CONSERVATION MANAGEMENT AND NITROGEN FERTILIZATION TO ENHANCE SOIL CHEMICAL AND BIOLOGICAL PROPERTIES

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ABSTRACT

Cover crops and no-tillage are increasing in use across Texas. On the Southern High Plains (SHP) these practices are important mitigators of wind erosion and are suggested to increase soil health and other positive soil attributes. This study aimed to monitor and evaluate the soil chemical and biological changes that occur shortly after implementing conservation practices and nitrogen management strategies on the SHP. It was determined that in the short term some soil chemical and biological changes may be attributed to cover crop and no-tillage implementation. In addition, cotton lint yield was increased with no tillage and cover crop compared to conventional till three years after implementation.

INTRODUCTION

The Southern High Plains (SHP, MLRA 77C) are an intensively cropped semi-arid region surrounding Lubbock, TX. The major crop on the SHP is cotton (*Gossypium hiristum* L.), which comprised about 3.1 million acres in in 2019 (NASS, 2019). Over the last century, much work has been done to reduce wind erosion across the region resulting in a significant reduction in erosion (Zobeck & Van Pelt, 2011). In the last few decades, these efforts have increased due to increasing encouragement for producers to adopt soil health promoting practices through government assistance and cost-share programs aimed at increasing the use of winter cover crops in the area. However, there isn't much data regarding the short-term impacts of these conservation systems on cotton production on the SHP.

The main objective of this study was to evaluate soil chemical and biological properties at major points in the cotton growing system 3 years after implementing soil and N management practices. In addition, cotton lint yield was evaluated to increase our knowledge about how these practices and soil health factors impact cotton lint yield on the SHP.

MATERIALS AND METHODS

This study was conducted at the Texas A&M AgriLife Research and Extension station in Lubbock, Texas (33.68767°, -101.827696°) during 2018. The soil in this area is an Acuff loam and was evaluated for macronutrient composition prior to beginning the study in 2016 (McDonald et al., 2019). Rainfall for this area averages about 19 in, and this study was irrigated as needed using furrow irrigation.

A randomized complete block arranged as a split plot was used in order to make tillage practice consistent through the entire length of the field. The main-plot was tillage system including no-tillage with a triticale (*Triticale hexaploide Lart*) cover crop (NTW), no-tillage winter fallow (NT), and conventional tillage winter fallow (CT). The split-plot for this study was the timing of N fertilizer application including: 100% pre-plant application (PP), 100% mid-season application applied at pinhead square (MS), 40% PP and 60% MS application (SPLIT), 100% PP with N stabilizer (urease inhibitor, STB), and a no N control. Plots were 50 ft in length by 4 rows wide (40" spacing) and all tillage and treatment combinations were conducted in triplicate. The wheat cover crop was drilled (8" spacing) several times before a successful establishment of triticale (Trical 813) was planted on 15 February 2018 at 60lbs/acre. The cover was terminated on 22 May 2018 prior to cotton (Delta-Pine 1518 B2XF) planting on 24 May 2018 at a rate of 53,000 seeds/acre. The late termination was in response to the late planting and the desire to allow the cover crop extra growth time prior to the growing season. Cotton was harvested on 16 November.

Soil samples were collected at major crop growth periods including vegetative growth (Veg, 28 June 2018), peak plant production (Peak, 24 August 2018), and reproductive growth (Repro, 1 November 2018). Soil samples were dried, and a 40 g aliquot was used to determine C mineralization with a 3-day incubation-titration (Franzluebbers, 2016). The remaining soil was ground to pass a 2mm sieve and evaluated for: nitrate-N (NO_3^--N) and ammonium-N (NH_4^+-N) by extracting with 2 N KCl at a 1:10 soil to extraction ratio and analyzing using flow injection spectrometry (FIAlab 2600, FIAlab Instruments Inc., Belevue, WA, Keeney and Nelson, 1982); pH with a 1:2 soil to deionized water slurry and a pH probe (Schofield & Taylor, 1955). In addition, the gravimetric water content (0-4 in, 4-8 in, GWC) of the soil was determined by drying the soil at 140°F for at least three days.

Statistical Analysis of soil characteristics and yield was conducted in SAS 9.4 using the PROC GLIMMIX procedure at a significance level of $a < 0.05$ (SAS-Institute, 2017). In addition, the data was analyzed via principle components analysis (PCA) using the ggbiplot function in the R statistical program (R-Core-Team, 2019; Vu, 2011).

RESULTS AND DISCUSSION

Analysis of soil characteristics determined differences due to the interaction of month and depth with the implemented tillage systems and N treatments. Due to the interactions, all soil characteristics were analyzed within month and depth. Carbon mineralization was affected by tillage system at the 0-4 in depth for the Peak (p<0.001) and Repro (p=0.005) samplings with the NTW and NT systems having greater mineralizable C than the CT system at both samplings (Table 1). No N treatment or interaction of tillage system and N treatment effects on mineralizable C were determined at the 0-4 in depth or at the Veg sampling. At the 4-8 in depth, there were no differences at any sampling for tillage system, N treatment, or their interaction. This lack of effects at the 4-8 in depth is likely due to the depth of tillage implemented in the CT system (2-3 in) and the recentness of the tillage system's implementation (November 2015) in addition to the majority of microbial activity occurring in the upper layers of the soil.

Gravimetric water content was affected by tillage system at the 0-4 in depth (p=0.027) with the NT and NTW systems having greater GWC than the CT system. Increased GWC in the no-tillage systems is expected at this point in the growing season due to the potential for reduced evaporation from these systems in semi-arid climates (Jones, Hauser, & Popham, 1994). The differences in GWC due to N treatment at Peak (0-4 in: p=0.002; 4-8 in: p=0.003) occur between no application and early-season N applications compared to the treatments with mid-season applications. When N is not applied till the first reproductive growth, the plant may be behind in growth stage and an application of N may spark rapid growth and thus increased the water demand within those treatments. At the Repro sampling, GWC was affected by tillage system at the 0-4 in depth (p=0.006) with the NTW system having greater GWC than the CT system (Table 1). This would be expected as late season rains would have increased GWC across all tillage systems, but with reduced evaporation and the NTW system is expected to have greater GWC.

Nitrate was affected by N treatment at the Veg sampling at 0-4 in (p=0.050) and 4-8 in depths (p=0.019) with the PP treatment having greater NO_3^--N concentrations than the control and MS treatment at both depths (Table 1). In addition, the concentration of NO_3^--N was greater for the STB treatment compared to the control and MS treatment at the 4-8 in depth. This difference in NO_3^--N concentration is expected at this sampling point due to the pre-season application of N within the PP and STB treatments and no N addition in the control and MS treatment at this point. The concentration of NO_3^--N was determined to be affected by tillage system at the Peak sampling (p<0.001) with the CT system having greater NO_3^--N concentrations than the NTW and NT systems. This could be due to greater plant growth in the NTW and NT systems which would reduce NO_3^--N for those systems. The concentration of NH_4^+-N was affected by N treatment at the Veg (p<0.001) and Peak (p<0.001) samplings at the 4-8 in depth. The PP treatment had a greater NH_4^+-N concentration at 4-8 in than the SPLIT treatment and the control for the Veg sampling. This difference, like the differences determined for NO_3^--N at the Veg sampling, is expected due to the application of N as UAN, and only the PP and STB treatments receiving the full rate at this point in the growing season. For the Peak sampling, the MS treatment had a greater concentration of NH_4^+-N than the rest of the N treatments and the control. As mentioned before, the MS treatment received all its N during the month of July, so a greater concentration of NH_4^+-N is expected compared to the rest of the N treatments. The lack of differences in NO_3^--N concentration compared to the differences seen for NH_4^+-N can be attributed to the mobility of NO_3^--N in the soil and other loss pathways of NO_3^--N.

Nitrogen treatment affected soil pH at all sampling points for all depths. At the Veg sampling the control had a greater pH than the SPLIT, PP, and STB treatments at the 0-4 in (p=0.003) and 4-8 in (p<0.001) depths (Table 1). In addition, pH was greater in the MS treatment compared to the PP and STB treatments at both depths and the split treatment at the 4-8 in depth. A similar trend occurred at the Peak sampling, with the control having a greater pH than the rest of the N treatment, and the MS treatment having a greater pH than the PP treatment at the 0-4 in depth (p<0.001). At the 0-4 in depth, pH was greater in the control compared to all N treatments at the Peak sampling (p=0.002). At the Repro sampling, the control had a greater pH than all N treatments except the MS treatment, and the MS treatment had a greater pH than the STB treatment at the 0-4 in depth (p=0.035). At 4-8 in, the pH of the control was greater than that of all the N treatments for the Repro sampling. It is expected that pH would be decreased following N application early in the season accounting for the reduced pH in the treatments with PP applications at the Veg sampling. The pH also consistently increases throughout the year which is likely due to the pH of the irrigation water at this location.

Cotton lint yield was affected by tillage system (p=0.016) with the NTW producing greater cotton lint (1018.7 lb ac^{-1}) than the CT system (598.2 lb ac^{-1}). This yield increase may be due to the early season protection of the cotton seedlings from harsh environmental conditions including 100°F temperatures and average wind speeds of about 14.5 mph. Nitrogen uptake was also affected by tillage (p=0.014) with the NTW system having greater N uptake (101.5 kg ha^{-1}) than the CT system (65.2 kg ha^{-1}). Greater N uptake is likely due to greater plant growth in the NTW system.

To better understand how soil characteristics discussed above affected cotton lint yield during this growing season, a principle components analysis was conducted (Fig. 2). It was determined that the first component (PC1) was a measure of soil C for the Veg sampling at 0-4 in in depth (Fig. 2a). the first component (PC1) was a measure of soil C for the Veg sampling at

Table 1. Soil chemical characteristics at 0-4 in and 4-8 in for the vegetative growth stage, peak plant production, and reproductive growth stages in 2018.

Depth	Tillage	N Treatment	Vegetative Growth					Peak Plant Production					Reproductive Growth				
			GWC[c]	Mineralized C	$NO3_3^-$-N	NH_4^+-N	pH	GWC	Mineralized C	$NO3_3^-$-N	NH_4^+-N	pH	GWC	Mineralized C	$NO3_3^-$-N	NH_4^+-N	pH
			%	--------------ppm--------------				%	--------------ppm--------------				%	--------------ppm--------------			
0-4 in	NTW[a]	Control[b]	13.7	97.4	5.2	26.6	7.8	9.4	87.0	5.2	26.6	10.3	17.4	144.8	5.2	26.6	8.3
		PP	13.3	135.0	15.3	1.4	7.4	9.6	84.5	15.3	1.4	6.7	16.7	143.8	15.3	1.4	7.9
		MS	13.6	124.3	2.8	1.0	7.7	8.7	87.5	2.8	1.0	8.7	17.4	151.8	2.8	1.0	8.3
		SPLIT	14.5	101.3	8.5	13.1	7.7	8.6	96.8	8.5	13.1	11.3	17.3	165.3	8.5	13.1	8.0
		STB	13.3	171.0	5.9	0.0	7.5	8.9	66.0	5.9	0.0	7.2	16.8	101.8	5.9	0.0	8.0
	NT	Control	13.2	168.7	1.5	13.4	7.8	8.6	85.5	1.5	13.4	7.0	16.0	102.0	1.5	13.4	8.3
		PP	13.3	128.3	10.1	17.1	7.4	9.5	82.0	10.1	17.1	8.4	16.0	136.0	10.1	17.1	8.1
		MS	13.4	82.2	1.5	0.0	7.8	8.2	90.5	1.5	0.0	11.2	17.8	105.3	1.5	0.0	8.2
		SPLIT	16.4	145.3	5.5	13.7	7.7	8.9	70.5	5.5	13.7	12.1	16.0	161.8	5.5	13.7	8.0
		STB	15.1	143.9	10.4	19.5	7.6	10.2	70.5	10.4	19.5	5.5	16.3	108.0	10.4	19.5	7.9
	CT	Control	11.1	104.8	9.9	19.1	7.8	9.0	41.0	9.9	19.1	11.6	15.2	87.8	9.9	19.1	8.4
		PP	13.8	140.0	9.3	0.0	7.6	8.7	48.3	9.3	0.0	6.5	15.9	105.0	9.3	0.0	8.2
		MS	13.6	141.7	28.9	27.3	7.7	7.3	54.3	28.9	27.3	11.0	15.3	100.8	28.9	27.3	8.3
		SPLIT	13.6	93.3	22.7	13.4	7.6	8.4	58.9	22.7	13.4	7.1	15.7	101.0	22.7	13.4	8.2
		STB	13.9	135.8	52.3	0.0	7.5	8.9	54.7	52.3	0.0	7.4	15.8	99.0	52.3	0.0	8.1
4-8 in	NTW	Control	15.5	91.5	3.7	0.0	7.9	11.1	40.5	3.7	0.0	8.0	15.6	88.3	3.7	0.0	8.4
		PP	15.8	54.8	2.1	8.2	7.8	10.5	58.5	2.1	8.2	7.7	16.0	97.3	2.1	8.2	8.2
		MS	15.6	96.7	5.6	1.7	7.8	9.1	89.3	5.6	1.7	8.0	17.2	106.9	5.6	1.7	8.3
		SPLIT	15.6	129.0	8.2	4.0	7.8	9.3	71.0	8.2	4.0	7.9	16.0	90.0	8.2	4.0	8.3
		STB	15.6	131.0	5.3	0.0	7.6	9.6	65.3	5.3	0.0	7.8	16.5	92.0	5.3	0.0	8.4
	NT	Control	15.6	105.0	2.3	5.1	7.8	10.7	84.8	2.3	5.1	7.9	15.2	89.0	2.3	5.1	8.2
		PP	15.2	76.9	7.8	0.0	7.6	10.6	53.3	7.8	0.0	7.9	17.1	75.3	7.8	0.0	8.1
		MS	14.5	94.1	3.2	0.0	7.8	9.0	63.0	3.2	0.0	7.9	15.9	97.8	3.2	0.0	8.1
		SPLIT	15.1	112.5	4.1	3.5	7.8	9.6	47.2	4.1	3.5	7.8	16.2	95.0	4.1	3.5	8.2
		STB	15.3	90.5	2.3	4.7	8.0	10.7	76.0	2.3	4.7	7.9	15.3	106.5	2.3	4.7	8.4
	CT	Control	11.5	60.8	5.7	0.0	7.7	10.3	52.3	5.7	0.0	7.9	15.0	85.8	5.7	0.0	8.0
		PP	15.4	84.4	2.2	0.0	7.7	9.2	43.0	2.2	0.0	7.7	15.1	94.3	2.2	0.0	8.1
		MS	16.0	108.0	5.2	0.0	7.8	10.2	65.0	5.2	0.0	7.9	15.5	115.0	5.2	0.0	8.3
		SPLIT	15.3	67.4	8.7	0.0	7.7	8.9	51.5	8.7	0.0	7.8	16.4	107.3	8.7	0.0	8.3
		STB	15.9	86.6	14.7	21.4	7.5	9.7	39.5	14.7	21.4	7.9	15.7	103.8	14.7	21.4	8.2

[a] NTW, no-till with winter wheat cover; NT, No-till winter fallow; CT, conventional tillage winter fallow

[b] Control, no added nitrogen (N) fertilizer; PP, 100% pre-plant N fertilizer application; MS, 100% mid-season N fertilizer application; SPLIT, 40% PP 60% MS N fertilizer application; STB, 100% PP N fertilizer application with N stabilizer product.

[c] GWC, gravimetric water content

0-4 in depth (Fig. 2a). Greater soil C during vegetative growth likely indicated increased soil health and was also positively associated with yield at this point in the growing season. The second component (PC2) was a measure of pH, and its contrasting relationship with NO_3^--N. As NH_4^+ is converted to NO_3^--N, the soil can be acidified through the release of hydrogen ions during this process so it was expected that increased soil pH would be associated with decreased NO_3^--N. At the 4-8 in depth (Fig. 2b), PC1 was also largely a measure of nitrification with the same contrasting relationship as seen at the shallower depth. In addition, PC2 at the 4-8 in depth was a measure of soil C (Fig. 2b).

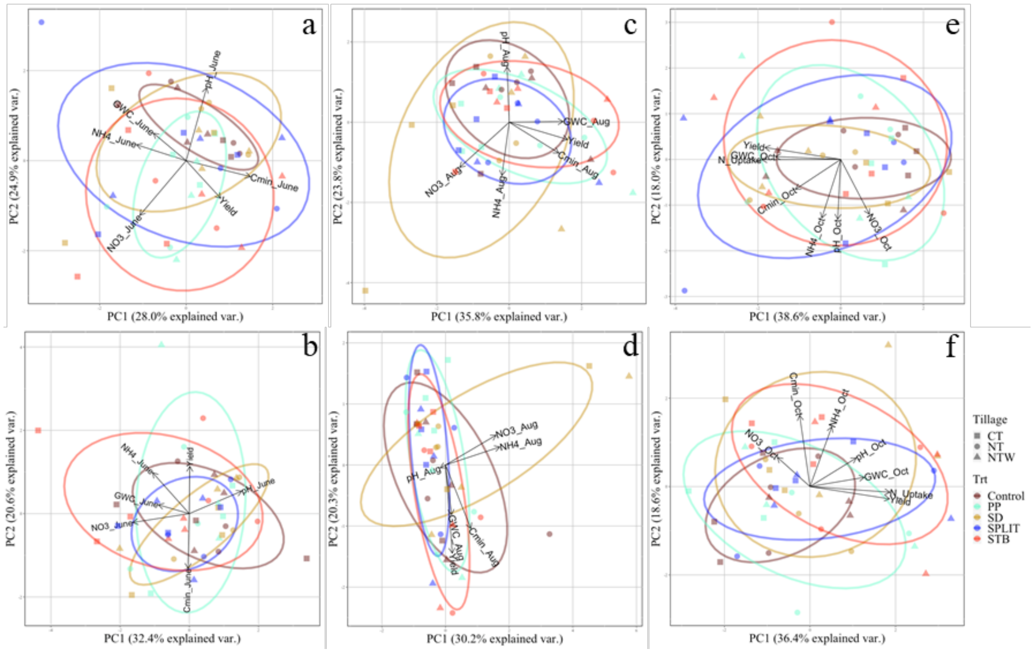

Figure 2. Principle components analysis of yield and soil characteristics at a) vegetative growth (Veg) 0-4 in; b) Veg 4-8 in; c) peak plant production (Peak) 0-4 in; d) Peak 4-8 in; e) reproductive growth 0-4 in (Repro); f) Repro 4-8 in. for 2018. NTW, no-till with winter wheat cover; NT, No-till winter fallow; CT, conventional tillage winter fallow; Control, no added nitrogen (N) fertilizer; PP, 100% pre-plant N fertilizer application; MS, 100% mid-season N fertilizer application; SPLIT, 40% PP 60% MS N fertilizer application; STB, 100% PP N fertilizer application with N stabilizer, Cmin, mineralizable C; GWC, gravimetric water content.

At 0-4 in for the Peak sampling PC1 was a measure of the positive relationship between GWC and yield at peak plant production (Fig. 2c). This was expected due to greater transpiration demand at the Peak sampling time. Yield and GWC had a contrasting relationship with NO_3^--N concentration at this point in the growing season, which occurs after all N applications have occurred for the year. This negative relationship was likely indicating reduced yield where the plant has taken up less NO_3^--N and thus may be N limited. Soil pH was the measure of PC2 and was likely due to the negative association with increasing NO_3^--N and yield as a measure of plant production (Fig. 2c). At 4-8 in for the Peak sampling, PC1 was a measure of soil N content where NO_3^--N and NH_4^+-N were positively correlated together, and the variability likely was the result of overall reduced nutrient uptake (Fig. 2d). The PC2 for the 4-8 in depth at Peak sampling was a measure of decreasing yield although there were no other associations with this variable (Fig. 2d).

The PC1 at 0-4 in for the Repro sampling was a measure of plant production and its main drivers as yield, GWC, and N uptake were all correlated negatively suggesting that reduced GWC and N uptake would decrease yield, which was expected (Fig. 2e). No variable was associated with PC2 although there might have been a slight relationship between decreasing inorganic N and decreasing pH, although this relationship is not understood at this time. For the 4-8 in depth at the Repro sampling, PC1 was a measure of the positive relationship between N uptake and plant production/yield (Fig. 2f) Mineralizable C was the variable most associated with PC2 at the 4-8 in depth at the Repro sampling and had a slight association with NH_4^+-N (Fig. 2f).

CONCLUSION

Cotton lint yield is affected when conservation tillage systems are implemented likely due to one of the inherent benefits of implementing cover crops on the SHP reducing wind erosion that can damage a cotton crop early in the growing season. In addition, 3 years after implementation, mineralizable C was increased in cover crop systems at peak plant production. As an indicator of soil health, a mineralizable C increase indicates an improvement in soil health and with this indicator also being strongly related to yield at Peak and Repro, it is likely that this parameter is a good indicator of agronomic productivity as well. Overall, the soil characteristics measured in this study are good indicators, whether by positive or negative association, of yield at different time points throughout the growing season. This study will continue through 2020 and should help indicate longer-term changes expected when converting to conservation systems on the SHP.

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