LONG TERM TILLAGE AND FERTILITY EFFECTS IN CORN[1]

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ABSTRACT

A long term study to evaluate tillage methods and fertilization practices on corn under monoculture was initiated in 1970. Effects on grain yields and soil property changes were evaluated over 20 growing seasons. Four tillages evaluated were continuous conventional, alternate till (2 years no-till: 1 year conventional till), continuous chisel till, and continuous no-till. The five fertilizer treatments evaluated were: control, 0-0-0; 175-0-0; 160-0-0 broadcast plus 15-80-120 row banded at planting; 175-80-180 broadcast; and 160-50-150 broadcast plus 15-30-30 row banded at planting. Yields have increased steadily over the years, averaging over 2.5 bushels per acre per year on the fertilized treatments. There was no added yield benefits from the application of a portion of the fertilizer as a row-band treatment at planting compared to all broadcast. Under high fertility management very few differences in yield have been observed among the four tillage methods. No-till yields tended to be somewhat lower in the initial phases of the study, but during the past 10 years that trend has changed such that no-till yields are comparable to those of the other tillage methods. There has not been any substantial yield benefit resulting from alternate tillage compared to continuous no-tillage.

Soil pH levels were reduced significantly on all fertilizer treatments compared to the control. Large increases of available soil P and K occurred with the high levels of P and K fertilizer application, to the point of being excessive. Depletion in soil P and K, when no P and K was applied as fertilizer, was more rapid under no-tillage than with other methods of tillage. Soil organic matter increased more rapidly under no-tillage than other methods and was also enhanced by complete N-P-K fertilization compared to the control or the nitrogen only fertilizer treatment.

INTRODUCTION

Dramatic shifts toward reduced tillage methods in corn production have occurred during the past 20 to 30 years. Improved herbicides and other pest control chemicals and the need for producers to become more labor, machinery, and time efficient have prompted much of the change. Likewise, the use of reduced tillage methods has been shown to decrease soil erosion losses and increase the amount of water available to the crop. A number of concerns and problems have arisen as reduced tillage

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has become commonplace. Perennial weeds, occasionally greater insect and disease problems, and soil compaction are some of the difficulties encountered as soil tillage is reduced toward no-tillage. One of the most common concerns is that of selecting the optimum fertilizer placement and management system which should be utilized.

A long-term experiment was initiated in 1970 and continued to date by Dr. George Kapusta at the Belleville Research Center of SIUC to study the combined effects of tillage and fertility in a continuous corn production system. The overall objective was to evaluate the effect of different phosphorus (P) and potassium (K) placement methods and strategies under four tillage systems on corn grain yields and soil property changes.

EXPERIMENTAL DETAILS

The study site is located on an Ebbert silt loam soil (fine-silty, mixed, mesic, Argiaquic Argialbolls) with a slope of 0 to 2 percent. Soil test measurements at the beginning of the experiment in 1970 were: pHw = 6.1; Bray P_1 phosphorus = 30 lbs P per acre; Bray P_2 phosphorus = 62 lbs P per acre; available potassium = 261 lbs K per acre; organic matter = 1.5%, and cation exchange capacity = 12 meq per 100 grams of soil. Corn hybrids changed several times as higher-yielding selections became available. Herbicide combinations with superior weed control performance over a variety of tillages were used. Insecticides were applied for black cutworm control as the pest pressure warranted. No phosphorus or potassium fertilizer was added during the course of the experiment except as added according to the treatment plan. Limestone was applied over the whole experiment in 1975 and 1983, each time at a rate of 3 tons per acre.

Tillage and fertilizer treatments were as follows:

<u>Tillage</u>

CT = Continuous conventional till (moldboard plow, disk, harrow)
AT = Alternate till (2 years no-till: 1 year conventional till (1972, 1975, 1978 etc.)
CC = Continuous chisel till (chisel, disk, harrow)
NT = Continuous no-till

<u>Fertility</u>

01 = no fertilizer control, 0-0-0
02 = nitrogen only, no P_2O_5 or K_2O (175-0-0 lbs N per acre)
03 = 160-0-0 lbs N per acre broadcast plus 15-80-120 lbs per acre 2" x 2" row banded.
04 = 175-80-180 lbs per acre broadcast
05 = 160-50-150 lbs per acre broadcast plus 15-30-30 lbs per acre 2" x 2" row banded.

The experimental arrangement was a split-plot design with tillages as main plots and fertilizer treatments as subplots. Treatments were replicated four times, giving a total of 80 plots in the experiment. Individual plots were 25 ft. in length X 20 ft. wide (8-30 inch rows). Nitrogen was applied as ammonium nitrate, phosphorus as triple superphosphate, and potassium as muriate of potash. All broadcast materials were applied prior to tillage or were left undisturbed on the soil surface (no-till). Row banded fertilizers were applied at planting.

Intensive composite soil sampling of individual plots was done in the late winter of 1990, including increment (2-inch) sampling to a ten-inch depth on the control and broadcast only treatments (01, 02, and 04) over all four tillage methods. Soil pH, Bray P_1 extractable P, exchangeable K, and soil organic matter content were determined on all samples.

RESULTS AND DISCUSSION

A. Tillage and Fertility Effects on Corn Yields

Using high fertility practices, corn grain yields have increased steadily during the experiment when evaluated over 5-year periods (Figure 1). The average annual increase ranged from 0.8 bushels per acre for the control (fertility 01) to over 2.5 bushels per acre for fertilized treatments over the 20-year period. Periodic changes to improved, higher-yielding hybrids probably accounted for much of the increase. When averaged over all tillages, corn yields for the complete fertilizer treatment (03, 04, and 05) were nearly identical. There was no benefit from applying a small portion as a row band treatment (fertility 05) compared to all of the fertilizer being broadcast (fertility 04).

When the level of fertility was high with respect to applied N, P, and K (Fertility 04), corn yields were nearly identical during the last 10 years (1980-1989) regardless of tillage method used (Figure 2). During the first 5 year period (1970-1974) with fertility 04, there was some evidence that no-till yields were lower compared to conventional or chisel till. This agrees with grower observations when they begin no-tillage corn production. However, with time, yields under no-till usually "catch up" to those of conventional till or surpass them.

The interactive effects of tillage and fertility over time on corn yields are shown in Figure 3. Of note are the yield changes that have occurred with no P or K application (fertility 02) as related to tillage. Corn produced using no-tillage was particularly suppressed by low soil P and K levels (for no P and K fertilizer applications) compared to conventional till. As shown in the 1985-1989 portion of Figure 3, yields from no-till corn with no P and K applied (fertility 02) averaged some 40 bushels per acre less than no-till corn receiving complete fertility (03, 04, or 05). A comparable comparison of conventional tilled corn showed that yields were reduced by an average of only 15 bushels per acre. One of the major contributing factors of the much lower yields for no-till compared to conventional till (for fertility 02) was the low levels of K in the plant (Figure 4). Therefore, these results show the extreme importance of adequate P and especially K fertility for successful no-till corn production.

B. Tillage and Fertility Effects on Soil Property Changes

Soil pH was affected differently by fertility treatment applications on the various tillages (Table 1). Application of 175 pounds N per acre annually resulted in the average soil pH being 0.7 to 0.9 pH unit less than the control treatment (fertility 01). The acidity resulting from nitrification of the ammonium nitrate fertilizer and the increased yields and grain removal of base cations probably resulted in most of the soil acidity differences. The lowest soil pH was observed with N only (fertility 02) applied to alternate tilled corn.

Bray P_1 extractable P levels were significantly affected by fertility treatments (Table 1). The lowest soil test for P was observed when N but no P or K fertilizers were applied (fertility 02). The reduced soil P reflects the uptake and crop removal of P without replenishment by any P fertilizers. The soil level of P for the control (29 pounds P per acre) remained nearly the same since the experiment was initiated. Application of 80 pounds P_2O_5 per acre annually resulted in substantial soil P increases (fertility 03, 04, and 05). The soil sampling method used failed to detect as much P in the soil when the fertilizer was all banded (fertility 03) as compared to when the phosphorus was all or mostly broadcast (fertility 04 and 05).

Soil test K was affected differently when K fertilizers were applied to the various tillages (Table 1). Higher soil test K levels were generally observed with no-tillage practices compared to other tillages when K was applied. When no K was added (fertility 02), very low soil test K (155 lbs K per acre) was observed under no-till. This resulted in the extremely low corn leaf K that was discussed earlier and shown in Figure 4.

There was a progressive increase in average soil test K levels with increasing rates of K application. The application of 180 pounds K_2O per acre annually (fertility 04 and 05) has led to excessively high levels of K in the soil. Application of 120 pounds of K_2O per acre annually as a band treatment (fertility 03) has maintained soil K tests at approximately the desired level.

Soil organic matter content has changed as a function of both tillage and fertility treatment (Table 1). No-tillage has led to a significantly increased soil organic matter content over the other three tillage methods. This has probably occurred because of the reduced rate of raw residue decomposition as tillage was reduced. The organic matter content under alternate till was no different from that observed with conventional or chisel tillage. Higher soil organic matter levels were also observed when fertilizers were applied, especially treatments 03, 04, and 05 which received the full compliment of N, P and K. Higher soil organic matter levels with these fertility treatments are probably a result of greater amounts of crop residues remaining following harvest.

Figures 5 and 6 show the distribution variability that was observed in soil pH, organic matter content, soil P, and soil K with depth in soil for the various tillages on the complete N-P-K broadcast treatment (fertility 04). Numerous studies have demonstrated that stratification of acidity, P, and K can occur as a result of continuous and prolonged no-tillage. These data support those reports. Figure 5 also shows that soil organic matter becomes stratified in the soil under no tillage to a degree very similar to that of soil P and K. This mulch accumulation has been the subject of much concern, but there is no evidence that tillage for the purpose of its redistribution is necessary for successful corn production.

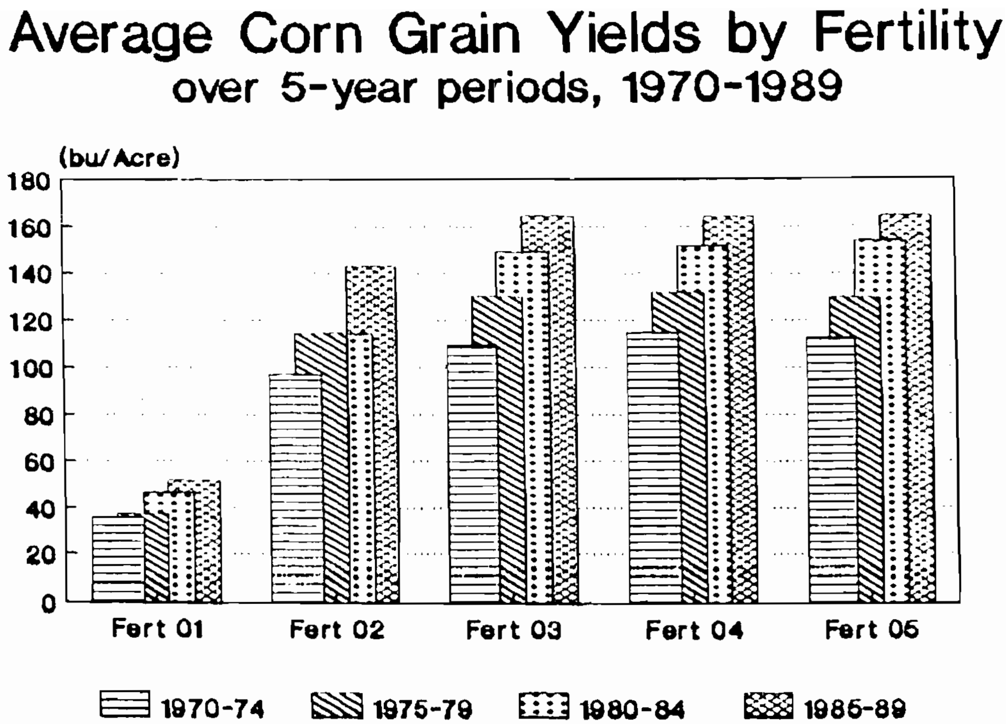


Figure 1. Effect of fertility treatments averaged over all tillages on corn grain yields evaluated in 5-year periods, 1970-1989.

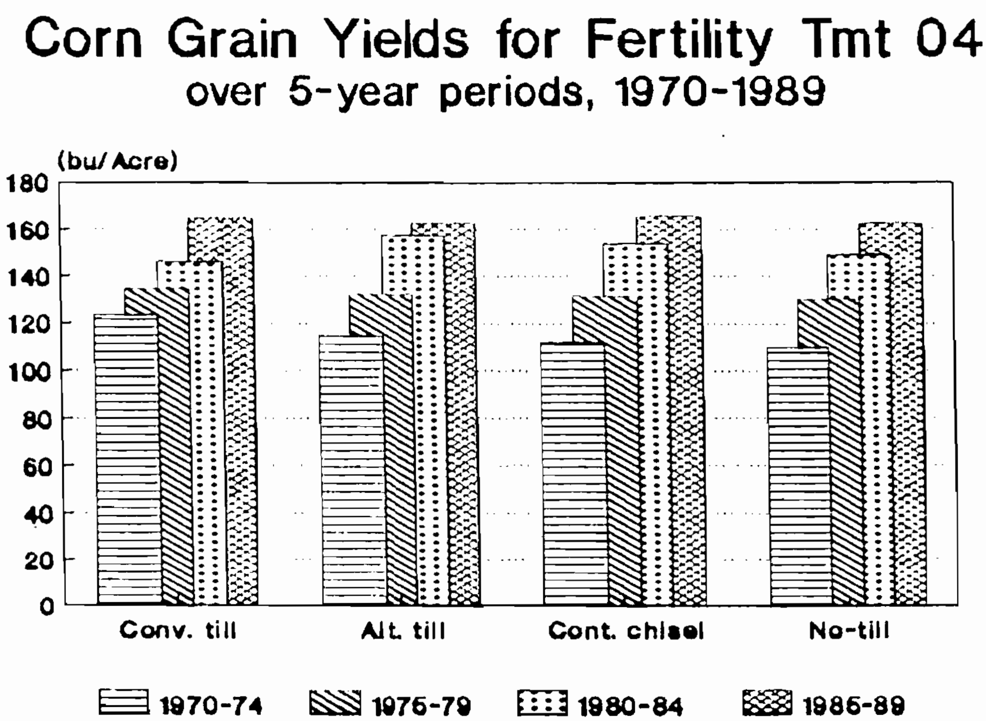


Figure 2. Corn grain yields obtained with four tillage methods on fertility treatment 04(175-80-180, broadcast annually) and evaluated over 5-year periods, 1970-1989.

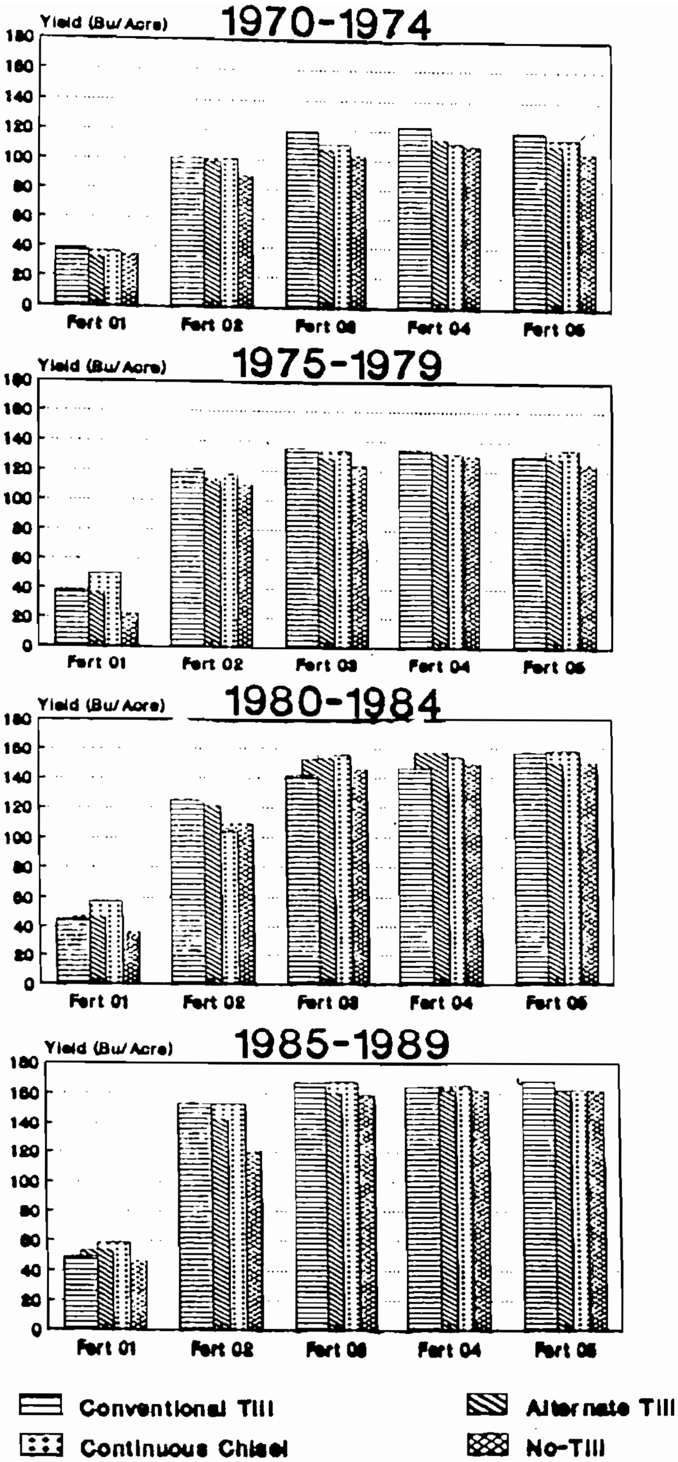


Figure 3. Corn grain yields as influenced by tillage and fertility over 5-year periods of the study, 1970-1989.

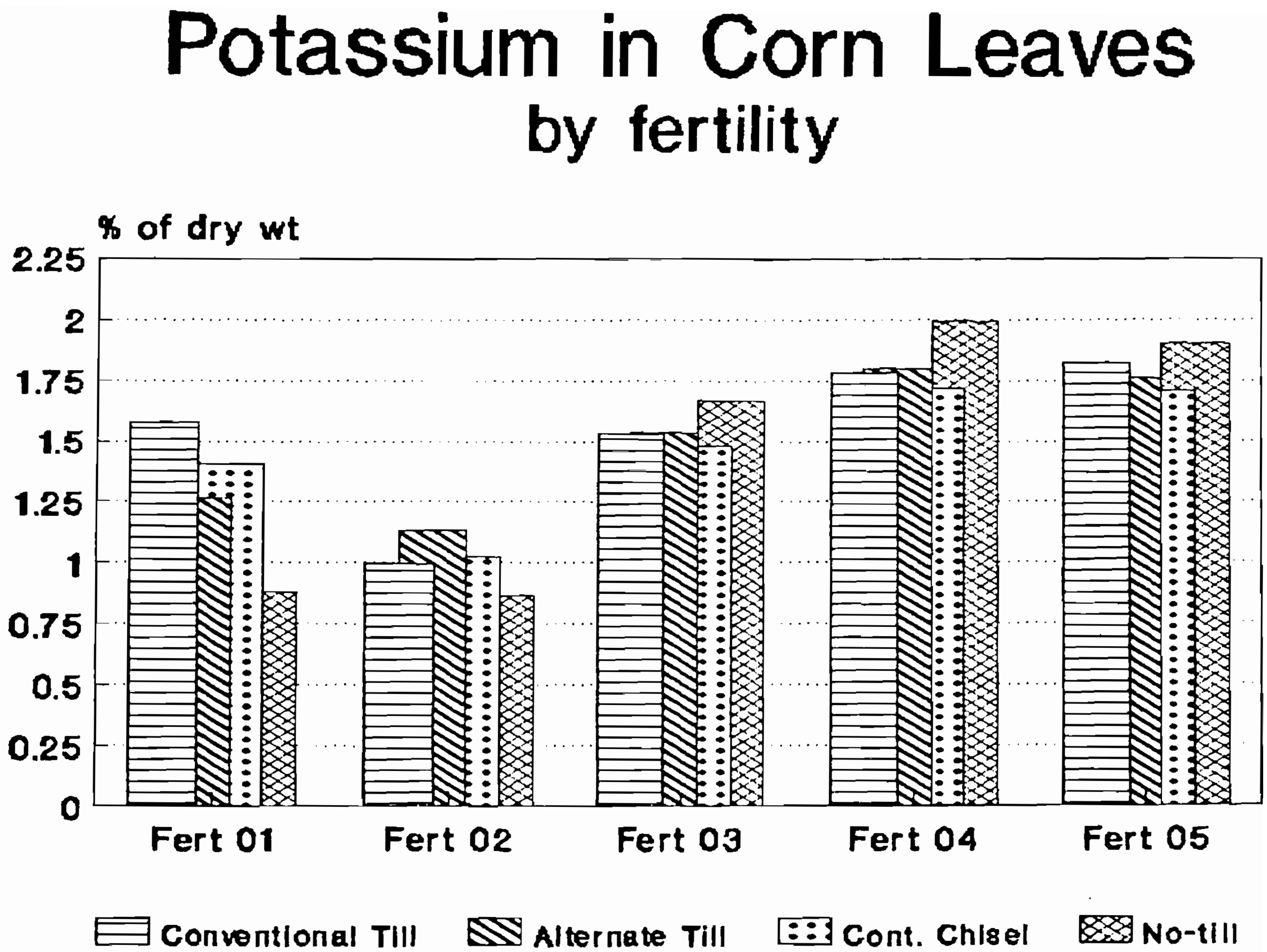


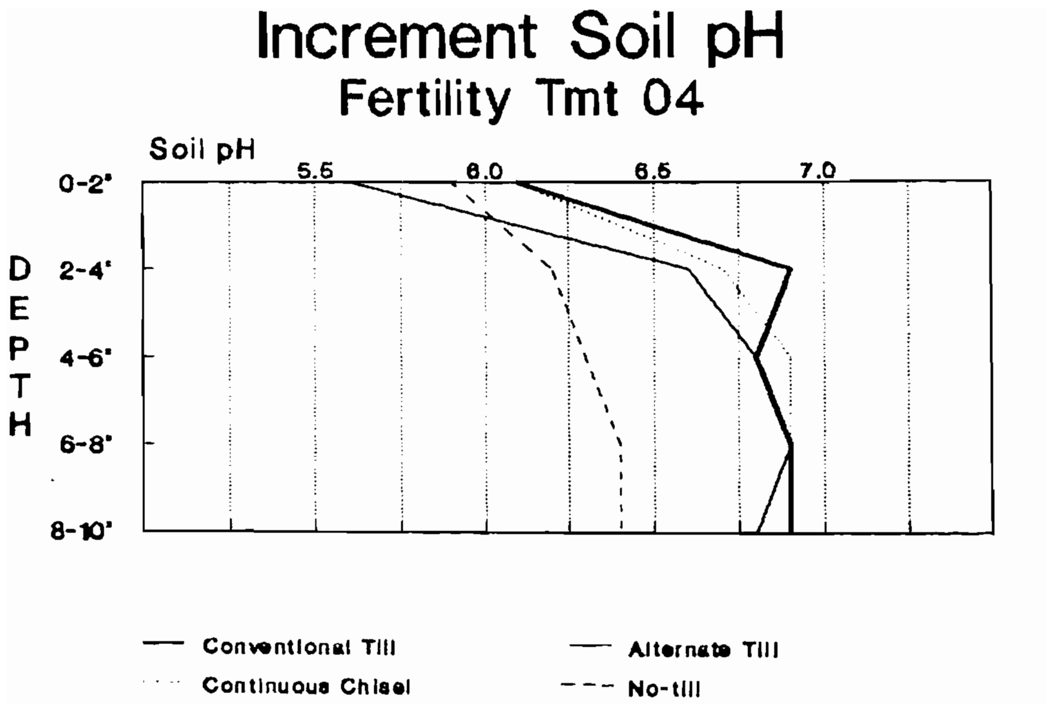
Figure 4. Potassium in the corn ear leaves of the 1990 crop as influenced by tillage and fertility treatments.

Table 1. Effect of tillage and fertility on soil pH, Bray P_1 extractable phosphorus, exchangeable potassium, and organic matter in soils after 20 years of continuous corn. Soil samples collected February 1990.

Fertility[1] Tmt. No.	Treatment	Soil pH Cont. Conv.	Alt. Till	Cont. Chisel	Cont. No-Till	Mean	Bray P_1 Phosphorus (lbs/ac) Cont. Conv.	Alt. Till	Cont. Chisel	Cont. No-Till	Mean
01	0-0-0	7.0	7.0	7.2	7.3	7.1	42	25	33	18	29
02	175-0-0(BC)	6.2	5.6	6.3	6.7	6.2	13	23	18	8	15
03	160-0-0(BC) +15-80-120(Row)	6.3	6.6	6.2	6.4	6.3	78	77	77	73	76
04	175-80-180(BC)	6.6	6.2	6.5	6.0	6.3	103	96	82	96	94
05	160-50-150(BC) +15-30-30(Row)	6.5	6.3	6.8	6.2	6.4	104	109	85	97	99
	Mean	6.5	6.3	6.6	6.5		68	66	59	58	
$LSD_{.05}$	Tillage		0.13					NS			
	Fertlity		0.17					8.7			
	Tillage X Fertility		0.34					NS			

Fertility[1] Tmt. No.	Treatment	Exchangeable Potassium (Lbs/ac) Cont. Conv.	Alt. Till	Cont. Chisel	Cont. No-Till	Mean	Soil Organic Matter (%) Cont. Conv.	Alt. Till	Cont. Chisel	Cont. No-Till	Mean
01	0-0-0	225	205	215	168	203	1.78	1.67	1.80	1.87	1.78
02	175-0-0(BC)	190	200	200	155	186	1.90	1.86	2.01	1.98	1.94
03	160-0-0(BC) +15-80-120(Row)	298	293	298	303	298	2.11	2.00	1.93	2.23	2.07
04	175-80-180(BC)	430	440	400	490	440	1.84	2.01	1.95	2.20	2.00
05	160-50-150(BC) +15-30-30(Row)	410	460	370	500	435	2.17	2.04	1.98	2.37	2.14
	Mean	311	320	297	323		1.96	1.92	1.93	2.13	
$LSD_{.05}$	Tillage		NS					0.14			
	Fertlity		25.1					0.12			
	Tillage X Fertility		50.3					NS			

[1]Denotes pounds of N, P_2O_5, and K_2O applied annually per acre as a broadcast (BC) or 2 inch x 2 inch row-banded (Row) treatment at planting.



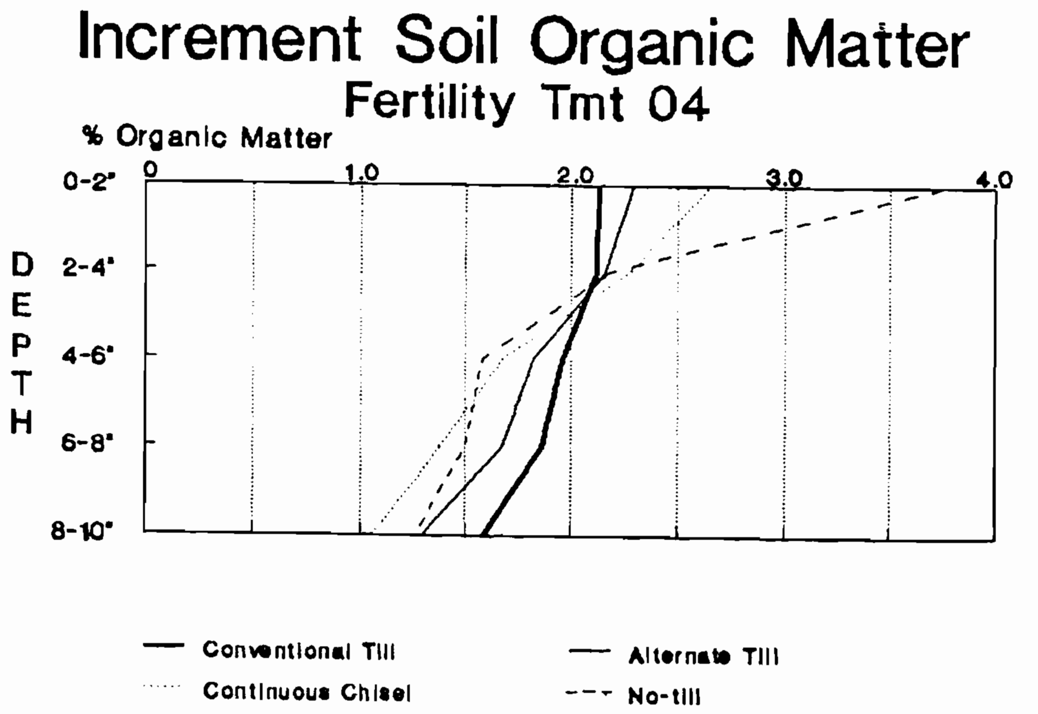
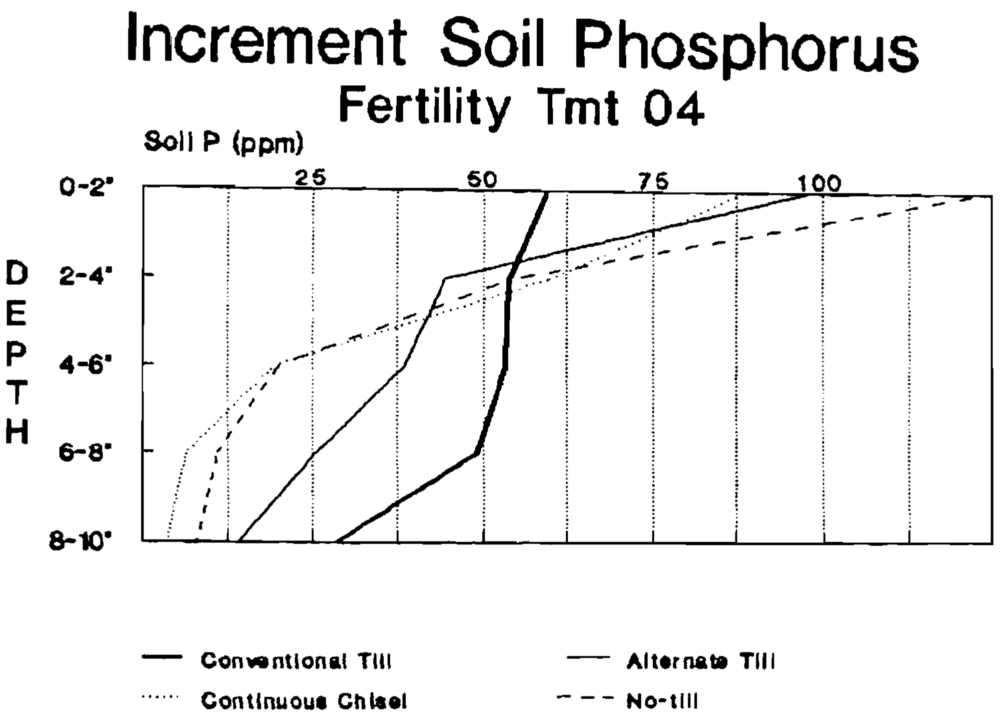


Figure 5. Soil pH determination and organic matter distribution in the plow layer of fertility treatment 04(175-80-180, broadcast annually, 1970-1989) in February 1990 as affected by tillage methods.



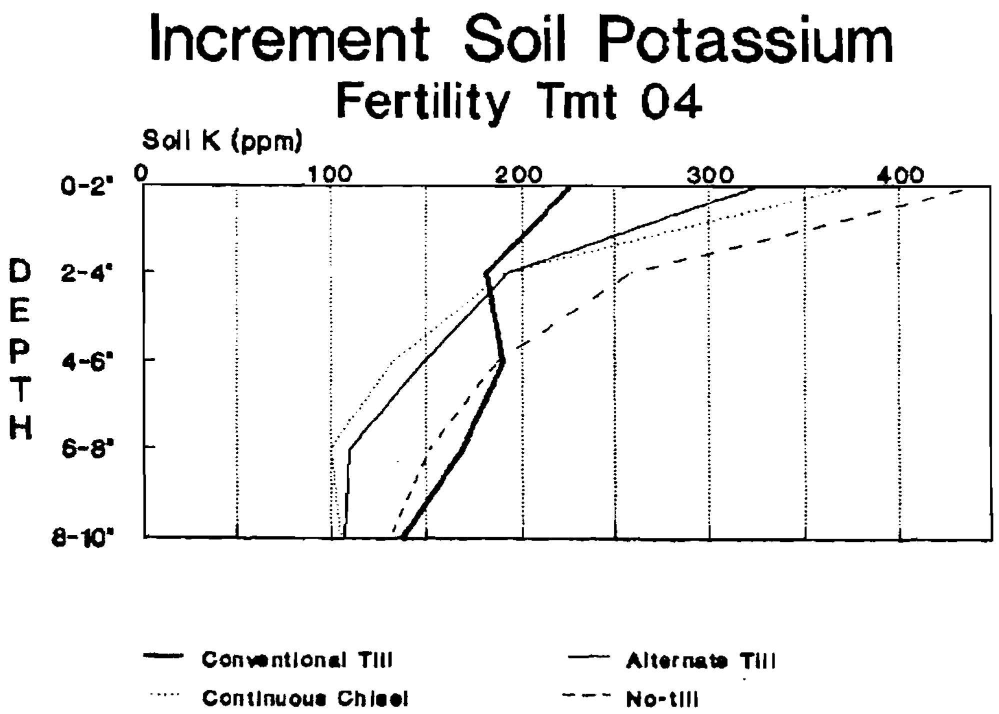


Figure 6. Distribution of available soil phosphorus and potassium in the plow layer of fertility treatment 04(175-80-180, broadcast annually, 1970-1989) in February 1990 as affected by tillage methods.

PROJECTS ON SOILS AND SOIL FERTILITY AT SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

Field Evaluation of Ammonium Thiosulfate (ATS) as a Urease Inhibitor. E.C. Varsa

Effect of N-(n-butyl) Thiophosphoric Triamide as a Urease Inhibitor applied to No-Till Corn. E.C. Varsa

The Influence of N Fertilizer Timing of Application and Plant Growth Regulator Use on Winter Wheat. E.C. Varsa

The Effect of Super Urea on No-Till Corn. E.C. Varsa

Residual Acidification of Soils from Different N Fertilizers and its Influence on Corn and Soybeans. E.C. Varsa* and B.P. Klubek

Efficient P Use by Corn and Soybeans through Placement of Liquid Formulations within the Rooting Volume under No-Till and Reduced-Till Systems. S.A. Ebelhar*, Dixon Springs Ag Center, University of Illinois, Simpson, IL and E.C. Varsa

Effect of Gelled Nitrogen Fertilizer Solutions on No-Till Corn. E.C. Varsa

Corn Tillage X Fertility Study (In place since 1970). G. Kapusta

Influence of ACA on Corn Production. G. Kapusta

Influence on Nutra-Gro on Corn, Soybeans, and Wheat. G. Kapusta

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