IMPACT OF FERTILIZER MANAGEMENT ON THE STRATIFICATION OF SOIL CHARACTERISTICS IN NO-TILL

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ABSTRACT

The increasing cost of fuel and machinery makes no-till management (NT) a good alternative for producers. With the demanding increase of production, fertilizer utilization efficiency and cycling must be evaluated to address such demand. However, the superficial input of soil amendments under NT may lead to the soil stratification of pH and nutrients and in the first six inches. Three dry-land NT long-term trials located in Perkins, OK (NT since 2005), Stillwater, OK (NT since 2010) and Lahoma, OK (NT since 2010) were sampled after the wheat (Triticum aestivum L.) harvest on 2018/19 growing season at stratified sampling layers of 0-1, 1-2, 2-3, 3-4, 4-5, 5-6 inches. Treatments included a non-fertilized check, half rate, and the full fertility management rate for each location. Nutrients availability (nitrogen (N), phosphorus (P), potassium (K), and organic carbon (OC)) and pH were analyzed at the stratified layers. The results suggest that soil attributes are stratified for all parameters tested in the study. Soil pH, N, and OC were mostly related to N applications, while N is also the most yield-limiting nutrient tested in all trials. The long-term addition of P and K fertilizers on the topsoil increases stratification and nutrients availability when compared to the non-applied plot. Non-fertilized plots were likewise stratified for the tested parameters, which indicates an isolated effect of the NT on the stratification rather than fertilizer addition. Organic carbon and N were highly stratified in the first 2 in and little or no impact was noticed in the subsurface.

INTRODUCTION

No-till management (NT) has increased in agricultural systems over the years. In 1999, areas under NT were 111 million acres around the world while more recently, in 2009, there was an estimation of around 274 million ac. This system can be part of the solution of the increasing demand for food production and fertilizer efficiency. There are many advantages when comparing with a system under conventional tillage practices, including savings on labor, time, and fuel thus being a more profitable economic activity (Derpsch et al., 2010). Moreover, the carbon sequestration is another advantage of the NT and partially solves the anthropogenic carbon dioxide (CO2) emissions responsible for the greenhouse effect and climate change (Lal et al., 1998). However, the superficial nutrient application along with the no soil disturbance under NT may lead to the OC, nutrients and pH stratification in the soil (Crozier et al., 1999; Lupwayi et al., 2006). Although this effect was noticed in previous works, there is still a lack of study considering the depth as an important on the carbon sequestration. No-tillage can avoid and/or reduce erosion, and increase soil OC but, in many cases, some practices could be no cost-effective since reduced tillage increases little or no C in the soils (Manley et al., 2005).

The objective of this study was to evaluate the long-term superficial fertilization effects on nutrient stratification and other soil chemical attributes in three different areas under NT across Oklahoma.

MATERIALS AND METHODS

For this study, soil was sampled after wheat (Triticum aestivum L.) was harvested on 2018/19 growing season from 3 long-term NT trials located in Perkins, OK - Established in 1996 and 2004 become NT; Lahoma, OK - Established in 1970 and 2010 become NT, and Stillwater, OK – Established in 1969 and 2010 become NT. In all locations, treatments were arranged in a randomized complete block design (RCBD) with three replications (n=3) and fertilizer was broadcasted at the pre-plant every year. The size of the plot units was 10 by 20 ft with 10 ft alleys between the replications. Soil sampling was performed utilizing a tubular probe and 25 cores (0 to 6 in depth) were taken from each plot unit. Stratified layers of 0-1, 1-2, 2-3, 3-4, 4-5, 5-6 in were separated by hand utilizing a ruler/knife and prepared for analyses as described by Zhang et al. (2013). The pH was determined using 1:1 soil to deionized water ratio. For bioavailable phosphorus (P) and potassium (K), Mehlich 3 (M3) was used as extractant and their determination was by inductively coupled plasma spectroscopy (ICP). Soil OC and total nitrogen (TN) were determined using a dry combustion carbon/nitrogen analyzer (Zhang et al. 2018). Trials have several treatments although, for the purpose of this study, only two were selected as representative to evaluate the long-term effect on soil attributes (Table 1). Treatments selected for this study was based on their influence on each of the parameters evaluated.

Table 1 - Treatments analyzed for each parameter in all three locations

Location	……………………………….Parameter………………………………				
	pH	P	K	OC	TN
Lahoma	0-40-60	60-0-60	0-40-60	0-40-60	0-40-60
	60-40-60	60-40-60	60-40-60	60-40-60	60-40-60
Stillwater	0-60-40	80-0-40	0-60-40	0-60-40	0-60-40
	80-60-40	80-60-40	80-60-40	80-60-40	80-60-40
Perkins	50-124-00	100-0-0	0-0-0	100-0-0	100-0-0
	100-124-0	100-124-0	100-0-0	100-124-0	100-124-0

Treatments describe as lb ac^{-1} *of applied nitrogen (urea),* P_2O_5 *(triple super phosphate), and* K_2O *(potash), respectively.*

Statistical analyses were performed utilizing JMP 13 PRO® (SAS institute) for each depth and at location for all of the determined parameters. Data was differentiated using ANOVA methods and least square difference to separate the means (Tukey test, $\alpha = 0.05$).

RESULTS AND DISCUSSION

pH

pH ranged from 5 to 7, 4.5 to 6.5 and 4.6 to 7.3 in Lahoma, Stillwater, and Perkins, respectively. Results suggest that pH is stratified in all locations (Figure 1). When comparing the treatments by location, it is noticeable that the N fertilization is causing the acidification in the topsoil, and is aggravating the stratification when comparing treatments that received less or no N fertilizer.

The effect on the pH stratification is also clear when no N fertilizer was applied. This indicates an effect of the NT in the stratification. Crop residue accumulation on the surface and its decomposition also appear to influence the pH stratification. Regarding crop yields (data not shown), N fertilization has been proved as the most limiting nutrient in all areas since this nutrient has increased yield more than when other nutrients were added. The increase in biomass and residues accumulation/decomposition due to N fertilization could also cause a higher stratification of soil pH

Phosphorus

Our results show that the distribution patterns of P are highly stratified in NT areas (Figure 1). In Lahoma, Stillwater and Perkins a treatment mean difference of 110, 165 and 121 ppm of M3 extractable P was found between the 0-1 and 5-6 in soil layers, respectively, for the same treatment. This demonstrates that broadcasting the P fertilizer can drastically stratify the extractable P in the soil. Treatments without any P addition were also stratified for all locations. This suggests that crop residues from previous years also had an impact on P stratification, not only the broadcasted fertilization.

Potassium

In the case of K, the treatments evaluated were chosen to show the impact of N fertilization in the K extraction by the crop (Figure 1). In Lahoma and Stillwater, a lower soil K content is observed when there is N fertilization. The difference in the K contents between treatments is apparent in all layers. However, such difference (especially at Perkins) decreases as the subsurface increases from the topsoil. For the treatments used in this study, there was still a difference in the deepest layer analyzed for Lahoma and Stillwater, which indicates a K stratification beyond that depth.

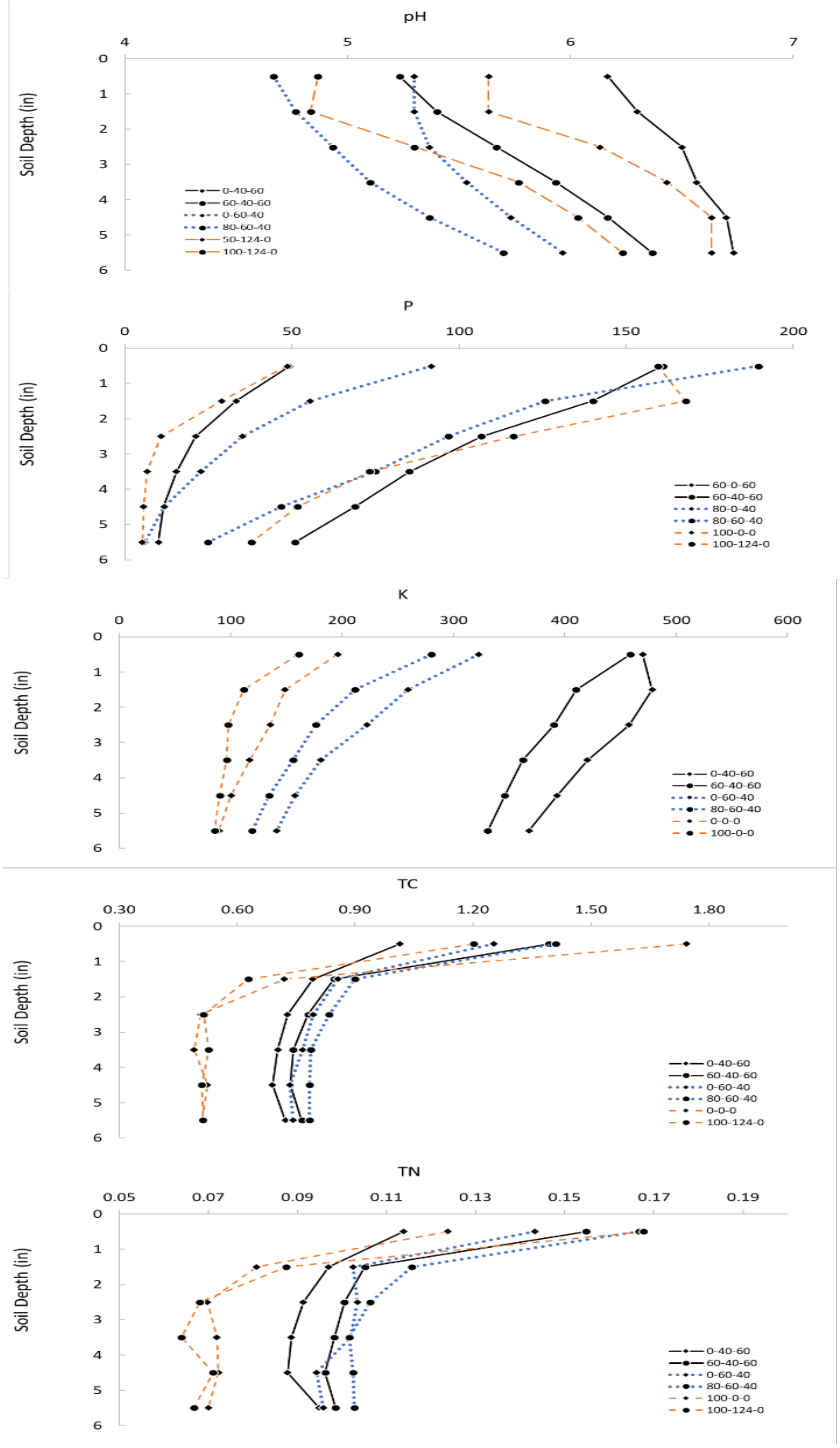
Phosphorus and Potassium build-up

Long-term P and K applications increased the soil available P and K (Figure 1). Since the establishment of the trials in Lahoma, Stillwater, and Perkins (only P), the successive application of P and K fertilizer brought up their bioavailable contents in soils. The results also suggest a reduction in soil P when N is applied at higher rates demonstrating the relation between N with P and K extraction.

Organic Carbon and Total Nitrogen

Differences in OC and TN were found only in the first 2 in regardless the location and appear to be mostly driven by N application.

Our partial results indicate that acidification due to ammoniacal fertilizers application is stratified in the long-term trials under NT. Long-term K and P application result in soil K and P build-up and stratification. Potassium and P removal is increased by N fertilization due to increase in yield. The increase in OC and TN re mostly related to the N fertilization. The stratification effect is more evident in the topsoil (0 to 2 in) and is due to the NT. This might be a consequence of the N being the most limiting nutrient in these areas. High P availability in low stratified pH could be caused by the organic anions produced from the organic matter (OM) and their aluminum (Al) and iron (Fe) complexation.



Figures 1. pH, phosphorus (P), potassium (K), total nitrogen (TN) and organic carbon (TOC) concentrations from stratified soil samples as a function of fertilizer application in 3 long-term NT trials (after at least 9 years under NT). Different lines and colors are locations.

(Black=Lahoma, OK; Blue=Stillwater, OK; Orange = Perkins, OK). Different symbols are fertilizers rates within each location.

Table 2 - Least significant difference (LSD) of stratified soil attributes as a function of fertilizer application (Tukey test, α = 0.05).

Depth (in)	pH	P	K	TN	TC
		……ppm……		……%……	
			……………………...Lahoma ……………………..		
0 - 1	0.29	41	52	0.027	0.44
1 - 2	0.29	44	55	0.017	0.10
2 - 3	0.34	52	64	0.005	0.06
3 - 4	0.45	60	85	0.009	0.08
4 - 5	0.28	57	65	0.009	0.06
5 - 6	0.41	50	75	0.012	0.12
			……………………...Stillwater……………………..		
0 - 1	0.54	54	64	0.021	0.19
1 - 2	0.28	49	58	0.018	0.16
2 - 3	0.34	37	66	0.023	0.06
3 - 4	0.26	23	61	0.017	0.07
4 - 5	0.60	32	59	0.015	0.10
5 - 6	0.60	28	50	0.021	0.10
			……………………...Perkins……………………..		
0 - 1	0.53	25	64	0.039	0.46
1 - 2	0.59	14	48	0.016	0.24
2 - 3	0.41	11	45	0.011	0.12
3 - 4	0.75	16	52	0.016	0.18
4 - 5	0.45	12	58	0.011	0.18
5 - 6	0.60	28	50	0.021	0.10

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