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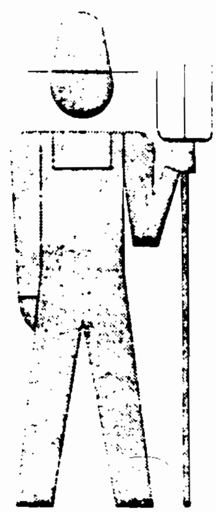

BIOGRAPHIES
&
SUMMARIES

International Association for New Science

The Benefits of No-till and Reduce-till Dryland Cropping Systems

by

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Abstract

No-till and reduce-till (commonly referred to as conservation tillage) have become important soil-crop management schemes on dryland farms of the Central Great Plains. They are important because they protect the soil from erosion. can increase soil-organic matter. improve precipitation-storage efficiency, increase biological yield and increase the number of crop options for rotations. In our region of the Great Plains. 12 to 20 inches of precipitation is typical. The traditional crop production scheme has been winter wheat fallow. Using our best management practices. we might store in the soil 50 percent of the precipitation that falls during the fallow period for use by a subsequent crop. Improved precipitation storage efficiency (PSE) with no-till. has enabled researchers and farmers to look for more intensive crop rotations. However. these rotations require careful consideration of the probability of receiving adequate precipitation for crop growth and development. Long-term weather data and water-use production functions can help guide farmers in making management decisions with respect to crop choice in a given year for no-till systems.

Introduction: Dryland farming in the West Central Great Plains-a short history

The traditional dryland production system in this region for the last 50 years has been winter wheat-summer fallow (Haas et al. 1974). Summer fallow is defined as the practice where: no crop is grown and all weeds are killed by cultivation or herbicides during the summer when a crop is normally grown. Summer fallow is done to store precipitation during the fallow year in anticipation of better yields and reduced risk of crop failure from drought the subsequent year. The average annual precipitation for Northeastern. Colorado varies from year to year. requiring producers to rely on stored water for crop success (Fig. 1).

In the "dirty thirties" summer fallow was conducted using moldboard or one-way disk plows that invert the soil and bury weeds. Unfortunately. this kind of tillage greatly increases soil water loss by evaporation. Researchers (USDA-ARS) at Akron. Colorado estimate that 0.4 inch of water is lost through evaporation within two days after tillage with a disk or chisel (Table 1). Precipitation storage efficiency (PSE) during the 30's was only 24% mainly because of the kind of tillage used (Fig 2).

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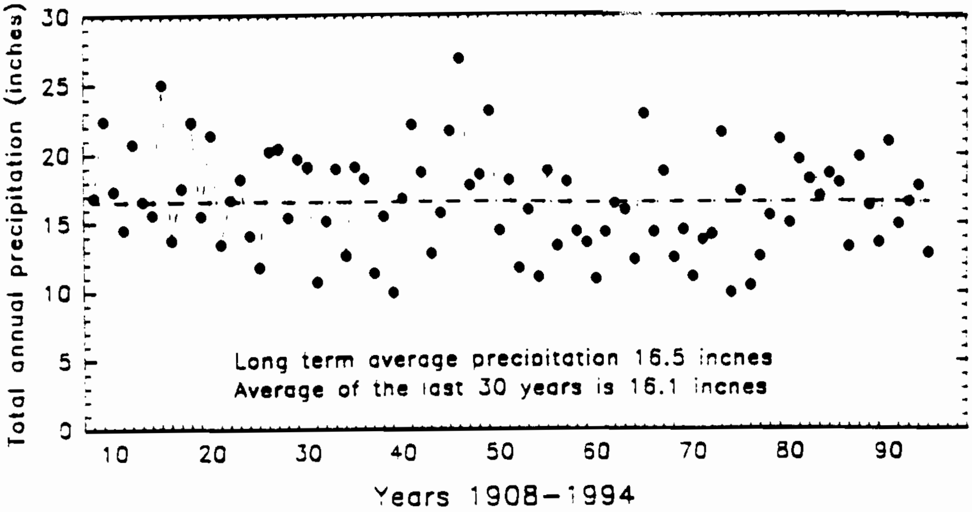

Fig 1. Long term precipitation record at Akron, Colorado. The dashed line is the long term average of 16.5 inches.

In the 1950's and 60's, the "stubble mulch" system was developed. Stubble mulch relies on the use of sweep-plows, consisting of v-shaped blades, pulled at shallow depths to undercut weeds. Sweep-plow tillage causes the loss of about 0.1 inch of water within 2 days after tillage (Table 1). Using sweep-plows in stubble mulch increased fallow PSE to 33%. Herbicides have allowed us to develop reduce-till and no-till fallow. With reduce-till, residual herbicides are used to control weeds after wheat harvest. Tillage with sweep-plows are then used after the herbicide has begun to lose activity. In reduce-till PSE is near 40% (Fig 2). With no-till, both residual and contact herbicides are used. The soil surface and crop residues are never disturbed increasing PSE to near 50%. In this respect, no-till is our best management practice for storing soil water during fallow.

The increased water savings with no-till has prompted researchers to examine more intensive non-traditional crop rotations (Peterson et al. 1992, Halvorson et al. 1994). These include: wheat-millet-fallow, wheat-corn-millet-fallow, wheat-millet-sunflower-fallow (several others). That research indicates that we can grow successfully more than one crop in two years. An examination of the response of some of these other non-traditional dryland crops to no-till elucidates the interest (Fig 3) particularly for dryland corn.

Table 1. Effect of tillage on residue reduction and soil water loss 1 through 4 days after tillage (from Good and Smika 1978).

		Soil water loss (inches) in the 0 to 5 inch depth		
Tillage implement	Residue reduction	1 day	2 day*	4 day
Tandem disk	75	------**	------	----
One-way disk	50	0.33	0.39	0.51
Chisel	10	0.29	0.35	0.48
Sweep-plow	10	0.10	0.11	0.14
Rod-weeder	15	0.04	0.10	0.22

* Values are linear interpolations between measured values at 1 and 4 days.
* data not collected for tandem disk in this study

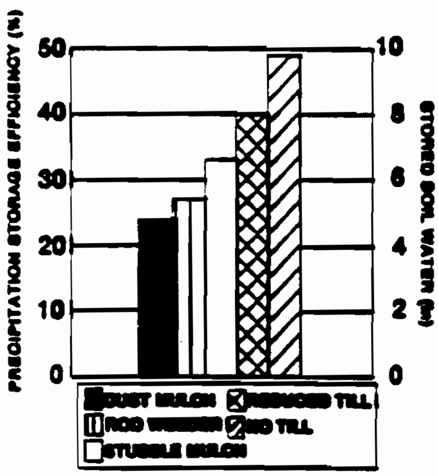

Fig 2. PSE and stored soil water for various fallow methods (from Nielsen and Anderson 1993)

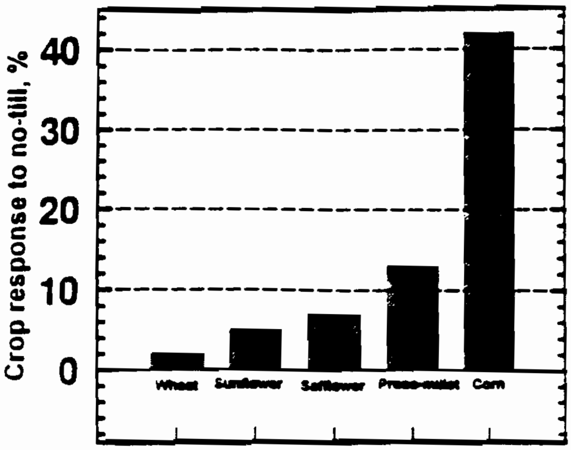

Fig 3. The percentage increase in yield using no-till over conventional till in a continuous dryland cropping system where the previous crop is winter wheat.

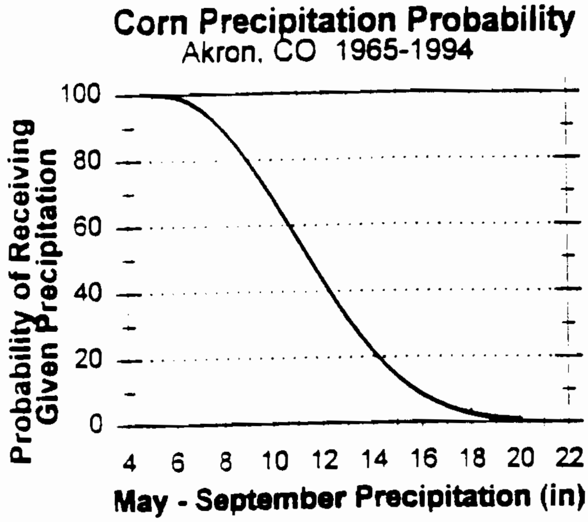

Fig 4. Rainfall-probability distribution for the growing season at Akron.

However, success of more intensive rotations depends on conservation-tillage management. Moisture is valuable and tillage not needed to control weeds can be costly. For the production of dryland wheat, at least 7 inches of total water are needed before any yield will be harvested. That 7 inches can come from stored soil water or precipitation. After the first 7 inches of water, any additional water (whether it be stored or fall as rain) produces about 6.5 bushels of grain per inch of water. For dryland corn the relationship is about 10 bushel per inch of stored soil water or precipitation after the first 9 inches. Using these relationships and those in table 1 we can calculate that two one-way disk operations cost as much as 10 bushels of grain ($20-$30).

We have established that more intensive rotations will work. However, with our variable climate farmers are cautious about adopting these schemes. Their caution is justified because such schemes require additional management, capital, knowledge and some additional risk.

Reducing the risk with production functions and probability distributions

In the preceding paragraph, we mention that wheat will produce about 6.5 bushels of grain per inch of water after the first 7 inches water. This relationship between wheat yield and available water is a water-use production function (D.C. Nielsen 1995). Production functions have been developed for other dryland crops grown under field conditions at the USDA-ARS Central Great Plains Research Station in Akron Colorado. Some of these are given below:

Proso millet (lbs/acre)	= 237	x (inch of water) -818
Corn yield (bushels/acre)	= 10.4	x (inch of water) -94.9
Wheat yield (bushels/acre)	= 6.5	x (inch of water) -43.95
Sunflower (lbs/acre)	= 161	x (inch of water) -843

More detail about these production functions can be found in the fact sheet cited. How to use these functions can be explained by an example. Let's assume a farmer in Washington County (near Akron) wishes to plant dryland corn. The farmer probes the soil the last day of April to assess soil available water to a 6 foot depth. For our example, the farmer finds 8.0 inches of available water in the profile. The farmer knows that the total long term-average precipitation for the months of May, June, July, August and September is 11.5 inches. If our field were to receive the average precipitation, the yield potential could be calculated as:

Corn yield = 10.4 x (8.0 inches available in profile + 11.5 inches as rain) -94.9
Corn yield = 107.9 bushels

That looks dandy, but how do we know if our farmer will get the average rainfall? How can we even guess if he/she will even get 50% of the average, or 75% of the average? This is where long term weather records can help. At Akron we have precipitation records since 1908 (Fig 1). However, if we take the last 30 years (which were drier than average) we can plot a rainfall-probability distribution for the corn growing months of May through September (Fig. 4). In Fig. 4. we see that 80% of the time (8 out of 10 years based on the last 30 years of data) that we will have at least 8.7 inches of precipitation for May through September. Our function can then be used to determine yield on an 80% probability:

Corn yield = 10.4 x (8.0 available in the profile + 8.7 inches 80% of the time) -94. 9
Corn yield = 78.8 bushels

This is a very good yield for dryland corn, but is not unreasonably high. However, we need to be cautious. Precipitation that falls during silking and pollination, influences corn yields more than that which falls at other growth stages. Timing can be as important as total amount of precipitation received. Silking and pollen shed (depending on the year and the variety) generally occur in Washington county the last week of July or the first two weeks of August. Pollen shed lasts about 9 days. During this period water use is about 1/3 of and inch per day. So, for maximum pollination, we need at least 3 inches of water available to the crop during this period. Again, some of this water can fall as rain and some can come from soil water storage. A rainfall-probability distribution for this three week period would be helpful. But soil water available during this time is just as important. So with respect to dryland corn we can't speculate any more about the probability of success.

For crops like proso millet and sunflowers, there isn't a dominating critical water stress period and the use of rainfall-probability distributions can be more predictive. Since proso doesn't root as deeply as corn (only about 3.5 feet) we have less soil profile to extract from and therefore less available.

Proso-millet yield = 237 x (5.4 available in the profile + 8.7 inches 80% of the time) -818
Proso-millet yield = 2520 lbs (about 50 bushel)

Sunflower roots as deeply as corn, but has a lower wilting point and will extract more water from the same soil profile than will corn. For sunflower we might have 10 inches available:

Sunflower yield =160.5 x (10 available in the profile + 8.7 inches 80% of the time) -843
Sunflower yield = 2158 lbs of sunflower.

Other effects of no-till: organic matter and the undisturbed residue layer

Continuous no-till increases the amount of surface-crop-residues, and over the long term increases soil organic matter at the soil surface (Fig 5). This build up of organic matter, along with the water conserving attributes of no-till can have some interesting side effects. Research conducted in eastern Kansas (Vigil et al. 1987) indicated a savings of up to 2 inches more water in no-till sorghum than in conventional sorghum. Water savings increased yields in dry years. Surprisingly, the reasons for the yield increase were not always what you might expect.

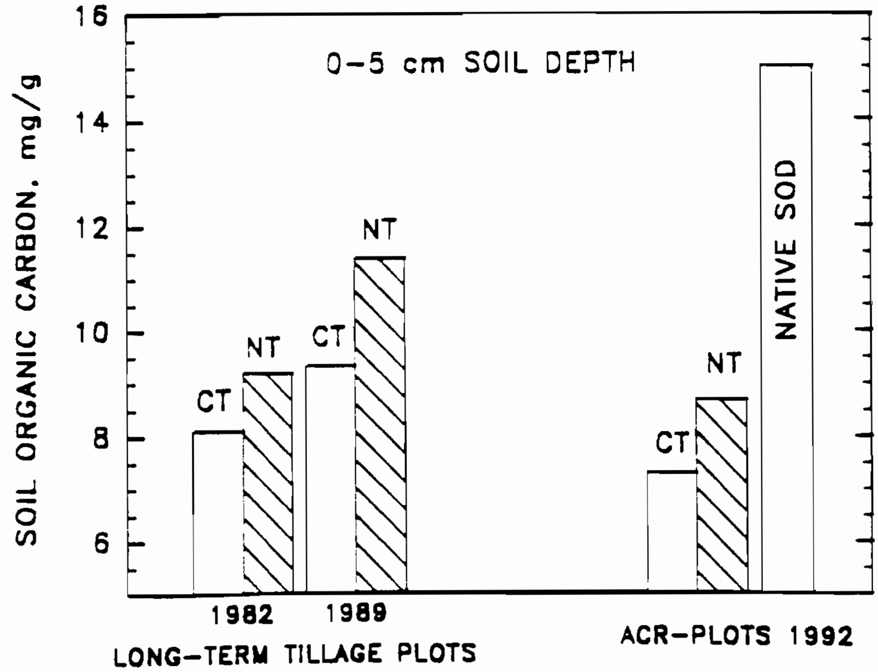

Fig. 5. The increase in soil organic carbon in no-till (NT) over conventional-till (CT) in the surface soil of two sets of research plots at the USDA-ARS, Central Great Plains Research Station, Akron Colorado.

In the Kansas study, we used a split-plot tillage design with tillage methods as main plots and method of fertilizer placement by N-rates (30, 60, and 120 lb N/acre) as the subplot treatments. Two methods of fertilizer placement were used: broadcast urea-ammonium-nitrate (UAN), and knifed UAN. A check plot without N fertilizer was also included in the design for each tillage method. Tillage consisted of disking three times between harvest and planting of the crop the next season. The last two diskings were immediately following fertilization to incorporate fertilizer.

That research showed no significant differences for methods of placement at high N rates. However, sorghum fertilized with a knife applicator (where N was placed below the surface residue layer) was better in no-till at the lowest N rate. The optimum N rate was between 60 and 120 lbs for either tillage system.

The N mineralization paradox

Surprising results showed more grain (10 to 20 bushels more!) in our no-till check plots (plots that received no fertilizer N) than in the conventional-till check plots in dry years (Table 1). Also interesting, is that the yield advantage in no-till, was not measured in plots fertilized at the higher N rates.

When N was knifed at about a 6-8 inch depth (at the 30 lb N rate) we measured 5 to 10% more grain yield in no-till plots than in conventional-till plots. That sort of made sense to us, because by knifing N below the surface residue layer, we avoided any potential fertilizer-N tie up by residues lying on the soil surface. But as the N rate increased, the yield advantage for no-till just wasn't there even with the knifed plots. That had us puzzled. Usually one would suspect that the yield advantage, if from moisture, would be seen at all N rates.

We suspected that the yield advantage in the no-till check plots (at low N rates) in dry years was not just a sorghum growth response to more water but a response to greater N fertility. This suspicion was supported by significantly greater plant tissue N found in sorghum growing in no-till check plots than in conventional-till check plots in years 1 and 5.

The bottom line was the crop was seeing more N even if we didn't apply it. How could that be if no N was applied in the check plots?

What we believe was happening in the no-till plots is a process called N mineralization (Nmin for short). Nmin is simply the release of N from soil organic matter that occurs when soil microbes munch on crop residues and other soil organic matter constituents.

Actually, the Nmin process was happening in both no-till and conventional till plots. However, in the no-till plots the surface soil was loaded with crop residues and was wetter than the conventional till plots that were tilled three times each year. And soil microbes are more active in moist soil than in dry soil (Vigil 1995). Also, tillage mostly dries out the tilled layer of soil (usually at the soil surface) where most of a soils organic matter can be found. Thus the condition of more organic substrate at the surface with no-till, combined with better conditions for Nmin may have enhanced Nmin in no-till above what may have occurred in conventional till.

The greater yields measured in the no-till plots (in check plots and at the low N rates) may have been as much a function of Nmin as a function of higher soil water storage. The dramatic yield advantage not measured in no-till versus conventional-till at the higher N rates may have been because fertility was adequate at those rates and the Nmin effect was hidden or masked by adequate fertility. Future research is planned to adequately study this process.

Table 2. Average grain yields (average of three replications) for tillage treatments for 5 crop seasons and across all N-rates and placement methods.

		Average grain yield				
Tillage system	Treatments	year 1	year 2	year 3	year 4	year 5
			bushels/acre			
No-till	check plots	42	66	52	62	53
Conventional	check plots	23	61	58	56	30
Stat. significance†		*	ns	ns	ns	*
No-till	All fertilized plots	50	85	92	97	74
Conventional	All fertilized plots	52	84	99	101	69
Stat. significance		ns	ns	*	ns	ns
Seasonal rainfall (March-September)		21.6	34.8	29.6	35.1	25.6

† Averages grain yields in a given year that have an "*" are considered truly different and based on this experiment, the differences are not due to chance alone. Average grain yields in a given year that have a "ns" associated with them are not considered significantly different. That is based on this test the measured differences may be due to chance alone and are not considered due to treatment effects.

In summary: Tillage practices that invert the soil (like disking and moldboard plowing) disrupt the protective surface-residue barrier. This opens and exposes moist subsoil to drying winds and direct sunlight. The greater the tillage depth, usually the greater the moisture loss. Non-traditional rotations are being studied that take advantage of the additional water savings with no-till. Increased rotation intensity using no-till/reduce-till practices, increases surface soil organic matter which can affect soil fertility and nutrient cycling. The use of rainfall-probability distributions for a given region, combined with water use production functions and soil sampling for available soil water can be used to help a producer decide which crop rotation will work best in a given year.

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