# Horizontal and Vertical Distributions of Soil C, N, P, K and pH in Continuous No-tillage Corn Production.

**M.D. Mullen and D.D. Howard[1]**

## INTRODUCTION

Long-term no-tillage crop production often results in the accumulation of organic matter and inorganic nutrients, particularly broadcast P and K, AT the soil surface due to a lack of soil mixing (Howard and Mullen, 1991, Karlen et al., 1991). The stratification of nutrients due to the lack of tillage can result in erroneous soil test results if soil sampling techniques are not carefully monitored (Kitchen et al., 1990; Tyler and Howard, 1991). The objective of this research was to determine the effect of long-term no-tillage corn production with broadcast applications of P and K fertilizers on extractable P and K concentrations within and between corn rows. In addition, total soil C and N and soil pH were evaluated.

## MATERIALS AND METHODS

A field experiment was established at the Milan Experiment Station, Milan, TN. in 1983 and continued through 1989 on a Loring silt loam soil (fme-silty, mixed, thermic, Typic Fragiudalf). During this time, no-tillage corn ('Pioneer brand 3389') was planted early- to mid-April each year in 30-inch rows.

The experimental design was a randomized complete block with a split-plot arrangement of treatments replicated five times. Main plots were $P_2O_5$ and $K_2O$ rates with sub-plots consisting of different starter $N$-$P_2O_5$-$K_2O$ combinations. For the purposes of this investigation, only the main plot treatments are considered. The P and K rates (P/K hereafter) were 0-0, 56-28, 112-56 and 168-84 kg $ha^{-1}$. The P/K treatments were broadcast applied in mid- to late-March using 0-46-0 and 0-0-60. Nitrogen, applied as UAN, was injected approximately 2 inches deep and 4 to 6 inches to the side of the row immediately after planting at a rate of 168 kg $ha^{-1}$.

Soil samples were taken between and within the corn rows. The between row samples consisted of seven soil cores taken 22 cm from two corn rows for a total of 14 subsamples per treatment. Likewise, 14 subsamples were taken directly over two corn rows. The soil cores were divided into three sections corresponding to the 0-7.5, 7.5-15, and 15-30 cm soil depths. Surface residue was removed from the soil surface prior to sampling. Extractable P and K were determined using the Mehlich I double-acid extractant followed by phosphovanadate colorimetry procedures for P determination and atomic absorption for K determinations. Total C and N were determined by dry combustion methods. Soil pH was determined by glass electrode in a 1:l soi1:water suspension. All data were analyzed using the ANOVA procedures of the Statistical Analysis System (SAS) computer program (SAS Institute, 1988). Mean separations were done using the LSD test.

## RESULTS AND DISCUSSION

As expected, both C and N have preferentially accumulated in the top 7.5 cm of soil. In addition to this vertical stratification, we also observed a horizontal stratification in C and N concentrations (Table 1). The trend was not strong for total C, however, total C concentrations were consistently higher within the corn rowsthan between the rows. The interaction between sampling position and soil depth was significant at $\alpha = 0.10$. This result

[1]Assistant Professor and Professor, Dept. of Plant and Soil Science. Univ. of Tennessee, Knoxville, TN.

is not surprising when considering that an accumulation of roots would occur in the row and this effect would tend to fade with distance from the row.

The effect of sampling position was much more evident for total N concentrations; N concentrations were 37%, 26%, and 15% higher within than between the row in the 0-7.5, 7.5-15, and 15-30 cm segments, respectively (Table 1). This is likely due in part to accumulations of fertilizer N since UAN was injected close to the row. The increase in N may also be root derived, however, this contribution would appear to be less important with depth, based on total C data. Microbial biomass N may also be higher in this zone, but the microbial biomass-N pool was not evaluated in this study. Previous work has found increases in biomass C and N under no-tillage conditions (Follett and Schimel, 1989). and conditions which promote increased organic C and N are likely to also promote higher biomass.

The C:N ratio in each soil segment was also significantly narrower within rows than between rows (Table 1). This narrowing is primarily due to the higher N within the row, as C concentrations differed only slightly between sampling positions at any depth.

Table 2 illustrates the effect of planting rows in the same location from year to year on Mehlich I extractable P and K. Extractable concentrations of both P and K were significantly affected by P/K application rates, as well as sampling position and soil depth. As P rate increased, P concentrations in the surface 7.5 cm also increased. There were no differences in P concentration in the 7.5-15 or 15-30 cm segments at any $P_2O_5$ rate. The vertical stratification of P at the soil surface in no-tillage has been previously documented (Howard and Mullen, 1991; Karlin et al, 1991; Tyler and Howard, 1991). Horizontal stratification of extractable P was also observed in the surface 7.5 cm of soil at the 112 and 168 kg $P_2O_5$ $ha^{-1}$ rates where P concentrations were higher between rows than within. These high rates evidently allowed for the accumulation of extractable P at the soil surface between rows over the seven year period. Tyler and Howard (1991) did not observe the horizontal stratification of P in these plots at the 112 kg ha- rate after three years, indicating that these extractable P concentrations have built over a relatively long period of time. We hypothesize that some of the P at the higher rates may be tied up in the organic P fraction, since organic matter also tended to be higher within the row. However, total P and organic P were not determined on these samples. Uptake of P within the row and subsequent removal with the grain would also be a factor, due to the relative immobility of P in soils.

**Table 1. Total carbon, total nitrogen, and C:N ratios between and within rows by sampling depth.**

| Depth (cm) | Total C (%) | | Total N (mg $kg^{-1}$) | | C:N Ratio | |
|---|---|---|---|---|---|---|
| | Between | Within | Between | Within | Between | Within |
| 0-7.5 | 1.06 b* | 1.10 a | 850 b | 1166 a | 12.61 a | 9.47 b |
| 7.5-15 | 0.65 c | 0.69 b | 690 c | 866 b | 9.47 b | 7.97 c |
| 15-30 | 0.39 d | 0.38 d | 508 e | 582 d | 7.68 c | 6.52 d |

* C means followed by the same letter are not significantly different by LSD at a = 0.10. N or C:N ratio means followed by the same letter are not significantly different by LSD at a = 0.05.

The pattern for K accumulation in the soil was different than observed for P (Table 2). In contrast to the P data, K in the 0.7.5 cm segment was lower between rows than within rows at all $K_2O$ rates. The K concentrations also were numerically greater within rows in the 7.5-15 cm segment at all $K_2O$ rates, with the difference being significant at the 84 kg $ha^{-1}$ $K_2O$ rate. The horizontal segregation of K between and within rows was also observed after three years of continuous no-tillage by Tyler and Howard (1991). A possible explanation for this concentration may be that K is being recycled from plant and root tissue remainiig near the row after crop harvest. The corn rows were planted within several centimeters of the original row each year, which would support this explanation, Potassium concentrations were numerically greater within rows at the 15-30 cm depth for all K rates; however, these differences were not significant.

Extractable P and K were also evaluated for the 0 to 15 cm depth to evaluate differences relative to a standard soil test sample depth. Table **3** give soil test P concentrations *in* kg $ha^{-1}$.

Table 2. Mehlich I extractable P and K as affected by $P_2O_5$ and $K_2O$ application rates, depth of soil sample, and sampling position.

| | | Extractable P ($mg\ kg^{-1}$) | | Extractable K (mg/kg) | |
|---|---|---|---|---|---|
| P/K Rate ($kg\ ha^{-1}$) | Depth (cm) | Between Rows | Within Rows | Between Rows | Within Rows |
| 0/0 | 0-7.5 | 4.4* | 5.0 | 73.4 | 91.2 |
| | 7.5-15 | 3.8 | 2.1 | 48.4 | 54.8 |
| | 15-30 | 2.9 | 2.1 | 50.6 | 54.6 |
| 56/28 | 0-7.5 | 16.7 | 17.1 | 85.2 | 96.0 |
| | 7.5-15 | 4.8 | 3.1 | 52.4 | 59.0 |
| | 15-30 | 2.8 | 2.0 | 50.0 | 55.1 |
| 112/56 | Q-7.5 | 45.9 | 38.2 | 92.0 | 103.2 |
| | 7.5-15 | 5.6 | 4.4 | 50.2 | 62.4 |
| | 15-30 | 3.6 | 3.5 | 51.3 | 51.5 |
| 168/84 | 0-7.5 | 93.5 | 66.4 | 94.4 | 141.6 |
| | 7.5-15 | 6.6 | 4.9 | 56.6 | 77.2 |
| | 15-30 | 3.8 | 3.8 | 51.8 | 56.9 |

* The rate *x* depth *x* position interaction was highly significant at $P < 0.0001$ for both extractable *P* and K concentrations. The $LSD_{0.05}$ for the P means is 4.9 mg $kg^{-1}$ and the LSD, for the K mean6 is 9.8 mg $kg^{-1}$.

Table 3. Mehlich I extractable P and K in the top 15 cm of soil between and within corn rows.

| P/K Rate ($kg\ ha^{-1}$) | Extractable P: Between Rows | Extractable P: Within Rows | Extractable K: Between Rows | Extractable K: Within Rows | Yield** (bu/ac) |
|---|---|---|---|---|---|
| | ------------------- $kg\ ha^{-1}$ | | | -------------------- | |
| 0/0 | 9.3* | 8.0 | 136.4 | 163.5 | 135 c |
| 56/28 | 24.1 | 22.7 | 154.1 | 173.6 | 143 b |
| 112/56 | 57.7 | 47.7 | 159.3 | 185.5 | 146 a |
| 168/84 | 112.1 | 80.0 | 169.1 | 245.1 | 147 a |

* The P/K rate by sampling position interaction was significant at $P < 0.01$ for both P and K. LSD,, for P is 10.2 kg ha" and for K is 21.6 $kg\ ha^{-1}$.

** Yields are means for three cropping seasons, 1987-1989. Means followed by the same letter are not different by LSD at a = 0.05.

The within row and between row differences in soil test P concentrations were not significant at any rate other than the 168 $kg\ ha^{-1}$ application rate. University of Tennessee Soil Testing Laboratory guidelines indicate that the soil test P level between and within rows is low in the check plots, medium in the 56 $kg\ ha^{-1}$ treatments, and high at the 112 and 168 $kg\ ha^{-1}$ rates. Although differences in soil test P were observed at the high P rates, these differences would not have any significant impact at this time with respect to P application recommendations for these soils.

Soil test K concentrations in the top 15 cm were significantly greater within rows than between rows except at the 28 $kg\ ha^{-1}$ rate (Table 3). Again, depending on the K rates used and accumulation patterns, disparities in soil test K classifications occurred. At this time, the only soil test level differences occur in the 56 and 84 $kg\ ha^{-1}$ treatments, where soil test K is rated as high within and medium between the rows.

Average corn yields over the three year period from 1987 to 1989 were significantly lower in the 0/0 and 56/28 treatments than at higher rates (Table 3). Both K and P may have limited yields in these treatments. The vertical and horizontal stratification of P at the low application rates, coupled with the low soil test P concentrations likely contributed greatly to these lower observed yields. Certainly the 22.7 $kg\ ha^{-1}$ P soil test P concentration within the row in the 56 $kg\ ha^{-1}$ treatment would provide less available P to a growing crop over time than the levels found at the higher rates.

In addition to C, N, P and K, soil pH was also evaluated. There were no significant effects of P/K rate or sampling depth on soil pH in this study. However, the sampling position did affect the pH. The within-row pH of 6.0 was significantly less than the between-row pH of 6.2. This is a small difference; however, the plots used in this study were limed regularly. It is conceivable that larger differences would become apparent with time if proper liming practices were not followed.

## CONCLUSIONS

The data from this experiment illustrate the potential variability which may be encountered in routine soil testing of no-tillage cropland. The continued planting of rows in the same relative position over a number of years in a no-tillage system may result in both horizontal and vertical stratification of nutrients in the soil. Even at high P/K application rates, this stratification becomes obvious and may, in time, lead to yield limiting conditions in no-tilled soils. When soil sampling, attention may need to be given to the technique used to minimize soil test variability.

## REFERENCES


**Follett, R.F., and D.S. Schimel.** 1989. Effect of tillage practices on microbial biomass dynamics. Soil Sci. Soc. Am. J. 53:1091-1096.

**Howard, D.D., and M.D. Mullen.** 1991. Evaluation of in-furrow and banded starter N P K nutrient combination for no-tillage corn production. J. Fert. Issues 8:34-39.

**Xarlen, D.L., E.C. Berry, T.S. Colvin, and R.S. Kanwar.** 1991. Twelve-year tillage and crop rotation effects on yields and soil chemical properties in northeast Iowa. Commun. Soil Sci. Plant Anal. 22:1985-2003.

**Kitchen, N.R., J.L. Havlin, and D.G. Westfall.** 1990. Soil sampling under no-till banded phosphorus. Soil Sci. Soc. Am. J. 54:1661-1665.

**SAS Institute, Inc.** 1988. SAS/STAT User's Guide, Release 6.03 edition. Cary, NC. p. 1028.

**Tyler, D.D., and D.D. 'Howard.** 1991. Soil sampling patterns for assessing no-tillage fertilization techniques. J. Fert. Issues 8:52-56.