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Water quality of surface runoff and lint yield in cotton under furrow irrigation in Northeast Arkansas

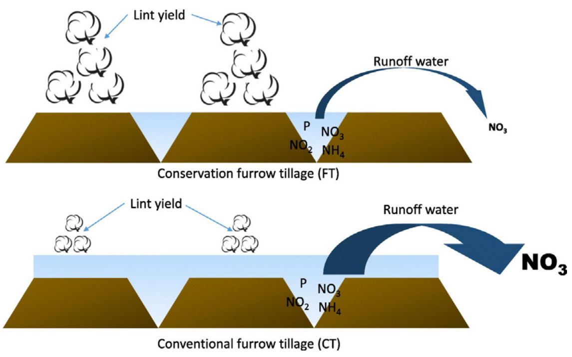
M. Arlene A. Adviento-Borbe [a,*], Brittany D. Barnes [b], Oluwayinka Iseyemi [a], Amanda M. Mann [d], Michele L. Reba [a], William J. Robertson [c], Joseph H. Massey [a], Tina G. Teague [d]

[a] *Delta Water Management Research Unit, United States Department of Agriculture-Agricultural Research Services, 504 University Loop, Jonesboro, AR 72401, United States*
[b] *Rabo Agrifinance, 2600 Alexander Drive, Jonesboro, AR 72401, United States*
[c] *Crop, Soil & Environmental Science, University of Arkansas Division of Agriculture, 649 Jackson 917 Newport, AR 72112, United States*
[d] *Agricultural Experiment Station, University of Arkansas Division of Agriculture, PO Box 2340, State University, AR 72467, United States*

HIGHLIGHTS

- Intensity and chemical form of nutrient losses were mainly controlled by volume of water runoff and agronomic practice.
- Nitrate was the highest N form in runoff water.
- Lint yields increased through improved furrow tillage irrigation and adequate N rate application.
- This information helps stakeholders develop efficient cropping systems that minimize water pollution and sustain high yield.

GRAPHICAL ABSTRACT



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ABSTRACT

Use of furrow irrigation in row crop production is a common practice through much of the Midsouth US and yet, nutrients can be transported off-site through surface runoff. A field study with cotton (*Gossypium hirsutum*, L.) was conducted to understand the impact of furrow tillage practices and nitrogen (N) fertilizer placement on characteristics of runoff water quality during the growing season. The experiment was designed as a randomized complete block design with conventional (CT) and conservation furrow tillage (FT) in combination with either urea (URN) broadcast or 32% urea ammonium nitrate (UAN) injected, each applied at 101 kg N ha^{-1}. Concentrations of ammonium (NH_4-N), nitrate (NO_3-N), nitrite (NO_2-N), and dissolved phosphorus (P) in irrigation runoff water and lint yields were measured in all treatments. The intensity and chemical form of nutrient losses were primarily controlled by water runoff volume and agronomic practice. Across tillage and fertilizer N treatments, median N concentrations in the runoff were <0.3 mg N L^{-1}, with NO_3-N being relatively the highest among N forms. Concentrations of runoff dissolved P were <0.05 mg P L^{-1} and were affected by volume of runoff water. Water pH, specific electrical conductivity, alkalinity and hardness were within levels that common to local irrigation water and less likely to impair pollution in waterways. Lint yields averaged 1111 kg ha^{-1} and were higher (P-value = 0.03) in FT compared to CT treatments. Runoff volumes across irrigation events were greater (P-value = 0.02) in CT than FT treatments, which increased NO_3-N mass loads in CT treatments (394 g NO_3-N ha^{-1} $season^{-1}$). Nitrate-N concentrations in CT treatments were still low and pose little threat to N contaminations in

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* Corresponding author.
E-mail addresses: arlene.advientoborbe@ars.usda.gov (M.A.A. Adviento-Borbe), brittany.barnes1@smail.astate.edu (B.D. Barnes), amann@astate.edu (A.M. Mann), michele.reba@ars.usda.gov (M.L. Reba), brobertson@uaex.edu (W.J. Robertson), joseph.massey@ars.usda.gov (J.H. Massey), tteague@astate.edu (T.G. Teague).

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waterways. The findings support the adoption of conservation practices for furrow tillage and N fertilizer placement that can reduce nutrient runoff losses in furrow irrigation systems.

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1. Introduction

Arkansas ranks third in irrigated acreage among US states (USDA NASS, 2013). In 2012, approximately, 10.4% of 1.94 M ha of irrigated cropland in Arkansas was planted in cotton. About 80% of this cotton was irrigated at least once during the growing season. Cotton production in Arkansas, Texas and Georgia comprised 53% of cotton produced, representing about 51% of the value of US cotton and cottonseed sales in 2012 (USDA NASS, 2013).

Arkansas cotton is typically produced using conventional furrow irrigation (roughly 50% of total irrigated fields) (USDA NASS, 2013). Plants are grown on raised beds with plastic pipe (polytube) used to deliver water into small channels or "furrows" constructed along the primary direction of field slope (Walker, 2003). While furrow irrigation effectively delivers water to the crop, flowing water can transport nutrients, sediments, salts, trace elements, microbes and other solutes to off-site locations through surface runoff. Sediment losses may range from near zero to >100 Mg ha^{-1} for surface-irrigated crops (Carter, 1990). Bjorneberg et al. (2006) reported surface runoff from furrow irrigated fields in Kimberly, Idaho, contained mean dissolved reactive P (DRP) concentrations from 0.04 to 0.10 mg L^{-1} and total P (TP) from 0.3 to 12.5 mg L^{-1}. Additionally, TP was linearly correlated to runoff suspended sediment. Lentz and Lehrsch (2010) found nutrient concentrations (mg L^{-1}) in runoff from furrow-irrigated maize in Kimberly, Idaho, ranged from (i) NO_3-N: 0 to 4.07, (ii) NH_4-N: 0 to 2.28, (iii) K: 3.6 to 46.4, (iv) DRP: 0.02 to 14.3 and TP: 0.03 to 41.5. They concluded 2.7% of total urea-N applied and 1.5% of total manure added were lost in irrigation runoff. Similarly, Cessna et al. (2001) estimated 2.2% of TP and 1.9% of ammonium nitrate applied as fertilizer was lost in flood-irrigated cropland in southern Saskatchewan, Canada. Recognizing the relative contribution of irrigation runoff on nutrient transports and accumulations, runoff from agricultural fields remains a key source of contamination and non-point source pollution in waterways (USEPA, 2000).

Although mean annual rainfall in Arkansas often exceeds 1000 mm, most precipitation occurs during winter and spring months. As a result, irrigation is often applied to summer row crops to increase yield potential. The primary source of irrigation water in the region is the Mississippi River Valley Alluvial Aquifer. However, irrigation withdrawals exceed aquifer recharge in portions of Arkansas (Fugitt et al., 2011). To reverse the declining groundwater supply, mitigating approaches such as water conservation practices (i.e. conservation tillage, computerized hole selection) and water reuse (i.e. tailwater recovery, reservoirs) are being recommended and evaluated in the region (Vories and Evett, 2014; USDA NRCS, 2011).

Much of furrow irrigation research conducted in cotton fields has focused on water use efficiency and reduction of surface runoff. Many of these studies reported total water savings from various furrow irrigation strategies (i.e. wide- or narrow-spaced furrow irrigation schemes) ranged from 12 to 22.5% (Stone and Nofziger, 1993; Webber et al., 2008; Subramani and Martin, 2012). In a study of furrow irrigation, Rice et al. (2001) reported runoff was reduced, but deep percolation increased when alternate row irrigation was used in a surface irrigated cotton production system. Although total water savings from these innovative irrigation strategies have been widely studied and recognized as an important driver in effective irrigation management, nutrient losses and water quality associated with tillage and crop practices have not been examined under these irrigation systems. In the MidSouth US, most of the studies that have evaluated water quality of surface water were conducted in on-farm storage reservoirs (i.e. Moore et al., 2015) or watersheds in which the main purpose was to produce baseline monitoring information and/or watershed characterization (i.e. Turner and Rabalais, 2004). Given the limited irrigation-related research in the region (Vories and Evett, 2014; Clary et al., 2012), measuring nutrient losses and water quality of irrigation runoff is needed to substantiate and improve conservation practices that aim to sustain crop yields while minimizing nutrient runoff losses. This experiment was conducted to understand the impact of furrow tillage treatments and N fertilizer placements on water quality characteristics of surface runoff quality and lint yield in irrigated cotton. Specific objectives were to determine the greatest nutrient losses from irrigation runoff during the growing season, as well as relate water quality parameters and lint yield to tillage and fertilizer placement.

2. Materials and methods

2.1. Field experiment

This study was conducted in 2016 at the Judd Hill Foundation Research Farm, Trumann, Arkansas (33.60 N; 90.53 W; elevation 65 m above mean sea level [amsl]). Crop management details are reported in Table 1. The experiment utilized a 2 × 2 factorial arranged in a randomized complete block with three replications. Furrow tillage treatments were conventional (CT) and conservation furrow tillage (FT), and N fertilizer treatments were either urea broadcast (URN) on the surface soil or 32% urea ammonium nitrate (UAN) applied side-dress. The rate of both fertilizer treatments was 101 kg N ha^{-1}. Plots were eight rows, 0.97 m wide and 162 m long (Fig. 1).

Cotton cultivar ST 4946GLB2 was seeded at 9 seeds m^{-1} of row on 28 Apr 2016 into a Dundee silt loam (Table 2). Prior to planting, raised beds were re-formed with disk-bedders and then the tops smoothed using a field cultivator fitted with rolling baskets. On 14 June, 47 days after planting (DAP), UAN or URN was applied, and the following day, water furrows were cleared using either a conventional sweep plow (Buffalo cultivator) or a "conservation" plow (Furrow Runner). The Furrow Runner features 51 cm (20 in.) scalloped disc furrowers, a shovel plot and a steel packer wheel (www.perkinsales.com/page3.html#furrowrunner).

Treatment assessments included weekly plant monitoring using COTMAN (Oosterhuis et al., 2008) as well as a drop cloth sampling for tarnished plant bug (*Lygus lineolaris*). COTMAN Squaremap sampling protocols included counts of number of main stem squaring nodes, first position square and boll retention and plant height for five consecutive plants on two adjacent rows in two points per treatment plot. COTMAN Bollman sampling included counts of Nodes Above White

Table 1
Crop management details including dates of planting, fertilizer application, tillage practices, irrigation and harvest timing.

Operation	Date	Days after planting
Date of planting	28 April 2016	0
N fertilizer application	14 June	47
Water furrows cleared	15 June	48
Irrigation	17, 24 June; 7, 14, 21, 29 July; 5 August	50, 57, 70, 77, 84, 92, 99
Harvest	29 September	154

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