occur because of added diversity, and because the species may have complementary traits—for instance, one might be viny, and the other upright (providing a living trellis of sorts). They might grow at different temperatures, with one doing well in the heat and the other dormant till cooler temperatures arrive. One might survive the winter, while the other doesn't. One might suppress weeds with rapid growth while its slower companion becomes established.

Max Williams of Redfield, SD tried a cover-crop mix during '05, drilled into wheat stubble (the field goes to corn in '06). The mix of canola + black lentil + clover produced a vigorous 5 tons/a of biomass (dry weight). Beck thinks the ideal management of this mix would be to clip or roll the canola when it bolts, to prevent it from seeding and to release the clover and lentil from competition.

We should explore similar cocktails in KS, OK, and TX, wherever the wheat >>milo (or corn) transition has enough moisture to do so, and isn't otherwise being utilized. Since this region has a much longer time from wheat harvest to fall freezes (8 – 10 weeks more than Redfield, SD, and much more warmth), it might be better to use a mix of bin-run sunflowers + lentils (or hairy vetch) + turnips (or radish or canola). The sunflowers grow when it's hot, the crucifers cover the soil, and the vetch survives the winter to provide spring growth.

Issues do arise when one species of the mix is highly aggressive, such as oats, which can kill out broadleaf seedlings in their midst. Oilseed radish can similarly choke out other species, including oats. Results are quite dependent on stand densities of each, as well as variety and environment. One trick Groff has used is to separate the two species in alternate rows, to let the less-competitive species survive (see photo). Another option is to reduce the proportion of the aggressive species in the mix.

Feel free to mix your own! Splendid new cocktail recipes are being discovered all the time—whether we're talking cover crops or beverages.

Other Options

There are a great many other species that can be of value. I'm certainly not ruling anything out, except ryegrass (due to its weedy and herbicide-resisting habits).

Sudangrass is something that produces a tremendous amount of growth in a short time, is low-cost to seed, and can sequester a large warehouse of nutrients for future cash crops. Sudan can also be used as hay or forage. Sudan can be allelopathic to wheat, so manage accordingly.

Various millets (pearl, proso, Japanese) can be useful. Again, these grow quite rapidly, and seed is quite affordable. If the crop sequence is to go to milo or corn next, be aware of issues with volunteer (don't let it seed, or have a plan for effective herbicide control in the subsequent crop).

Cowpeas (*Vigna unguiculata*) have value, due to their aggressive growth in warmer and drier conditions than what some species can handle. Note that cowpeas are considered a veggie under FSA rules, although exemptions for cover crop usage occur—each county has its own rules.

Winter oats makes lots of sense in Oklahoma & Texas, either as a pure cover crop ahead of cotton or soybeans, for instance, or for winter grazing. Expect more winter-hardy varieties from USDA-ARS in the near future, which will expand this possibility farther north.

Summary

Some producers are frustrated that they haven't found something that works consistently. However, in biological systems, consistency isn't the norm—think how variable your crop yields are, or how wacky fertilizer responses can be. We must go forward with cover crops if they work a high enough percentage of the time to confer an economic advantage over doing nothing, and this

Cover-crop Effects on Corn Yield (bu/a) in Brazil

	N rate lbs/a 0	N rate lbs/a 80
Check (no winter cover crop)	70.7	95.4
Hairy Vetch	109.6	117.0
Common Vetch	116.9	121.7
Sweet Pea (*Lathyrus* spp.)*	102.3	120.4
Oilseed Radish (*Raphanus sativus*)	91.7	111.4
Blue Lupin	109.5	102.2
Wheat	79.6	95.4
Rye	68.3	106.2
Italian Ryegrass (*Lolium multiflorum*)	68.2	111.2
Black Oats (*Avena strigosa*)	73.0	108.9

*Calegari uses "sweet pea" for ***L. cicera*** and ***L. sativus***—the latter is often called chickling vetch, grass pea, white pea, or khesari in English, while ***L. cicera*** is vetchling, red pea, or chickling vetch. The common names are rather jumbled worldwide.

In regions with high rainfall, cover crops enhanced corn yield considerably, and improved N efficiency. Vetch, sweet pea, and lupin are legumes. Non-legume species confer benefits by recycling nutrients, as well as other biological effects that are poorly understood. The cover crops were killed approximately one week prior to planting. Study conducted by Calegari in 1998 at Pato Branco, Paraná, Brazil. Average of 3 replications, no-till. Sources: A. Calegari, 2006, Soil and crops improvement with a No-Tillage system [sic], in Proceedings: 2006 No-Till on the Plains Winter Conference (Salina KS, 30-31 Jan. 2006), No-Till on the Plains Inc. Calegari, personal communication Feb. 2006.

Photo by Jim Millar.

Due to less-than-perfect mixing, the proportions of species varied a bit across Max Williams' plots. This spot had more sweetclover. Areas with the 'proper' mix made 5 tons/a of dry matter.

probably is the case more than anyone realizes.

Others are skeptical that the advantages haven't been proven in replicated studies over many years. While we shouldn't throw caution to the wind, we definitely need to keep focused on improving water and nutrient cycling in soils, and on having sufficient diversity to keep pests off-balance and create healthier cash crops. There is considerable evidence that cover crops do this.

We are excessively focused on having the bucket (soil moisture profile) full up at planting time of our cash crop, *and not nearly focused enough on efficient water usage <u>during</u> the growth of the cash crop* (increasing infiltration, decreasing evaporation, and improving root growth). You do not need the profile full at planting if you are efficient enough in terms of water storage and usage *while the crop is growing*. We do this partly by not tilling the soil, but the 'big stone' is still the amount of mulch covering the soil surface. We need 100% cover most of the time, and in many warm regions it takes cover crops to do this.

Mindemann, one of the most diligent cover-crop users, offers this observation: "Cover crops are the shortest path to a productive no-till system, and will rapidly improve soil structure. From what I've experienced, low-residue no-till versus high-residue no-till— *big* difference."

Correction

In the March 2003 issue, p. 96, we erred in the rendition of a graph which should have its vertical axis labeled "Soil Organic Matter Oxidized," not "Carbon Oxidized." Soil organic matter is ~ 58% carbon. We apologize for any confusion.

—The Editors.

Skip, Skip, . . . Crash?

by Matt Hagny

Planting with ultra-wide gaps—for instance, row spacing of 30-60-30 (inches), a.k.a. "single-skip"—has gotten considerable attention lately, especially in eastern Colorado and western Nebraska & KS. Some credible and conscientious researchers have showered favorable commentary on it.

Wait a minute. Haven't we learned anything about plant spacing, crop competition, or the value of residue cover? It seems like this stuff goes in cycles, with various myths and fads re-emerging every decade or so. We get all these reductionist studies and practices without any regard for how the system works.

The theory is the wide gap stores water that the crop doesn't find till late in the season, during grain-fill. And, studies in western Nebraska and eastern Colorado do tend to show some yield advantage to skip-row in extremely dry years (sub-60-bu/a corn). However, the skip-row falls apart badly if you get average or above-average precip (which is when you make the money anyway; insurance covers the dry years). Skip-row typically *lags* normal (plant-every-row) 30-inch spacing by 10+ bu/a once you get into the 70 bu/a and up range. That's a big hit.

Another downside to skip-row is weed control, with nearly everyone agreeing that it requires extra preplant and in-crop herbicide applications. A couple more hits.

What about residue production? Take out 1/3 of the rows, and you'll be losing up to 1/3 of your biomass and soil cover. To my knowledge, no one has measured the effect of skip-row on subsequent crops, but it certainly can't be good. (For the value of mulch, see the March '05 *Leading Edge* 'Maximize Crop Residues.') Whack!

Row-spacing and plant-population jiggering is a recurring theme. While we appreciate inventiveness, a bit more conceptual framework could be useful so we don't spend so much time and money testing concepts that are ultimately frivolous or even harmful. There *are* underlying principles governing crop production. Ultra-thin plant populations or super-wide rows fail to consider other effects on the field ecosystem, and aren't all that effective at guarding production in dry years anyway (think of all the sunlight and wind getting down to the soil surface and increasing evaporation). Skip-row was big in Australia's summer crops, in regions notorious for hot dry summers (much worse than western KS or eastern CO). Yet even the Aussies are abandoning skip-row. So let's work on solving some real problems instead of chasing these distractive mirages.

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An Inquisitive Nature

by Matt Hagny

The wheels were falling off. That's the uneasy feeling James & Richard Wuerflein ("WUHR-fline") had in the '80s and early '90s concerning their 100% wheat and stocker operation north and west of Enid, OK. Of course, it was maximum tillage. They had been relatively successful, no doubt, and had some late-model machinery as tentative evidence of this. But the factory itself wasn't behaving like it should—the soil didn't take in moisture very well, stand failures were common, salt spots slowly crept across the field, and elsewhere large areas of wheat had no grain-fill.

The Wuerflein brothers, who own farm assets individually but work together, have always had their senses attuned to research, and try to think about what their surroundings are telling them—whether it's the behavior of the soils, the weed spectrum, or what the markets indicate is valuable or not.

Wuerfleins, who today have some crop diversity and zero stockers, began their no-till journey in a rather unusual way—by doing more tillage. In the early '90s, in an attempt to improve water infiltration, they deep ripped nearly every field over the course of a couple years, and some fields twice. They noticed it wasn't helping drainage or soil condition at all. Could conventional wisdom be wrong? Then James had an experience that "impressed me to the hilt"—the K-State rainfall simulator at a field day in the Oklahoma panhandle in '95: "They pumped till they ran out of water, and it still didn't run off the [high-residue] no-till." Having seen a JD 750 drill at that field day, James went home and ordered one—the first in their part of the world—and double-cropped a bunch of milo after wheat harvest.

That went okay, but what really convinced Wuerfleins of the need to change was their experience with two fields, as James describes: "Every year, we'd have 50-bushel-per acre straw, but the heads were blank. We tested it for micronutrients, everything. Finally [attributed] it to root disease. We rotated out, and the wheat was fine [after that]." With these revelations—that no-till was both useful and feasible, and that crop rotation solved problems that technology was powerless to overcome—the Wuerfleins kept adding fields to their new scheme.

"Between rotations and no-till, we started seeing some responses. We broke the disease cycle. We started infiltrating the water."

Finally, Wuerfleins had enough evidence that no-till would work: "Diseases went away, and the yields were there." As Richard tells it, "We said to ourselves, 'Why have tillage equipment for 3,000 acres and only be tilling 1,000?' We had too much overhead." So by 2001, they were 100% no-till and sold all their tillage equipment. Richard adds, "We did keep one chisel to fill in combine ruts, but since we went to no-till, we haven't had any."

Photo by Matt Hagny

Wuerfleins' wheat after milo. While not the greatest crop sequence, the plant health is much better than continuous wheat in the area.

"Between rotations and no-till, we started seeing some responses to our problems. We broke the disease cycle. We started infiltrating the water," Richard explains. "For instance, the field across the road was half salt spots. Now the salt spots are shrinking. [Previously] nothing grew in those salt areas—the soil was cement. We don't grow huge crops in those spots now, but at least the plants survive and make grain. And it's getting better every year."

Gainful Procedures

Wuerfleins' rotation essentially has been wheat >>wheat/dc milo >>milo, growing four crops in three years. They've continually experimented with several other crops, focusing on "the need for different crop types." They've noted the boom-or-bust tendency of soybeans, but haven't totally given up on them yet. Cotton did alright the one year they tried it, but they insist that hiring harvest is difficult, and the frequency of 2,4-D and other herbicides being flown onto pastures in the area is problematic for sensitive crops like cotton. This is their second year with winter canola, which made 1200 lbs/a for them last year ('05) when the wheat nearby was only 20 – 30 bu/a due to drought. Canola goes into wheat stubble carried over the summer, replacing the second year of wheat in the rotation. They will try some corn in '06, but are cautious about it (soils at Enid are less than wonderful).

James' 750 drill was traded for a planter in '02, as they'd gradually migrated from putting milo in with this drill to using a planter. James' 12-row 30-inch planter is now used for all their milo. Fertilizer for single-crop milo gets applied during the winter as urea, in the range of 120 – 140 lbs/a of N. Richard explains, "The co-op has an anhydrous cold-flow rig that we rented quite a bit last year. We didn't like it. We think it dries the soil too much—the moisture wicked out wherever the knife went." He notes that it got too dry in those zones to germinate seed in April, which is their optimum planting date for first-crop milo. "We're leaning away from NH_3. If you have vapor losses, that offsets some of the price difference." Milo also gets 7 – 8 gallons of 10-34-0 alongside the row with the planter, with a 2x0 opener. Wuerfleins have had some chinchbug issues on edges of milo fields, but otherwise few insect problems. Richard explains that they have very few greenbug problems with no-till, and that midge hasn't shown up yet, perhaps because so little milo is in the area.

"One thing we do know: Put the lime on top— it works."

Early on, Wuerfleins didn't put any fertilizer at all on their double-crop milo, but gradually started applying up to 45 lbs/a of N for it, and have seen substantial yield responses. They've tried broadcasting urea for the dc milo, as well as running liquid through the planter's fertilizer openers. James says, "We're still working on fertilizer placement. But one thing we *do* know: Put the lime on top—it works." (*Editors: The effectiveness of surface-applied lime is well documented*.)

Wheat goes in with Richard's 36-ft JD 1890 air drill, along with 11-52-0. (Due to various trades, Richard ended up owning the drill instead of James, and they've stuck with the Deere 750-style opener: "We have tight clays, so we need something with good down-pressure.")


Photo by Matt Hagny

Wuerfleins' winter canola growing amidst the old wheat stubble.

Wuerfleins' wheat gets 40 – 60 lbs of N surface-applied in the fall (especially the wheat following milo), and another top-dress in February of 30 – 60 lbs of N. Most surface N applications are urea.

Wuerfleins' management of wheat does differ substantially from the Okie norm. Their wheat is planted considerably later than anyone else's, for two reasons: They don't intend to graze it, and, as Richard points out, "We do a lot of custom seeding, and everyone wants theirs in early for grazing." They see some advantages to later planting, including fewer aphid problems. As for the stocker situation, they dropped the practice mostly due to high stocker prices eliminating much profit potential, although they don't seem overly eager to return to the practice, despite maintaining a stock-cow herd anyway. Some of their milo stalks get grazed, and on rare occasion a wheat field. "There's some surface compaction with cattle in no-till, but it doesn't really show up much in the next crop."

James explains their rotational observations thus far: "We definitely don't ever want to go to third-year wheat, because all the grasses show back up. . . . One year out of wheat is enough to clean up the bromes [downy brome, etc.], but not the feral rye [*Elymus* spp., not cereal rye]." Apparently the feral rye hasn't gotten too bad, nor has Italian ryegrass infested their area yet as it has elsewhere in Oklahoma. Wuerfleins' rotational system has worked for 5 – 10 years, apparently acceptably so far. Richard says they don't use any grass herbicides in their wheat: "It's cheaper to rotate."

Reading Between the Lines

Many of Wuerfleins' choices are built around efficiency, with land scattered across 30 miles, and several thousand acres of custom seeding each year. “We try to harvest full-season milo, then plant wheat, then harvest double-crop milo,” and with this rotation scheme, Richard says, “Our one combine covers three times the acres than if we just had wheat.” They still hire about half to 2/3 of their wheat harvested. Wuerfleins also hire all spraying done, since their co-op does a good job and is timely.

Some of Wuerfleins’ exposure to new ideas comes from being seed suppliers, both of wheat and an NC+ dealership. James especially likes to stay in the milieu, serving on commodity commissions, taking in some field days, meetings, and so forth. Both Wuerfleins are willing to get involved with researchers whenever something needs investigation, and are good observers themselves.

Locals will know the John Deere dealer convinced Richard to let them do a tillage demonstration on a tract of his next to Enid. (James remarks, “I wouldn’t let them on mine!”) Richard asked them to only do a small area of the 80. Later, the Deere guys told him, “We did you a favor and chiseled most of the field,” to which he replied, “Oh, you just *think* you did me a favor.” They planted soybeans across all of it, and watched the beans on the tilled area put on a burst of early growth—“The no-till side looked puny.” But later, the tilled soybeans began showing drought 2 weeks earlier than the no-till side. In the end, yields were the same. Richard says, “They proved the opposite of what they intended.” Wuerfleins knew better, given their previous experience with ripping.

Wuerfleins have had some welcome surprises with their no-till. Richard remarks, “We used to have to replant about half the wheat every year. We’ve hardly ever replanted anything since we went to no-till—just one field [in 10 years]. The neighbors [who do tillage] still have trouble though—crusting, covering the seed too deep, etc. . . . We even get perfect stands on the old red gumbo. Now *there’s* the answer [to seeding in gumbo]—with no-till, the problems went away.”

Photo by Matt Hagny

James examines his wheat.

Any downsides to no-till? Richard answers, “On the pastures surrounded by land we farm, we don’t get enough runoff to keep the ponds full.” Needless to say, the infiltration on the no-till cropland is valuable enough that he’s not bitching much.

No·till On The Plains

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