Agricultural Water Management 96 (2009) 1078–1084

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Agronomic and economic response to furrow diking tillage in irrigated and non-irrigated cotton (*Gossypium hirsutum* L.)[☆]

R.C. Nuti [a,*], M.C. Lamb [a], R.B. Sorensen [a], C.C. Truman [b]

[a] USDA-ARS, National Peanut Research Laboratory, 1011 Forrester Drive, SE, Dawson, GA 39842, USA
[b] USDA-ARS, Southeast Watershed Research Laboratory, Tifton, GA 31793, USA

ARTICLE INFO

Article history:
Received 5 August 2008
Accepted 3 March 2009

Keywords:
Irrigation scheduling
Water capture
Water consumption
Best management practices
Conservation tillage

ABSTRACT

The Southeast U.S. receives an average of 1300 mm annual rainfall, however poor seasonal distribution of rainfall often limits production. Irrigation is used during the growing season to supplement rainfall to sustain profitable crop production. Increased water capture would improve water use efficiency and reduce irrigation requirements. Furrow diking has been proposed as a cost effective management practice that is designed to create a series of storage basins in the furrow between crop rows to catch and retain rainfall and irrigation water. Furrow diking has received much attention in arid and semi-arid regions with mixed results, yet has not been adapted for cotton production in the Southeast U.S. Our objectives were to evaluate the agronomic response and economic feasibility of producing cotton with and without furrow diking in conventional tillage over a range of irrigation rates including no irrigation. Studies were conducted at two research sites each year from 2005 to 2007. Irrigation scheduling was based on Irrigator Pro for Cotton software. The use of furrow diking in these studies periodically reduced water consumption and improved yield and net returns. In 2006 and 2007, when irrigation scheduling was based on soil water status, an average of 76 mm ha^{-1} of irrigation water was saved by furrow diking, producing similar cotton yield and net returns. Furrow diking improved cotton yield an average of 171 kg ha^{-1} and net return by \$245 ha^{-1} over multiple irrigation rates, in 1 of 3 years. We conclude that furrow diking has the capability to reduce irrigation requirements and the costs associated with irrigation when rainfall is periodic and drought is not severe.

Published by Elsevier B.V.

1. Introduction

Current agricultural water issues and the need for reduced input costs in farming operations add importance to making sound irrigation decisions to ensure efficient use of available resources. Improving water capture and infiltration into the soil may lead to less frequent irrigation, reduce irrigation expenses, and stabilize non-irrigated cropping systems. Current recommendations for reducing runoff and erosion in much of the United States is with reduced tillage methods leaving greater than 30% of the field surface covered with crop residue. Adoption of reduced tillage practices, as of 2004, for Georgia row crop area was about 60% (CTIC, 2004). According to this report, Georgia cotton (*Gossypium hirsutum* L.) growers had adopted reduced tillage practices by nearly 50%, leaving the remainder managed under conventional tillage. According to the 2002 United States Census of Agriculture, 74% of cotton in Georgia was non-irrigated (USDA-NASS, 2002). The majority of economically significant row crops in the United States are grown without irrigation, making the production of these commodities [cotton (61%), peanut (*Arachis hypogea* L.) (62%), and corn (*Zea mays* L.) (86%)] more susceptible to drought conditions and poor yield stability (USDA-NASS, 2002). These statistics suggest that the majority of row crop producers in Georgia and similar states in the Southeast U.S. would benefit by improving water capture and erosion prevention in conventional tillage systems.

Furrow diking is a tillage method that creates a series of basins and dams between crop rows for capturing surface applied water to increase infiltration opportunity time by reducing runoff. Much furrow diking research has been conducted with variations in equipment and terminology including basin tillage, micro-basin tillage, reservoir tillage, furrow blocking, soil pitting, and tied-ridging (Lyle and Dixon, 1977; Hackwell et al., 1991; Unger, 1992; Wiyo et al., 2000; Brhane et al., 2006). Many U.S. patents on furrow diking equipment were issued between 1915 and 1998 (United States Patent Office, 2008). Robert H. McAdams from Abbeville county South Carolina stated in his 1913 application for the 1915 U.S. patent "The object of the present invention is to improve the

[☆] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

* Corresponding author. Tel.: +1 229 995 7449; fax: +1 229 995 7416.
E-mail address: Russell.Nuti@ars.usda.gov (R.C. Nuti).

0378-3774/\$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.agwat.2009.03.006

construction of plows, and to provide a simple, efficient and comparatively inexpensive plow designed for the cultivation of cotton, corn and other plants, and equipped with means for automatically lifting a plow proper or furrow opening device to provide a series of reservoirs or furrow sections separated by intervening dams, and adapted to catch and hold the water, which might otherwise run off the ground." (United States Patent Office, 2008). This invention is of the raising shovel or wheel type design described by Jones and Stewart (1990) and Harris and Krishna (1989), respectively. It seems, however, that McAdam's contribution was overlooked or discredited during the advancing and development of similar technology. Other literature mentions that furrow diking equipment was first developed during the 1930s in Kansas, Colorado, Nebraska, and Iowa with a similar purpose as McAdam's invention (Lyle and Dixon, 1977; Jones and Stewart, 1990). Lyle and Dixon (1977) further outline the history of the early progress of furrow diking stating that the first commercialized equipment was a result of successful field demonstrations in Kansas, Colorado, and Oklahoma after advances with equipment in 1935. Since this early beginning, many benefits to furrow diking have been recorded in the United States including yield improvement of grain sorghum (*Sorghum bicolor* L.) and cotton (Bilbro and Hudspeth, 1977; Clark, 1983; Gerard et al., 1983, 1984; Jones and Clark, 1987; Tewolde et al., 1993). Irrigation efficiency and reduced precipitation runoff have been documented in furrow diked land compared to non-furrow diked land (Jones and Baumhardt, 2003). Researchers reported successful crop yield improvements and soil conservation benefits from furrow diking experiments in Tanganyika, Nigeria, and Tanzania between 1944 and 1967 (Lyle and Dixon, 1977).

Jones and Stewart (1990) provide a review of furrow diking work and report the range of furrow dike basin depth of water holding capacity to be 25–150 mm, depending on field slope and rainfall intensity. Experiments designed to measure runoff from field surfaces consistently report that furrow diked fields capture more precipitation and/or irrigation than conventionally prepared land (Gerard et al., 1983; Hackwell et al., 1991; Baumhardt et al., 1992; Unger, 1992; Hasheminia, 1994; Truman and Nuti, 2009). Although runoff may be prevented even in fields with minimal slope, furrow diking may provide little benefit for conserving water and improving yield in the arid and semi-arid regions where the majority of furrow diking testing has been done in years with limited overall rainfall (Baumhardt et al., 1993). The Southeast U.S. receives high intensity storms that frequently produce runoff from agricultural fields, however periodic drought is also frequent (Sheridan et al., 1979; Bosch et al., 1999). High intensity storms producing >50 mm are common in the Southeast Coastal Plain (Sheridan et al., 1979; Bosch et al., 1999), thus furrow diking may provide a consistent benefit to row crop producers and reduce the amount of supplemental irrigation used.

The equipment used to install furrow dikes is not expensive and can be attached to conventional equipment making the cost of the practice reasonable (Harris and Krishna, 1989; Jones and Stewart, 1990; Tewolde et al., 1993). Furrow dikes increase field surface area and improve water capture by increasing opportunity time for water percolation (Lyle and Dixon, 1977; Jones and Stewart, 1990) and minimize evaporation of irrigation water (Lyle and Bordovsky, 1983). By permitting higher rates of infiltration, erosion is reduced (Hackwell et al., 1991; Baumhardt et al., 1993; Truman and Nuti, 2009), and water is distributed more uniformly between high and low elevation areas within a field (Hasheminia, 1994). Furrow diking can be used to improve application efficiency of irrigation water (Lyle and Bordovsky, 1983; Hackwell et al., 1991; Hasheminia, 1994) as well as improve the soils' capturing ability of natural precipitation in non-irrigated systems (Jones and Baumhardt, 2003). Non-irrigated crops are more likely affected by erratic rainfall distribution rather than low seasonal rainfall totals (Rathore et al., 1996). To improve efficient use of water in non-irrigated systems, water loss from the soil other than through evapotranspiration such as runoff must be minimized (Rathore et al., 1996). Literature documenting furrow diking in the Southeast U.S. is limited to a single year of research in Alabama using the commercial Dammer Diker (U.S. Patent No. 4508177) (Hackwell et al., 1991) and some Georgia extension experiments conducted in the 1990s evaluating self tripping paddle dikers for peanut production (Bader et al., 1994; Bader and Wilson, 1996). Hackwell et al. (1991) reported that infiltration of irrigation water delivered via low energy precision application was greater with furrow diking and the benefit was more pronounced in compacted soil. Furrow diking irrigated peanut improved pod yield by 135 and 190 kg ha^{-1} in 2 of 3 years (Bader and Wilson, 1996).

Rainfall simulation showed that land without furrow dikes had 3 times more runoff and 3.5 times more erosion compared to land with furrow dikes during a 50 mm rain event (Truman and Nuti, 2009). These results are similar to previous work where the differences in erosion were between 3 and 25 times greater when comparing furrow diking to other practices (Kowal, 1970; Rawitz et al., 1983). Furrow diking limited runoff to 17% of the total water applied compared to land without furrow dikes (53% runoff) (Truman and Nuti, 2009).

Both irrigated and non-irrigated cropping systems may benefit from furrow diking by improved water capture and water use efficiency. Field studies were established with the following objectives: (1) relate furrow diking to seasonal crop water use when irrigation scheduling is based on a computerized decision support system, (2) determine the degree that furrow diking affects cotton yield with (2a) variable irrigation rates including (2b) non-irrigated systems, and (3) compare the economic returns of furrow diking to conventional tillage without furrow diking.

2. Materials and methods

2.1. Experimental sites

Research was conducted between 2005 and 2007 at two irrigation research farms managed by USDA-ARS-NPRL. Two separate field studies with individual objectives were managed independently at these locations. The soil type at Dawson, Georgia was Tifton (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults; 0–2% slope) and the soil type at Shellman, Georgia was Greenville (Fine, kaolinitic, thermic Rhodic Kandiudults; 0–2% slope). Objective 1 and 2b are addressed by the project at Dawson, objective 2a is addressed by the project at Shellman, and economic analysis was performed on treatments at both locations to address objective 3.

2.2. Crop management and description of equipment

Both research sites were managed with conventional tillage consisting of disking the previous crop stubble, and planting a winter rye (*Secale cereale* L.) or wheat (*Triticum aestivum* L.) cover crop. Each spring, the cover crop was disked and field cultivated. All plots were prepared with a ripper–bedder that subsoiled >0.4 m deep. In furrow-diked treatments, furrow diking was conducted after cotton seedlings emerged. Furrow diking requires loose soil for creating the dams and basins, so this is commonly done in combination with a cultivator (Cooper, 1971; Lyle and Dixon, 1977). The two paddle self-tripping furrow dikers used in the present study create furrow dikes that are approximately 1.5 m long, 0.30 m wide, and 0.2 m deep (Fig. 1). These units were pulled in conjunction with a two-row Brown Chiselvator (Brown Manufacturing Company, Ozark, Alabama) (Fig. 1). The Brown