Crop Yield and Financial Investment of Sub-Surface Drip Irrigation over the Life of the System

R. WELLS*, D.L. JORDAN, and D. WASHBURN, North Carolina State University, Raleigh, NC 27695; and S. BARNES and T. CORBETT, Peanut Belt Research Station, Department of Agriculture and Consumer Services, Lewiston-Woodville, NC.

INTRODUCTION

Irrigation has the potential to increase crop yield and financial return on coarse-textured, coastal plain soils in the mid-Atlantic region of the US. While the majority of irrigation is delivered through over-head sprinkler irrigation, sub-surface drip irrigation (SDI) has been shown to be a reasonable alternative to sprinkler irrigation because of efficiency on small, irregularly shaped fields (Bosch et al., 1992 1998; O'Brien et al., 1998). Increased yield and/or water use efficiency are often cited as benefits of SDI over overhead sprinkler irrigation (Bosch et al., 1992 1998; Rowland et al., 2007; Sorensen and Butts, 2014; Whitaker et al., 2008). Prior to research beginning in 2001, information in North Carolina was limited in terms of comparing crop response to SDI and the financial viability this approach to water delivery, especially for corn (*Zea mays* L), cotton (*Gossypium hirsutum* L.), and peanut (*Arachis hypogaea* L.). To address this limitation, a SDI system was installed in North Carolina in 2001 to determine corn, cotton, and peanut response to SDI in a wide range of experiments with different treatment variable. Results from these trials can be found elsewhere (Grabow et al., 2006; Jordan and Johnson, 2007; Jordan et al., 2014; Lanier et al., 2004; Nuti et al., 2006 2012). The objective of this paper is to compare yield and financial return in SDI with dryland production over the life of the SDI system (2001-2013).

MATERIALS AND METHODS

The SDI systems was installed in spring 2001 prior to the growing season on a Norfolk loamy sand soil (fine loamy, siliceous, thermic, Aquic Paleudalfs) near Lewiston-Woodville, NC (36.1337679°N, -77.1705179°W). Details of the installation process and the system are reported in published papers from short-term, individual experiments conducted from 2001-2013 (Grabow et al., 2006; Lanier et al., 2004; Nuti et al., 2006). In this summary, the average yield from replicated plots with the same agronomic and pest management practice for both SDI and dryland production are used to compare irrigation systems during the life of the SDI system. Although life of SDI systems can be 15 years (Enciso-Medina et al., 2009; Lamm and Camp, 2007), the SDI system discussed here was replaced after 13 years. Numerous leaks in the in-row tape were common in 2012 and 2013 and often compromised results from some research plots. Unfortunately at this point in time, actual plot data from the experiments is not available for many of the years. Therefore, means reported in individual trials are used along with the statistical significance included in the published papers mentioned previously or statistical analysis of experiments not currently published. To estimate the financial return over the life of the SDI system compared with dryland production, each crop-year entry was considered a replication.

MATERIALS AND METHODS (continued)

Cost of installing the system was estimated to be $1,619/acre (Owens, 2013) with cost of installation annualized over 13 years for a yearly cost of $125/acre. Annual maintenance was set at 3% of installation cost (Burt et al., 1999) for a yearly cost of $49/acre. Total cost of SDI was set at $174/acre. To estimate financial return, fixed and variable costs other than SDI for corn, cotton, and peanut was set at $453/acre, $613/acre, and $925/acre, respectively (Jordan et al., 2014). Low, medium, and high pricing structures were compared (Washburn and Jordan, 2022) and included low, medium, and high price for corn was $3/bushel, $5/bushel, and $7/bushel, respectively. Prices for cotton in these respective structures was $0.6/lb lint, $0.8/lb lint, and $1/lb lint. For peanut, the low, medium, and high price for peanut was $0.24/lb, $0.27/lb, and $0.3/lb, respectively. Estimated financial return for each pricing structure was calculated as the product of crop yield and price, minus total cost of production including SDI.

Over the life of the system (e.g., 13 years), the number of crop cycles for corn, cotton, and peanut was 5, 11, and 7, respectively. Peanut in North Carolina is often grown in rotation with corn and/or cotton with at least 2 years between peanut plantings. The ratio of years of corn and cotton to peanut was 2.3:1 over the 13 years. However, plantings during the 13 years were not designed to represent a consistent rotation sequence of these crops and reflect individual experiments that were important at the time. Data were analyzed by each crop for yield and estimated financial return using a t-test at $p \leq 0.05$. Data for estimated financial return with all crops was also calculated. The total amount of revenue over the life of SDI system was compared to dryland production.

Table 1. Yield of corn, cotton, and peanut total water during the cropping cycle in dryland production versus sub-surface drip irrigation (SDI) from 2001 to 2013 in North Carolina.*

Crop/Year	Crop yield		Total water	
	Rain only	Rain plus SDI	Rain only	Rain plus SDI
	bushels/acre		inches	
Corn				
2008	96	146*	11.3	21.9
2009	62	148*	12.9	27.6
2010	64	155*	3.6	16.8
2011	64	101*	13.6	20.7
2013	137	131	19.8	21.8
Cotton	lbs lint/acre			
2001	800	1020*	8.6	13.8
2002	460	900*	13.0	18.5
2003	840	850	18.9	24.4
2004	920	1010	24.9	31.8
2005	850	1300*	12.2	18.3
2006	810	860	19.5	27.8
2007	470	1020*	11.5	21.3
2008	390	840*	13.8	25.2
2011	480	800*	19.9	39.1
2012	1370	1450	18.1	26.6
2013	1430	1490	19.8	21.8
Peanut	lbs/acre			
2001	2350	3400*	8.6	13.8
2002	2020	2960*	13.0	18.5
2003	3020	3210	19.6	24.8
2004	2660	2830	20.0	25.0
2010	2540	3880*	9.3	21.9
2011	3440	4040*	19.9	39.1
2012	5100	4910	18.1	26.6

RESULTS AND DISCUSSION

Corn yield was 150 to 240 percent greater in years 2008 to 2011 under SDI compared with dryland production in four of five years (Table 1). Cotton yield under SDI was 130 to 220 percent greater than dryland production in six of 11 years, while peanut yield was 120 to 150 percent greater under SDI than growing peanut without irrigation in four of 7 years. In years where crop yield increases were noted, the amount of rain for corn was 46 to 66 percent of rain plus SDI. When a difference in corn yield between irrigation treatments was not observed (2013), the amount of water from rain only was almost the same as rain plus SDI. When cotton yields did not differ between irrigation treatments, the amount of water from rain only was 70 to 91 percent of rain plus SDI. In most years when a difference in yield was observed, water from rain only provided 55 to 70 percent of the amount of water by rain and SDI. For peanut, yield differences were observed when rain provided 42 to 70 percent of the amount of water of rain plus SDI. In contrast, when differences in yield were not observed for this crop, rain only provided 68 to 80 percent of the water measured for rain plus SDI.

When pooled over 5 years, corn yield was 85 bushels/acre under dryland production and 136 bushels/acre under SDI (Table 2). Cotton yield for these respective irrigation treatments was 800 pounds/acre and 1050 pounds/acre. Peanut yield increased from 3010 pounds/acre to 3600 pounds/acre when SDI supplemented rain. However, in spite of these yield increases for corn, cotton, and peanut, no significant difference in estimated financial return was noted regardless of pricing structure when comparing dryland and SDI systems (p = 0.2035 to 0.9789) (Table 2). When estimated financial return was pooled over years and crops, there was no difference for the low and medium pricing structures (p = 0.0934 to 0.4647). Total revenue in the SDI system across crops and years was $-4589/acre (low prices), $-89/acre (medium prices), and $4386/acre (high prices) (data not shown in tables). Revenue across crops and years for dryland production was $-3974/acre, $-668/acre, and $2616/acre for these respective pricing structures.

Table 2. F-statistic, P>F, yield, and estimated financial return for corn, cotton, and peanut without irrigation versus sub-surface drip irrigation (SDI) from 2001 to 2013 in North Carolina.

SDI irrigation‡	Yield	Estimated financial return		
		Pricing structure†		
		Low	Medium	High
		$/acre		
Corn	*bushels/acre*			
No	85	-199	-30	139
Yes	136	-217	-55	327
F statistic	8.5	0.1	0.9	2.3
P>F	0.0435	0.7491	0.3913	0.2035
No. of years	5	56	5	5
Cotton	*lbs lint/acre*			
No	800	-133	27	187
Yes	1050	-158	52	261
F statistic	16.8	0.5	0.3	16.8
P>F	0.0022	0.5119	0.6186	0.2468
No. of years	11	11	11	11
Peanut	*lbs/acre*			
No	3010	-216	-116	-19
Yes	3600	-252	-133	-18
F statistic	7.8	0.5	0.1	0.1
P>F	0.0317	0.4895	0.7728	0.9789
No. of years	7	7	7	7
All crops and all years				
No	-	-173	-29	113
Yes	-	-200	-4	191
F statistic		1.2	0.6	3.1
P>F		0.2865	0.4627	0.0934
Crop-years	-	23	23	23

RESULTS AND DISCUSSION (continued)

Collectively, these data indicate that SDI increased yield of corn in all but one year and cotton and peanut in just over half of the years of production. However, over the life of the system financial returns reflecting yield and annualized cost of the system and maintenance will likely be the same under SDI and dryland production under the assumptions of our analysis. Crop yields were modest but represent typical yields across the North Carolina coastal plain during the life of the SDI system. A comparison of SDI and dryland production with more recent advances in crop yield would be informative, as would a more precise estimate for SDI installation cost and maintenance. On the surface, these results suggest that SDI is breakeven at best over the life of the system. However, the value of SDI in years where a significant difference in yield between dryland and SDI occur, the sustainability of the farm in the near term may be attributed to SDI. However, because replication level data for all years are not available, it is not possible to determine the contribution of SDI to sustainability on a yearly basis for each crop. None-the-less, results from this analysis can inform practitioners on the financial value of SDI on coarse-texted soils in the mid-Atlantic region of the US.

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