TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
MICHIGAN

AGRONOMY #30
Nutrient Stratification in No-Till
April 1992

To: All Offices

From: Shirley A. Gammon, Assistant State Conservationist

Numerous studies have identified nutrient stratification occurring under long-term no-till conditions. Questions often asked by growers about nutrient stratification are:

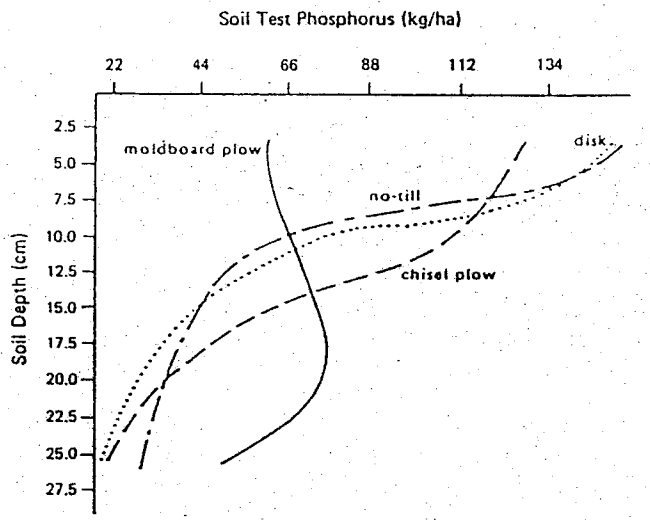
- If there is nutrient stratification with no-till, what is the stratification?
- How do nutrients stratify in no-till?
- How much stratification is there and what should a farmer do about it?
- Is there any way to slow nutrient stratification?
- Should you plow your no-till occasionally?

If there is nutrient stratification with no-till, what is the stratification?

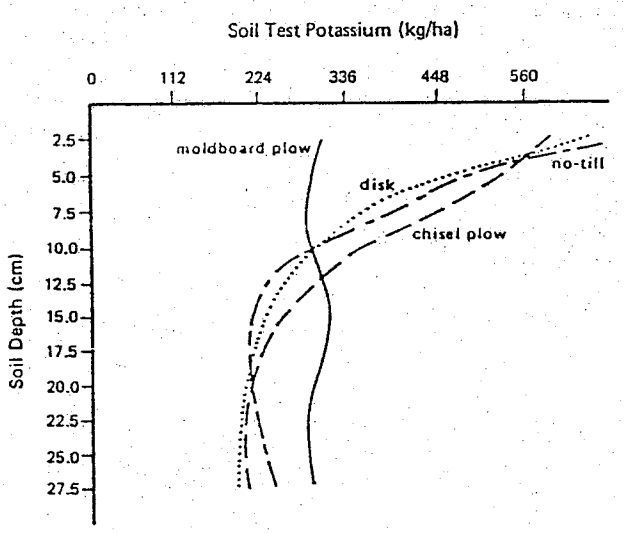
George Rehm, Soil Scientist, University of Wisconsin, documented nutrient stratification at the Waseca, Minnesota tillage trials for the disk, chisel plow and no-till tillage systems. (Fig. 1) Phosphorus accumulated at the surface in the no-till, chisel and disk tillage plots. (4)

In 1982, Dave Mengel, Department of Agronomy, Purdue University, also reported nutrient stratification under long-term no-till. P and K levels were approximately 3 times higher at the 0-3 inch sample depth than the 3-6 inch depth. (3) (Table 1)

FIGURE 1



Effect of tillage system on the soil test values for phosphorus, Waseca, MN.



Effect of tillage system on the soil test values for potassium, Waseca, MN.

TABLE 1

P & K Soil Test Levels Found At Various Depths In The Soil

After 7 Years No-till

	Soil Test	
	P	K
Depth	No-Till	
Inches	Bray P1, Kg/Ha	Exch. K, Kg/Ha
0-3	180	570
3-6	55	200
6-9	35	200
9-12	15	200

Source: Developing Fertilizer Programs For Conservation Tillage David B. Mengel, Dept. of Agronomy, Purdue Univ. Cruz et al., Ph. D. Theisis, 1982,

TABLE 2

TABLE 2 The effect of four years of no-till corn production upon soil test levels in an irrigated Tedrow loamy sand soil (Gratiot County)

Soil Sample Depth	Soil pH	Soil Test P (ppm)
0-2	5.6	220
2-4	5.9	104
4-6	6.4	47
6-8	6.6	35

Source: MSU Extension Bulletin E-1616, 1983

And at Michigan State University, Vernon Meints and L.S. (Bus) Robertson reported nutrient stratification of phosphorus after four years of no-till corn production on an irrigated Tedrow loamy sand soil (Gratiot County). (Table 2) There was 5 times the P at the 0-2 inch depth and 3 times the P at the 2-4 inch depth. (6)

Therefore, it seems nutrient stratification of P and K can occur under long-term no-till management.

Other concerns by growers regarding nutrient management were addressed by Rehm in his paper, **"Managing P and K in Conservation Tillage Systems"**. According to Rehm, "As growers switched from the more conventional tillage to conservation tillage ... several questions about fertilizer management have been raised." (4)

- How important is starter fertilizer?
- Can I continue to broadcast P and K or will concentration of these nutrients near the soil surface reduce yield?
- Will recommended rates of P and K change (... under long-term no-till?) (after 5 years?)
- How much P and K can I place close to the seed?

The following paragraphs, tables and figures will share some of the current thinking on these questions.

How do nutrients stratify in no-till?

Two ways: normal crop growth and by not incorporating broadcast fertilizer.

According to Dr. Earl Erickson, Michigan State University agronomist, there is a trend for "a rich layer near the surface and depleted zone below it ... and depending on soil test levels, it shows up in 3-5 years." (3)

How much stratification is there and what should a farmer do about it?

The best way to check nutrient stratification is through soil testing. Generally most publications suggest testing for surface pH changes. However, Mengel suggests 1 of 3 methods to sample as follows:

1. In tillage systems that use the moldboard plow, at least once every four years, take one sample 0-8" or 0-10" deep.
2. In no-till where nitrogen fertilizers are injected into the soil, split the soil sample, one from the 0-4" layer and one from 4-8" deep. Monitor the liming needs of the deeper placement zone where the nitrogen could have created an acid layer.
3. In no-till systems where nitrogen fertilizers are applied to the soil surface, split soil samples into 0-2" segments and 2-8" segments. (1)

Methods 1 and 3 agree with recommendations from Michigan State University, Penn State and Ohio State. The goal is to maintain the surface pH. Triazine herbicides like Sencor, Atrazine, Bladex and Princep will then remain "active" and not "tied up" by a low surface pH.

Dr. Erickson, Michigan State University, noted that: "Phosphorus is very immobile and tends to stay put where you put it!!" (3) And according to Mengel, "Because 70% root concentrated under no-till are on the top 4" of soil, phosphorus rate should be based on soil tests ... 0-4" deep if P is testing in the medium range or higher. (Table 3) **Low or very low testing soils** may need "buildup" via deep plowing periodically and a fertility buildup program." (1) Soil test 0-8" deep in this case. However, under no-till corn, he suggests using 25-30 lb. P_2O_5 because of cooler soil temperatures even if soil tests do not call for it.

-Table 3

Effect of tillage system on root weight and distribution.

	Tillage System		
Depth	Plow	Chisel	No-till
inches	-- root weight (milligram/core) --		
0- 3	250	275	625
3- 6	325	325	250
6- 9	170	160	160
9-12	75	70	75
Total	820	830	1110

George Rehm, Minnesota, also noted that:

- "phosphorus fixation/tie up is a consideration. In calcareous soils (pH greater than 7.3), free calcium reacts with soil or fertilizer P to form insoluble calcium phosphate materials ... the more contact of fertilizer with soil the more fixation (4) ..."

He prefers banding P where fixation is a possibility because it should be more efficient than broadcasting.

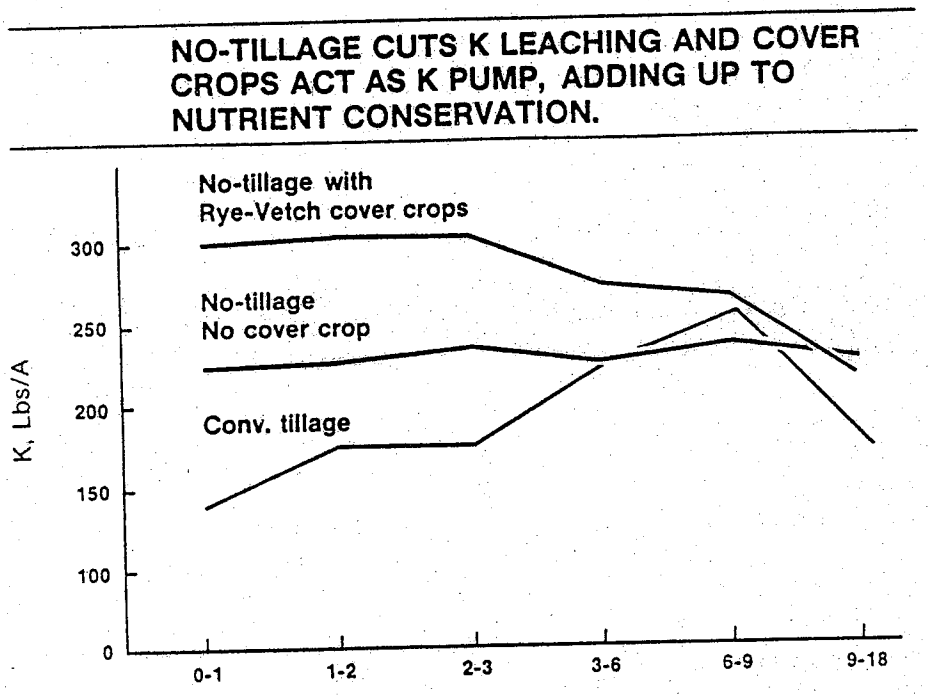
In Michigan, at the Clarksville Agricultural Experiment Station, Ionia County, as part of the Morrison Lake Project, banded P starter fertilizer was compared to no-starter corn with existing high soil P levels. After four years of continuous corn; no-till and tilled; with starter verses no-starter; irrigated and non-irrigated; the replicated plots resulted in no significant response to starter P. (5) (Table 4)

Table 4

CLARKSVILLE AG EXPERIMENT STATION PHOSPHORUS STUDY

1988	IRRIGATED	NON-IRR	OVERALL	MSU SOIL TEST AVAIL. PHOS. LBS/AC. BRAY P1 RANGE
CONV.TILL- NO P205	126.6	92.6	109.6	74-215
CON.TILL- WITH P205*	126.6	90.1	108.4	
NO-TILL NO P205	129.7	92.6	111.2	
NO-TILL WITH P205*	128.7	94.6	111.6	
* 69 lbs/ac starter				
1989				
CONV.TILL- NO P205	171.3	161.4	166.3	82-219
CONV.TILL- WITH P205*	170.6	164.5	167.5	
NO-TILL NO P205	155.0	156.4	155.7	
NO-TILL WITH P205*	159.6	159.2	159.4	
* 55 lbs/ac starter				
1990				
CONV.TILL- NO P205	159.1	157.7	158.4	64-202
CONV.TILL- WITH P205*	166.7	161.1	163.9	
NO-TILL NO P205	142.9	151.9	147.4	
NO-TILL WITH P205*	144.8	156.0	150.4	
* 44 lbs/ac starter				
1991				
CONV. TILL- NO P205	156	123	132	64-202
CONV.TILL-WITH P205 *	154	128	141	
NO-TILL NO P205	135	119	133	
NO-TILL WITH P205 *	154	121	139	
* 50 lbs/ac starter.				

Figure 2



Potassium (K), likewise, can accumulate under long-term no-till.

W. H. Mitchell, extension agronomist, University of Delaware, looked at "fourteen pairs of farm fields (tillage versus no-tillage) involving one to eight years of continuous corn production." (2)

On the loamy sand soils of the eastern shores of Delaware, under continuous corn, he found that: No tillage cuts K leaching and cover crops act as a K pump, adding up to nutrient conservation. (See Figure 2)

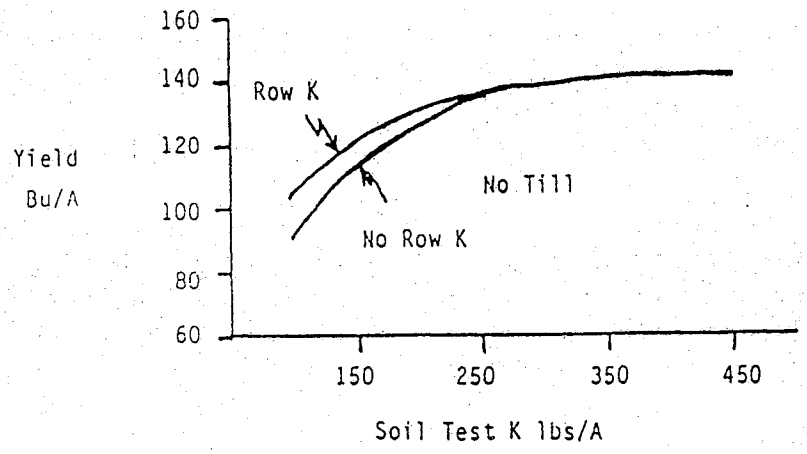
Continuous no-till corn with rye vetch cover crops resulted in 2 times the accumulated K at the 0-3" depth versus conventional tillage. Soil tests averaged 300 lb/acre for the no-till using cover crops in the system verses 150 lb/acre for conventional tillage using no cover crop.

In this same study, **no-till corn without a cover crop** also increased the available potassium. According to Mitchell, "Soil samples from no-tillage fields contained 30 percent more potassium than soil from tilled fields. There was evidence that accumulated organic matter under no-tillage ... reduced potassium leaching." (2)

What about the response of no-till corn to starter potassium?

Rehm, in his Goodhue County study, showed no-till corn yield increases with 11 lbs. of starter K_2O in 1985 where soils test K values were 200 lbs/acre or less. (Fig. 3)

Figure 3



The effect of tillage, row potassium, and soil test K on corn grain yields at Goodhue County, 1985.

However, when soil test K levels were 300 lbs/acres or higher there was not corn yield response to applied K_2O under no-tillage management. (4)

In 1989, Ray Rawson, Rawson Coulters, Farwell, Michigan, wanted to know if his soils were stratified after 14 or more years of no-till. Soil samples were taken at 0-2", 2-4", 4-6", 6-8" and 0-8" depth on an Ithaca loam and Perrinton loam. Both soils had stratification of P, K and organic matter at the 4" depth. (Table 5)

Table 5

NUTRIENT STRATIFICATION LONG TERM NO-TILL

RAY RAWSON FARM 15 YEARS NO-TILL

SOIL: Perrinton loam (1.5a) [well-drained loam]

	DEPTH (In.)				
SAMPLE	0-2	2-4	4-6	6-8	0-8
P	138	122	76	52	64
K	380	288	216	178	250
Ca	1600	1500	1400	1400	1600
Mg	230	200	170	190	210
pH	5.8	5.6	5.7	5.5	5.8
O.M.	2.4	2.8	2.4	1.9	2.0
CEC	5.8	5.6	5.7	6.1	6.4

note: P- Phosphorus; K- Potassium; Ca- Calcium
Mg- Magnesium; O. M.- Organic Matter
CEC- Cation Exchange Capacity

SOIL: Ithaca loam (1.5b) [somewhat poorly-drained loam]

SAMPLE	0-2	2-4	4-6	6-8	0-8
P	120	78	48	34	120
K	336	258	204	160	120
Ca	2480	2240	2160	1920	2320
Mg	320	350	335	312	358
pH	6.7	6.2	5.8	5.9	6.2
O.M.	2.8	2.1	2.2	2.1	2.3
CEC	8	9	9	8	9

note: P- Phosphorus; K- Potassium; Ca- Calcium
Mg- Magnesium; O. M.- Organic Matter
CEC- Cation Exchange Capacity

Also, Rawson evaluated strip banding of all the required potash for 150 bushel/acre corn yield. Sometimes this exceeded the 100 lbs starter potash rate recommended by Michigan State University.

Six rows of Rawson's twelve-row planter had the conventional fertilizer placement; a leading cutting coulter ahead of a single disk dry fertilizer opener. The other six rows were set up with a coulter drop tube system to deliver the fertilizer in a zone by the seed. Fertilizer is placed on the lead edge of the coulter and incorporated in a band beside the seed at planting. Two years of corn yield data was collected by using 1/1000 acre paired samples 30" apart at random across two different fields.

In 1989 there was a 12 bushel/acre yield advantage for corn with the Rawson coulter fertilizer tube setup compared to his conventional 2 X 2 placement. (Table 6)

Table 6

RAWSON FARMS CORN FERTILIZER STUDY 1989

LOCATION; GILFORD TWN ISABELLA COUNTY RIVER TERRACE FIELD

FERTILIZER WITH COULTER TUBE			FERTILIZER WITH SINGLE DISK		
ROW	POP	WGT.	ROW	POP	WGT.
30	24	8	31	23	7.3
43	24	8.5	42	23	8
54	25	9.6	55	24	8.8
54	25	9	55	24	7
43	22	7	42	21	7
30	26	8.5	31	25	7.5
30	27	7.9	31	23	7.5
43	25	8	42	22	7.6
54	26	7.1	55	23	5.8
30	25	7	31	24	6.8
totals	249	80.6		232	73.3
average	24,900			23,200	
x1000		8060			7330
%moisture	21.5%				
Dry bu/ac.		133.71	15.5% moisture		121.60
15 YEARS OF NO-TILL					
%moisture	26%				
Dry bu/ac.		126.04	15.5% moisture		114.62

In 1990, strip banding was again compared to 2 X 2 placement on corn. This time fourteen random 1/1000 acre paired samples were hand shelled. There was no difference in the yield. (Table 7)

Table 7

RAWSON FARMS CORN FERTILIZER STUDY 90
LOCATION; GILFORD TWN ISABELLA COUNTY LARRANCE PLACE

FERTILIZER WITH COULTER TUBE				FERTILIZER WITH SINGLE DISK		
ROW	POP*	WGT.	VARIETY	ROW	POP	WGT.
6	24	9	PIO 3751	7	24	10
6	25	9.8	PIO 3751	7	25	10.5
6	23	8.4	PIO 3751	7	22	7.5
9	21	7.7	GL 420	10	23	7.6
4	22	8.2	PIO 3733	3	23	8.3
9	23	7.3	PIO 3794	10	22	7.7
4	23	7.5	GL 350	3	19	6.5
9	24	7.7	SUP.CRS.1594	10	24	7
4	25	8.7	" " 424	3	24	8.3
9	26	10.3	DEKALB 451	10	21	9
4	24	9.3	GRT.LKS. 459	3	19	7.3
9	19	6.3	GOLD HV.H2344	10	21	8.4
4	24	8.3	BAYSIDE BX91	3	27	8.5
9	23	7	DEKALB 421	10	26	8
totals	326	115.5			320	114.6
average	23286			22857		
x1000		8250			8186	
%moisture	21.5%					
Dry bu/ac.		136.86	15.5% moisture		135.79	
15 YEARS OF NO-TILL						
%moisture	26%					
Dry bu/ac.		129.01	15.5% moisture		128.00	

* Population

Rawson discontinued this study, feeling strip banding produces equal yields to 2 X 2 placement. A major advantage is less parts to maintain because the single disk fertilizer opener was eliminated by using the coulter tube banding method.

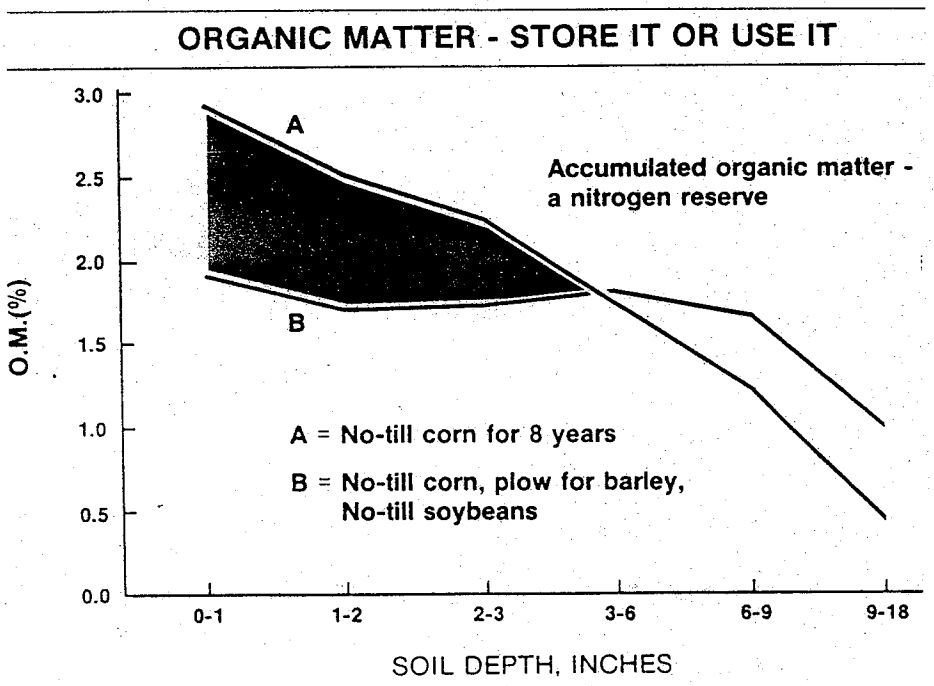
In Delaware, Mitchell compared no-till corn for 8 years to a 3-year rotation of no-till corn, plow for barley, followed by no-till soybeans. Mitchell reported:"

> "Accumulation of organic matter and residual nitrogen on farm fields A and B as shown in (Fig. 4). In each case, the farmer was pleased with his tillage system. On both fields the o.m. level was higher than in nearby tilled fields, but with alternate year tillage on field B, there was less o.m. accumulation. There was also no evidence of a nitrogen deficiency, which reflects the faster recycling of organic nitrogen. This could be explained by nitrogen contribution of soybeans in the rotation.

Field A has produced outstanding corn yields, but the farmer regularly uses more nitrogen than would be applied on tilled fields. Occasionally, tillage with a chisel plow, disc or other implement will aerate the soil and release some nitrogen. There is much speculation about the wisdom of doing this every three or four years, but there is no good evidence to show that it is necessary to use a moldboard plow to achieve consistently high yields.

In field A, the factors associated with high organic matter, such as higher exchange capacity, potassium accumulation, micro nutrient recycling and soil moisture conservation, have contributed to increased yields."

Figure 4



Dr. Erickson stated that, "Nutrient stratification is a bigger concern with phosphorus than with potash." He also added, "If you do it right, nutrient stratification should not be a problem." (3)

Perhaps, Rawson's strip banding, zone tillage and Mengel's 0-4" sampling depth can teach us all how to get more or the same yield with less phosphorus input and improve our Great Lakes water quality.

References

1. Mengel, Dave, 1982, **Developing Fertilizer Programs for Conservation Tillage**, Purdue University Cooperative Extension Service Bulletin.

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3. Petersen, Dean, 1986, **Manage the Effects of Less Tillage**, Michigan Farmer.

4. Rehm, G., 1988, **Managing Phosphorus and Potassium in Conservation Tillage Systems** and **Proceedings: Conservation Tillage on Wet Soils**, SCSA Conference, Clear Lake, Iowa, p. 68-75.

5. SCS Fact Sheet 680-1, 1992, **Zero Phosphorus on Corn**, USDA/SCS/Michigan, 1992.

6. Robertson, L.S. and Meints, V.W., 1983, **Soil Sampling for No-till and Conservation Tillage Crops**, MSU Facts, Extension Bulletin E-1616.

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