Kansas Agricultural Experiment Station Research Reports

Volume 3
Issue 3 *Kansas Fertilizer Research*

Article 3

6-2017

Long-Term Tillage and Nitrogen Fertilization Effects on Soil Surface Chemistry

A. Obour
Kansas State University, aobour@ksu.edu

J. D. Holman
Kansas State University, jholman@ksu.edu

Recommended Citation

Obour, A. and Holman, J. D. (2017) "Long-Term Tillage and Nitrogen Fertilization Effects on Soil Surface Chemistry," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 3. https://doi.org/10.4148/2378-5977.1394

Long-Term Tillage and Nitrogen Fertilization Effects on Soil Surface Chemistry

Abstract

Long-term crop management practices can affect nutrient cycling and availability to crops. This study examined the long-term effects of nitrogen (N) fertilizer application (N rates of 0, 20, 40, and 60 lb N/a) and tillage intensity (conventional tillage (CT), reduced tillage (RT), and no-tillage (NT)) on soil phosphorus (P), micronutrients, and soil acidity in a dryland winter wheat (*Triticum aestivum* L.)–sorghum (*Sorghum bicolor* L.)–fallow cropping system. Results showed soil organic matter (SOM), iron (Fe), and zinc (Zn) concentrations were greater under NT compared to CT or RT. Similarly, NT (32 ppm) increased P accumulation in the upper 3 in. soil depth compared to CT (21 ppm) or RT (26 ppm). Soil pH at the surface (0 to 3 in.) declined markedly with increasing N fertilizer application rate, ranging from 6.1 with the control to 5.5 when 60 lb N/a was applied. Averaged across N rates, soil pH was lower with NT (5.7) compared to CT (6.3) and RT (6.2) treatments. Iron and manganese (Mn) concentrations increased with increasing N application rates, probably due to the decrease in pH associated with N application.

Keywords

Tillage, nutrient stratification, pH

K-STATE
Research and Extension

KANSAS FERTILIZER
RESEARCH 2017

KANSAS STATE UNIVERSITY

Long-Term Tillage and Nitrogen Fertilization Effects on Soil Surface Chemistry

A.K. Obour and J. Holman

Summary

Long-term crop management practices can affect nutrient cycling and availability to crops. This study examined the long-term effects of nitrogen (N) fertilizer application (N rates of 0, 20, 40, and 60 lb N/a) and tillage intensity (conventional tillage (CT), reduced tillage (RT), and no-tillage (NT)) on soil phosphorus (P), micronutrients, and soil acidity in a dryland winter wheat *(Triticum aestivum* L.)–sorghum *(Sorghum bicolor* L.*)*–fallow cropping system. Results showed soil organic matter (SOM), iron (Fe), and zinc (Zn) concentrations were greater under NT compared to CT or RT. Similarly, NT (32 ppm) increased P accumulation in the upper 3 in. soil depth compared to CT (21 ppm) or RT (26 ppm). Soil pH at the surface (0 to 3 in.) declined markedly with increasing N fertilizer application rate, ranging from 6.1 with the control to 5.5 when 60 lb N/a was applied. Averaged across N rates, soil pH was lower with NT (5.7) compared to CT (6.3) and RT (6.2) treatments. Iron and manganese (Mn) concentrations increased with increasing N application rates, probably due to the decrease in pH associated with N application.

Introduction

Growers in dryland environments of the Great Plains region are increasingly adopting conservation tillage practices such as no-tillage (NT). No-tillage has several benefits, including reduced soil erosion and runoff, improved soil physical properties, enhanced soil organic matter (SOM) content, and improved soil water retention. Despite these benefits, continuous NT practice results in accumulation of crop residue at the surface and leads to SOM build-up and stratification of nutrients compared to CT or RT systems. In the semi-arid environments, low precipitation and drought conditions may enhance nutrient accumulation in the upper soil layer, reduce nutrient movement to the lower soil layers, and could decrease nutrient availability for plant uptake.

Long-term studies are valuable and critical to improve our knowledge and understanding on the influence of different management practices on soil nutrient dynamics. Few studies have investigated the effects of long-term (> 20-yr) tillage and N fertilizer management on soil chemistry in semi-arid cropping systems. The objective of this study was to examine soil chemical properties after 50 years of tillage and nitrogen applications to a wheat-grain sorghum-fallow (W-S-F) cropping system in western Kansas.

Procedures

This long-term study was conducted at the Kansas State University (K-State) Agricultural Research Center-Hays, Kansas on a Harney silt loam soil (fine, montmorillonite, mesic Typic Agriustoll). The study was established in 1965 to investigate the effects of tillage intensity on winter wheat and grain sorghum yields in a W-S-F rotation scheme. The three tillage treatments were conventional tillage (CT), reduced tillage (RT), and no-tillage (NT) arranged in randomized complete blocks with four replications. Each phase of the W-S-F crop rotation was present in each year of the study.

The experiment was modified in 1975 to add N fertilizer application rates in a split-plot arrangement. The original tillage treatments (CT, RT, and NT) were the main plots and sub-plot factor was four N application rates (0, 20, 4, and 60 lb N/a). Individual plot sizes were 67 × 100 ft for the tillage treatments, and 11 × 100 ft for the N application rate treatments. There was an 11 feet wide border between tillage treatments. Soil fertility analysis conducted at the beginning of the study in 1965 was not different among the preassigned crop rotation and tillage treatment plots. Averaged across the four experimental blocks, soil pH in the upper 0 to 3 in. of the soil was 6.3, extractable P was 62.5 ppm , and SOM was 2.1%. Similarly, soil pH measured at 3 to 6 in. depth was 6.6, while P and SOM concentrations were 40.1 ppm and 1.9%, respectively. Ammonium nitrate was the N fertilizer source from 1975 to 2002, thereafter; urea was the N fertilizer source applied to the plots. Nitrogen fertilizer was broadcasted in the fall prior to wheat planting while N application to grain sorghum plots were done in early spring before sorghum planting in June. Fertilizer was incorporated in the CT and RT tilled plots while fertilizer addition remained on the soil surface under NT. Because soil test levels for available P were medium to high over the study period and exchangeable potassium (K) are inherently high in this soil, N was the only fertilizer applied over the 50-year study period.

Seedbed preparation in the CT plots during fallow was done by disking and plowing with residue-incorporating implements (disk, and mulch treader) to about 6 in. depth. In the RT treatments, tillage was accomplished with residue-saving implements such as V-blade and sweeps to about 6 in. depth. Approximately 3 to 4 tillage operations were performed in the fallow phase prior to winter wheat planting in CT while 2 to 3 tillage operations occurred in the RT plots. One tillage operation was usually conducted in both CT and RT plots prior to sorghum planting. Only herbicides were used for weed control in the NT plots. Weed control during the growing season and fallow periods were accomplished with appropriate herbicides as needed across all tillage practices.

During the 50 years of the study, winter wheat was usually seeded in late September through October 15, and sorghum seeding was done in mid-May through the third week in June. Grain yields were determined by harvesting an area of 5 × 100 ft from each plot with a plot combine. Grain sorghum was usually harvested in October while winter wheat was harvested in July of each year of the study.

Soil samples were collected at the beginning of the study in the fall of 1965. Three soil cores (1 in. diameter) were collected randomly from each plot at 0 to 3 in. and 3 to 6 in. soil depths. These initial samples were air-dried, crushed, and sieved through a 2-mm sieve and then analyzed for soil pH, SOM, and P concentration. Soil samples were taken again in May 2015 in the fallow phase to determine changes in soil chemical properties after fifty years of tillage and N fertilization. Three soil cores (1 in. diameter) were randomly collected in each plot from 0 to 3 in. and 3 to 6 in. soil depth. The samples were composited per depth for each plot, air-dried, crushed, and sieved to pass through a 2-mm stainless steel screen. The sieved soil samples were then analyzed for pH and soil extractable nutrients at the K-State soil testing laboratory using standard soil testing procedures.

Results

Soil pH and Organic Matter

Results showed a decrease in soil pH in all tillage treatments in the upper 6 in. of soil compared to the initial soil pH levels. Averaged across N rates and soil depth, soil pH was 5.7 with NT, which was significantly lower than pH of 6.2 with CT or 6.3 under RT (Table 2). Compared to the initial soil pH, this represents 0.8, 0.3, and 0.2 units decrease in soil pH with NT, CT, and RT, respectively. In NT systems, mineralization of SOM and nitrification of applied N fertilizer occurs on the soil surface that can result in a significant decrease in pH at the soil surface. However, tillage operations employed in CT or RT incorporate and mix fertilizer with a larger soil volume. In addition, tillage results in mixing and redistribution of soil from the subsoil that has relatively greater pH and concentrations of Ca and Mg. This process provides some buffering against pH changes under CT or RT.

Soil pH was also affected by the interaction of sampling depth × N fertilizer application rate. Application of N at 60 lb N/a significantly decreased soil pH in the top 3 in. compared to the other N rates. However, beyond this depth, pH was not different among the N application rates (Table 3). The decrease in pH may be due to nitrification of NH_4^+ to NO_3^- when ammonium-containing fertilizers (ammonium nitrate and urea in the present study) are applied. In the present study, soil pH with 20 and 40 lb N/a were similar to the control after 50-yr of the study. However, applying N at a higher rate of 60 lb/a decreased soil pH markedly relative to the control, suggesting soil acidification from N fertilization depends on the amount of N applied.

Nitrogen application had no effect ($P > 0.05$) on soil organic matter concentration. However, SOM was affected by tillage system. Averaged across N application rates and soil depth, SOM concentration with NT and RT were not different, but greater than that measured under CT (Table 2). Regardless of tillage treatment, SOM concentration increased in the upper 6 in. of the soil after 50-yr of the study. This observation may be due to increase in cropping intensity that adds more residues to the soil. The increase in SOM concentration between 1965 and 2015 ranged from 0.42% under CT, 1.2% with RT, and 1.2% with NT (Table 2). No difference in Δ SOM was observed between NT and RT. These changes correspond to 21% increase in SOM associated with CT and 58% increase in SOM concentration associated with NT and RT. The elimination or reduction in tillage operations reduced soil disturbance and SOM decomposition resulting in greater crop residue accumulation. This leads to the significant SOM accretion under NT and RT in the present study.

Extractable Macronutrients

The extractable P concentration measured in 2015 was affected by tillage × sampling depth interaction. Phosphorus concentration in the upper 3 in. of soil under NT was 32.0 ppm, greater than P concentrations under CT (20.6 ppm) or RT (26.1 ppm) measured at this depth (Figure 1). Below 3 in., P concentration was similar among the tillage treatments. This observation was expected because P is relatively immobile within the soil and tends to accumulate on the soil surface in NT systems where there are no tillage operations to incorporate crop residue and redistribute P to deeper soil layers. The differences in soil P associated with different depths were due to tillage operation and soil mixing up to 6 in. depth with CT and RT treatments. After 50 years of tillage and N fertilizer application, P concentrations measured in the upper 6 in. of the soil declined markedly regardless of tillage intensity. Averaged across tillage and N application rates, soil P concentration in the upper 3 in. in 1965 was 62.5 ppm, significantly greater than P concentration of 26.3 ppm that was measured at this same depth in 2015 (Figure 2). This represents a 58% decline in soil P concentration relative to the initial P concentration. Similarly, soil P concentration measured at 3 to 6 in. soil depth in 2015 was 83% less than that measured at the same depth in 1965 (Figure 2). This decrease in P concentration was expected because no P fertilizer were applied during the 50 years of the study. Over all, the significant P reduction from 1965 to 2015 was due to crop P uptake for the last 50 years.

Average P concentrations measured in 2015 in the upper 6 in. were 13.7 ppm for CT, 17.3 ppm for RT, and 18.6 ppm with NT. Current KSU fertilizer guidelines recommend P fertilizer application when Mehlich-3 soil test P concentration in the upper 6 in. soil depth is < 20 ppm (Leikam et al., 2003). Based on this P fertilizer guideline, P fertilizer required for a 40 bu/a winter wheat yield goal will be 25 lb P_2O_5/a for wheat produced under CT, and 15 P_2O_5/a for wheat that will be planted under RT or NT.

Extractable K, Ca, and Mg concentrations were not affected by either tillage or N application rate. The lack of tillage effects on exchangeable cations observed in the present study is probably due to inherently greater levels of basic cations in soils at the experimental site. In water-limited environments as in the case of western Kansas, limited leaching of basic cations occurs in the soil. It is therefore common to measure greater concentrations of Ca, K, and Mg in the upper surface of soils in these environments.

Micronutrients

Soil Fe and Zn concentrations differed among tillage treatments but not Mn. Averaged across N rates and sampling depth, Fe concentration ranged from 27 ppm with either CT or RT, to 40 ppm under NT. Similarly, Zn concentration was greater with NT compared to the other tillage treatments. It is likely that the observed differences in Fe and Zn concentrations among the tillage treatments were due to the lower soil pH observed under NT that increased Fe and Zn availability. The interaction of sampling depth × N application significantly affected soil Fe and Mn concentration but not Zn. Both Fe and Mn concentrations in the upper soil surface (0 to 3 in.) increased with increasing N fertilizer application rate (Table 3). Averaged across tillage treatments, Fe concentration with 60 lb N/a was 1.8-fold greater than that of the control N rate at the soil surface. Similarly, Mn concentration ranged from 24.2 ppm with the control to 40.4 ppm when 60 lb N/a was applied (Table 3). Conversely, Fe and Mn concentrations below 3 in. soil depth were not different among the N application rates. The increase in Fe and Mn concentrations with increasing N application rates is probably due to the decrease in pH associated with N application. Regression analysis showed an inverse relationship between pH and soil micronutrient concentrations (Figure 3). The correlation coefficients of the relationship between soil pH and Fe, and Mn concentrations were 0.59 and 0.71, respectively. Availability of these micronutrient cations (Fe and Mn) increased when the soil pH was slightly acidic to neutral (Figures 3a and b). Micronutrient availability is reduced at higher soil pH because of the change in ionic form of the cations into metal oxides or hydroxides that are relatively insoluble.

Table 1. Soil pH, soil organic matter, iron, and zinc concentrations measured in 2015 as affected by tillage and soil sampling depth

Tillage system	pH	Δ pH	Soil organic matter	Δ soil organic matter	Iron	Zinc
			------------- % -------------		----------- ppm -----------	
Conventional tillage	6.2 a[†]	-0.25 b	2.4 b	4.2 b	26.9 b	0.4 b
Reduced tillage	6.3 a	-0.23 b	3.1 a	1.2 a	26.6 b	0.5 ab
No-tillage	5.7 b	-0.75 a	3.1 a	1.1 a	39.9 a	0.6 a
SE[‡]	0.2	0.19	0.1	0.1	2.1	0.1

[†] Means followed by same letter (s) within a tillage system are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$). Data are averaged across four nitrogen rates, two sampling depths and four replicates ($n = 32$).

[‡] SE = Standard error of the mean.

Δ pH = difference between pH measured in 2015 and 1965.

Δ SOM = difference between SOM measured in 2015 and 1965.

Table 2. Soil pH, iron, and manganese concentrations measured in 2015 as affected by tillage and soil sampling depth

Nitrogen rates (lb/a)	pH	Iron	Manganese
		ppm	ppm
0 to 3 in.			
0	6.1 a[†]	23.8 c	24.2 c
20	6.0 a	28.8 c	29.9 b
40	6.0 a	37.0 b	31.6 b
60	5.5 b	43.7 a	40.4 a
SE[‡]	0.1	3.3	2.7
3 to 6 in.			
0	6.4 a	22.2 a	19.6 a
20	6.2 a	23.5 a	21.3 a
40	6.3 a	26.0 a	22.2 a
60	6.2 a	25.3 a	21.0 a
SE	0.1	3.3	2.7

[†] Means followed by same letter(s) within nitrogen rate are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$). Data are averaged across three tillage treatments and four replicates ($n = 12$).

[‡] SE = Standard error of the mean.

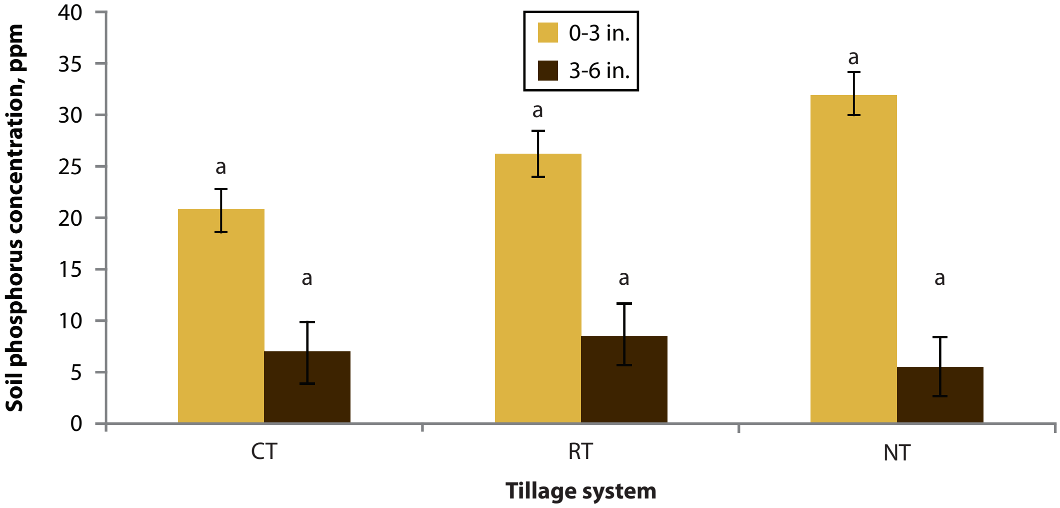

Figure 1. Soil phosphorus concentration measured in 2015 as affected by tillage practice. Error bars represent one standard error of the mean. Means followed by the same letter(s) within a soil depth are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$).
CT = conventional tillage.
RT = reduced tillage.
NT = no-tillage.

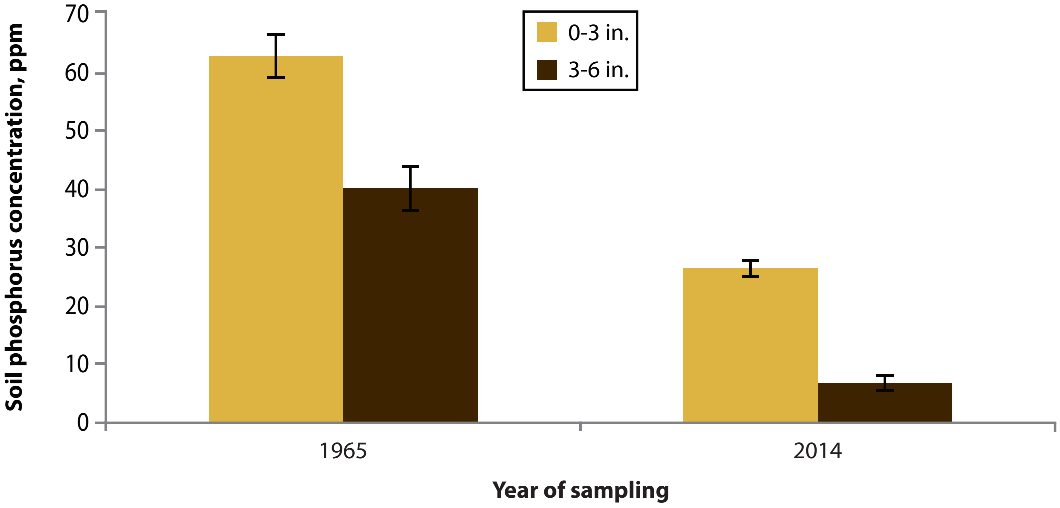

Figure 2. Changes in soil phosphorus concentration during the 50-year study period. Error bars represent one standard error of the mean. Means followed by the same letter(s) within a soil depth are not significantly different using the least squares means (LSMEANS) and adjusted Tukey multiple comparison procedure ($P > 0.05$).

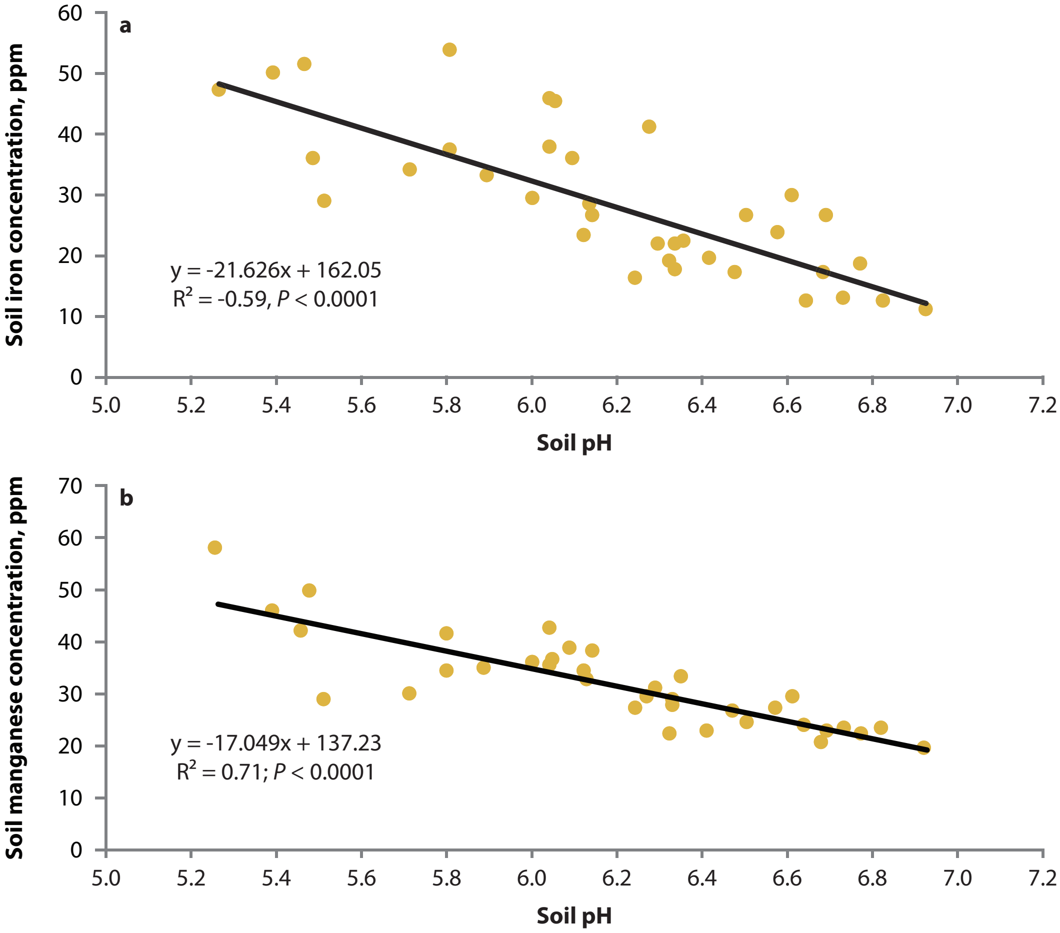

Figure 3. Relationship of soil pH with iron (a) and manganese (b) availability in the upper 3 in. of the soil measured in 2015.