Influence of Tillage practices on Lint Yield, Water Quality, and Soil Exchangeable N in Cotton Production

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Abstract

Objectives of a 2017 field trial were to quantify how different tillage and N fertilization practices affect cotton productivity and nutrient management in a furrow-irrigated cotton production systems. Lint yield, soil N and runoff water quality metrics were measured after using either a conventional sweep plow or conservation tillage plow to clear water furrows combined with either broadcast urea or 32% urea ammonium nitrate (UAN) sidedressed at 90 lb acre^{-1}. Seasonal NO_3-N and P were the largest nutrient in runoff and associated with the intensity of irrigation and rainfall. Lint yields ranged from 550 to 1143 lb ac^{-1} and were unaffected by tillage and fertilizer-N treatments. There was no downward movement of soil NO_3-N in the deeper depths across tillage and N fertilizer treatments. Water quality metrics such as pH, electrical conductivity, hardness, total suspended solids (TSS) and soil sediment concentrations (SSC) were within acceptable ranges and expected to have minimal impacts on surrounding waterbodies.

Introduction

Cotton (*Gossypium hirsutum* L.) is grown on raised beds and commonly furrow-irrigated using poly-tubing. In the mid-South, cotton producers typically use tillage to clear water furrows prior to first furrow irrigation. Tillage method may affect infiltration, runoff and risk of nutrient loss especially in soil prone to surface sealing. While furrow irrigation improves delivery of water to the plants and consequently increases water use productivity, this practice may increase nutrient loss and impact field runoff. In a 2016 study on furrow-tillage practices with different fertilizer N sources (urea vs. 32% UAN), nitrogen (N) was the major nutrient that was lost (Adviento-Borbe et al., 2018). Furrow tillage and N application method had varying effects on total N loss and water quality of runoff. A follow-up investigation with these tillage and N management systems will verify their impacts on nutrient losses and water quality. This information is essential in assessing the

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potential of conservation tillage to sustain high lint yields while reducing N-fertilizer and irrigation water inputs.

The overarching goal of this research project was to improve understanding of the interactions of tillage, fertilizer use and irrigation to support recommendations for expanded adoption of soil and water conservation practices in U.S. cotton. Specific objectives were: (i) to quantify water quality of surface runoff under different tillage and fertilizer N practices, (ii) to quantify soil exchangeable N at different soil depths following irrigation events and (iii) to determine crop response under these tillage and fertilizer N practices.

Procedures

Two furrow-tillage treatments (conventional cultivator - standard sweep plow (CT) vs. conservation plow, Furrow Runner (FT)) and N-fertilizer type and placement (Broadcast urea vs. sidedressed 32% UAN each at a rate of 90 lb acre^{-1} fertilizer N) were arranged in a randomized complete block design with three replications at the University of Arkansas System Division of Agriculture's Judd Hill Cooperative Research Station, Trumann, Arkansas. Each treatment plot was 12 rows wide and 520 ft long. The cotton cultivar used was ST 4946 GLB2, planted in a Dundee silt loam soil at about 3 seeds per foot. Furrow irrigation was implemented using poly-tubing made to deliver water efficiently to all treatment plots.

Irrigation water runoff collection was made on 17, 26 July, and 3 August while runoff water samples following rain events were collected on 14, 26 and 28 July, and 9 August using automated water samplers and H-flumes (6712, Teledyne ISCO) installed in each test plot. At each sampling event, two 1-L samples were collected. The samples were stored on ice and filtered with a 0.45-µm CA syringe filter within 24-h of sample collection and stored frozen prior to chemical analyses.

Water samples were analyzed for NH_4-N, NO_3-N, NO_2-N (Doane and Horwath, 2003), PO_4- (Murphy and Riley, 1962), pH, electrical conductivity, hardness, alkalinity (APHA, 1999), total suspended solid (APHA, 1999) and suspended sediment concentration (SSC) (ASTM, 2000). All of the water samples were stored at 4 °C before physical analysis. Composite soil samples were collected after first bloom (19 July), during flowering (7 August), during boll loading (26 August), and during boll opening (13 September) at four soil depths; 0–15 cm, 15–30 cm, 30–60 cm and 60–90 cm. Yield determinations were made using a two-row cotton picker in designated harvest rows.

Results and Discussion

Lint yields of plots ranged from 550 to 1143 lb ac^{-1} (616 to 1280 kg ha^{-1}) with a mean yield of 873 lb ac^{-1} (977 kg ha^{-1}) (Fig. 1). Highest average lint yields were measured in FT-UAN treatments during the 2017 growing season. However, there were no significant lint yield differences among tillage and fertilizer-N treatments

(*P* = 0.149), furrow-tillage treatments (*P* = 0.380) or fertilizer-N treatments (*P* = 0.079). The 2017 yield averages were lower by 18% when compared to lint yields from 2016. Suboptimal yield was related to high incidence of Verticillium wilt which was observed at historically high levels in research plots across the Judd Hill station. Symptomology ratings made in late season did not show evidence of treatment effects on disease incidence (data not shown).

Median concentrations of soluble nutrients in runoff increased in the order NH_4-N < NO_2-N < P < NO_3-N. Soluble NO_3-N ranged from 0.23 to 5.54 mg N L^{-1} while other nutrients ranged from 0 to 0.12 mg NH_4-N L^{-1}, 0.01 to 0.36 mg NO_2-N L^{-1} and 0.07 to 0.93 mg P L^{-1} (Table 1). Median concentrations of NO_3-N and NO_2-N in the study were below the drinking water standards of 10 mg NO_3-N L^{-1} and 1 mg NO_2-N L^{-1} (USEPA, 1994). Concentrations of soluble-P were above the EPA Ecoregion X background levels for lakes (60 µg L^{-1}) or rivers (128 µg L^{-1}) (USEPA, 2001). Amounts of NH_4-N, NO_2-N and soluble-P in the runoff water were variable and were not significantly different among tillage × fertilizer N treatments (*P* = 0.18 to 0.97) or between tillage treatments (CT vs FT) (*P* = 0.43 to 0.83). These findings indicate that tillage treatments or the interaction of tillage and fertilizer N placement had no effect on runoff concentrations of NH_4-N, NO_2-N and P nutrients. On the other hand, seasonal mean NO_3-N concentrations were significantly higher in CT-UAN treatments than other treatments (*P* = 0.01) (Table 1). Across all sampling events, high levels of NO_3-N occurred (*P* < 0.0001) on 3 and 28 July following rainfall and when irrigation was applied 7 days after N-fertilizer application, respectively. In the case of P, higher amounts of runoff P occurred in all treatments in the early growth stage. High levels of runoff P also coincided with high total suspended solids and soil sediment concentrations that were measured during the growing season.

Variations in water quality characteristics such as pH, specific electrical conductivity (EC), hardness, and turbidity were generally small and were within the normal range of irrigation waters (Table 2). Differences among the water quality metrics measured were not significant across all tillage and fertilizer-N treatments (*P* = 0.08 to 0.67); however, water quality properties were significantly affected by sampling date (*P* < 0.0001) (data not shown). The pH and EC values were within the range of irrigation water quality thresholds suitable for growing cotton. Total suspended solids (TSS) were higher in Conventional tillage (170–1896 mg L^{-1}) than TSS values from Conservation tillage treatments (150–1476 mg L^{-1}). In contrast, soil sediment concentrations ranged roughly the same in both tillage treatments (Conventional: 473–1929 mg L^{-1}; Conservation: 418–1828 mg L^{-1}). Turbidity values increased during the early growing season and were highly correlated to TSS and SSC levels. Concentrations of TSS, SSC and turbidity were not significantly different among the four treatments, suggesting that tillage and fertilizer-N did not impact variability that was measured throughout the growth period.

Across all treatments, sampling depths and dates, soil exchangeable N varied with concentrations ranging from 0.07 to 19.13 NO_3-N, 0 to 1.25 NH_4-N and 0 to 0.28 NO_2-N ppm. Nitrate-N constituted the major proportion of soil N in various depths (0.46 to 176 mg kg^{-1} soil). The largest amounts occurred during boll loading at the 60-90 cm soil depth range (data not shown). Application of fertilizer N slightly increased the amount of soil exchangeable NO_3-N. However, it was not until later in the season that a substantial increase was observed. The increase in NO_3-N concentrations coincided with the increased frequency of irrigation and rain events. Although soil NO_3-N varied largely during maturity stage, overall effects of tillage and fertilizer N application on soil NO_3-N contents at different depths were not significant. However, frequency and amount of precipitation and irrigation water greatly influenced the movement of exchangeable NO_3-N to deeper soil depths (>30 cm). These results show that N-fertilizer placement had minimal influence on the levels of exchangeable NO_3-N that moved down the soil profile. To avoid substantial nitrate leaching, improved irrigation practices using soil moisture monitoring and irrigation scheduling could be implemented.

Practical Applications

Concentrations of runoff N and P were associated with the intensity and frequency of irrigation and precipitation during the growing season. Water quality metrics were within the range that have minimal risk in waterways. Lint yields were not affected by tillage and fertilizer- N placements. Also, our treatments had minor impact on the NO_3-N levels that moved down the soil profile. Movement of soil-N in deeper profiles was most affected by irrigation events during boll filling-maturity stage. Over the 2-year study, our results support the adoption of conservation practices that minimize nutrient losses in furrow irrigation systems. Improving nutrient management will lead to more sustainable cotton systems.

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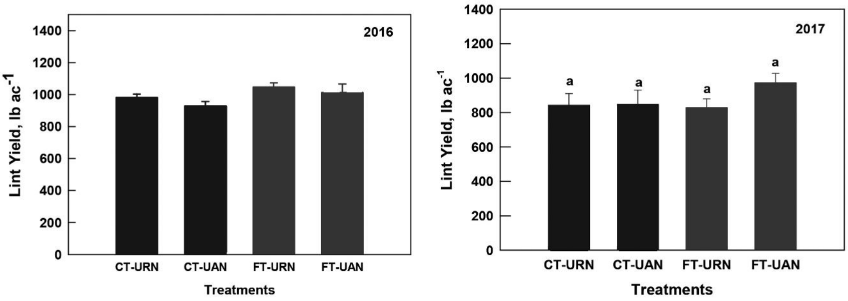

Fig. 1. Average lint yields in the different tillage and fertilizer N treatments (FT = Furrow tillage, CT = Conventional plow, URN = urea broadcasted, UAN = 32% urea ammonium nitrate injected) during 2016 and 2017 growing seasons. Lint yields followed by the same letter are not significantly different at $P < 0.05$.

Table 1. Seasonal mean (geometric) concentrations of soluble nutrients in runoff from the four tillage and fertilizer N treatments during the 2017 growing season.

Tillage treatment	Fertilizer N treatment	Soluble nutrient[a]			
		Ammonium-N (NH_4-N)	Nitrate-N (NO_3-N)	Nitrite-N (NO_2-N)	Phosphorus (P)
		----------------------	----------*mg L^{-}*	----------------------	----------------------
Conventional (CT)	Urea (URN)	0.01 (0-0.10)	0.63 (0.25-3.69)*b*	0.05 (0.01-0.29)	0.16 (0.06-0.31)
	32% UAN (UAN)	0.00 (0.0-0.02)	1.05 (0.73-1.77)*a*	0.04 (0.03-0.04)	0.19 (0.08-0.35)
Conservation (FT)	Urea (URN)	0.01 (0.01-0.05)	0.84 (0.32-5.54)*b*	0.06 (0.01-0.36)	0.24 (0.13-0.62)
	32% UAN (UAN)	0.02 (0-0.12)	0.78 (0.23-4.50)*b*	0.06 (0.01-0.30)	0.29 (0.07-0.93)

[a] Values inside parentheses are computed ranges. Mean concentrations in each column with same letter were not significantly different at $P < 0.05$ level.

Table 2. Seasonal mean water quality characteristics of irrigation water during runoff or irrigation event in the four treatments.

Tillage treatment	Fertilizer N treatment	Water quality parameters[a]						
		pH	Electrical conductivity	Hardness	Alkalinity	Turbidity	Total suspended solids	Soil sediment concentrations
			µS cm^{-1}	*mg L^{-1}*	*mg $CaCO_3$ L^{-1}*	NTU[b]	*mg L^{-1}*	*mg L^{-1}*
Conventional Tillage	Urea	7.7 (7.3-8.1)	431 (139-661)	158 (38-228)	72 (9-210)	931 (1-3263)	589 (170-1348)	830 (473-1929)
	32% UAN	7.6 (6.7-8.0)	458 (99-638)	170 (27-238)	27 (17-31)	1741 (2-3825)	967 (733-1896)	1245 (938-1860)
Conservation Tillage	Urea	7.8 (7.2-8.2)	404 (154-578)	146 (41-226)	43 (9-118)	1187 (2-3546)	635 (259-1476)	868 (418-1828)
	32% UAN	7.4 (6.1-8.1)	319 (66-649)	109 (13-220)	41 (1-91)	3875 (1-19273)	398 (150-723)	901 (390-1264)

[a] Values inside parentheses are computed ranges.
[b] Nephelometric Turbidity Unit.