Long-Term Irrigation Methods and Nitrogen Fertilization Rates in Cotton Production: The Last Three Years of the McConnell - Mitchell Plots

J.S. McConnell, J. A. Rauls, R.C. Doherty, and M. Mozaffari

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Nitrogen (N) and water management are two very important aspects of successful cotton (*Gossypium hirsutum* L.) production. If cotton becomes N deficient, the plants may become chlorotic and not photosynthesize sufficiently to meet the demands of crop growth. Nitrogen deficiency of cotton typically results in reduced yields, pre-mature cut out, and reduced fiber quality. Few studies of the interactions of N fertilizer and irrigation have been conducted for cotton. This is especially true under the humid production conditions of southeast Arkansas (McConnell et al., 1988). The objectives of these studies were to evaluate the growth, development, and yield of intensively managed cotton as a function of N fertilization and soil N dynamics under different irrigation methods.

Both over- and under-fertilization of cotton with N may result in reduced yields. Over fertilization may also induce delayed maturity in cotton (Maples and Keogh, 1971). Reductions in yield and quality due to N deficiency may severely reduce the value of the crop and have adverse economic consequences for producers (Bondada et al., 1996; Radin and Mauney, 1984).

Generally, cotton yields have increased with increasing N fertilization throughout the previous years of this test (McConnell et al., 1988; McConnell and Baker, 1998). The N treatments that usually resulted in the greatest yields were applications of 60- to 150-lb N/acre, depending upon the irrigation treatment and year. The yields of the high-frequency center-pivot irrigation block during some years were significantly influenced by verticillium wilt. The disease was more virulent in the plots receiving higher N rates, thereby reducing yields with increasing N.

Adequate soil moisture is also necessary for cotton to achieve optimal yields. Early and mid-season water requirements of cotton should be met to avoid yield loss that may occur if the crop undergoes drought stress (Jordan, 1986; Wanjura, et al., 1996). If the soil becomes either too wet or too dry, cotton plants will undergo stress and begin to shed fruit (Guinn et al., 1981).

In the previous years of this study, irrigation generally increased cotton yields except during seasons when early-season rainfall resulted in standing water that delayed maturity of the irrigated plants; or when verticillium wilt was prevalent. The method of irrigation that maximized yield varied among years, and therefore, appeared to be less important than irrigation usage.

PROCEDURES

An experiment to examine the interactions of N-fertilization strategy (N-rate and application times) and irrigation method was initiated at the Southeast Branch Experiment Station on a Hebert silt loam soil in 1982. This test, the McConnell-Mitchell Plots, is the oldest continuous field experiment in Arkansas. The experimental design was a split block with irrigation methods as the main blocks. Four irrigation methods were used from 1982 until 1987. Five irrigation methods were employed from 1988 to 1993. Only three irrigation methods have been used since 1993 (Table 1).

Ten total N treatments were tested within each irrigation method. Six different N rates (0, 30, 60, 90, 120, and 150 lb urea-N/acre) were tested with different application rates and timings (Table 2). Phosphorus and potassium fertilizer were annually applied as a preplant, blanket treatment to all plots at rates of 46 lb-P_2O_5/acre and 60 lb-K_2O/acre. Nitrogen fertilization was discontinued for the 2000 through 2003 growing seasons to examine the effects of residual soil nitrate-nitrogen (NO_3-N) on cotton development. Treatments were resumed in 2004 after 2003 yield results indicated minimal yield response from residual N. Soil samples were taken from the plots and analyzed for residual NO_3-N to a depth of five feet in 2000 and 2004 (Tables 3 and 4).

The McConnell-Mitchell Plots were planted on 23 April 2002, 12 May 2003, and 11 May 2004. Both the 2002 and 2003 crops were influenced by cool, wet conditions early in the growing season. The 2004 growing season was more moderate than in 2003.

All data were analyzed using the Statistical Analysis System (SAS). The experimental design was a randomized complete block with seedcotton yield data analyzed by year. F-tests and least significant differences (LSD) were calculated at the α=0.05 level of probability. Only yield responses of cotton to N-fertilization are presented in this report.

RESULTS AND DISCUSSION

Residual soil-N was largely depleted under furrow and center-pivot irrigation after four years of cotton production without N fertilization (Tables 3 and 4). Residual N under dryland production conditions was also substantially less in 2004 than in 2000. Additionally, the zone of accumulation of residual N appears to be deeper in the soil profile in 2004 than in 2000 under dryland production conditions.

The interaction between irrigation method and residual soil N from previous N-fertilization significantly affected yields during the 2002 and 2003 growing seasons (Tables 5 and 6). The interaction of N fertilization treatments with irrigation methods also significantly affected yields during 2004 (Table 7).

During the 2002 growing season, high-frequency irrigation usually increased cotton yields compared to furrow irrigation or dryland production (Table 5). Additionally, furrow-irrigated cotton tended to produce greater yields than dryland cotton. The cool, wet, early season of 2003 substantially delayed cotton development. The supplemental water applied in the irrigated blocks increased plant height (data not shown) and probably total plant weight, but delayed maturity of the crop. During 2003, delayed maturity and increased cotton growth resulted in reduced yields for cotton grown in both the high-frequency and the furrow-irrigated blocks (Table 6). The 2004 growing season was more moderate than the previous two years, thereby producing generally greater yields than in 2003 (Table 7). Greatest yields in 2004 were associated with furrow irrigation. Center-pivot irrigation tended to delay maturity of the crop resulting in the lowest yields.

Cool, wet conditions in the 2002 growing season resulted in severe seedling disease, but not stand loss. Near optimal growing conditions through the rest of the season resulted in acceptable yields, however, response to residual soil NO_3-N was limited in 2002 (Table 5). Cotton yields under dryland and high-frequency irrigation usually did not significantly respond to the residual soil NO_3-N. Cotton produced with furrow irrigation had only minimal yield response to residual soil NO_3-N when previous total N rates were greater than 60 lb N/acre. As the residual NO_3-N was consumed by the cotton crops, it had less influence on plant development and yield in subsequent years.

Compared with 2002 even worse early-season growing conditions occurred in 2003. Cool, wet weather persisted from early May through June and delayed growth, development, and squaring of the seedlings. The impaired plants of 2003 produced the lowest mean yields for the last three years of this study (Table 6). Response to residual soil NO_3-N was not significant in either the high-frequency irrigated or the furrow-irrigated blocks. The lack of yield response in these two blocks indicates that the residual soil NO_3-N was depleted. Cotton yields significantly increased due to residual NO_3-N from previous N fertilization in the dryland block. The greatest yielding treatments were those testing highest in residual NO_3-N in 2000 which had previously received 120- to 150-lb N/acre (Table 3). These results indicate that substantial residual soil NO_3-N still influenced plant development of cotton under dryland production conditions.

Resumption of N-fertilization treatments in 2004 produced immediate and significant yield responses (Table 7). Yield increased under all irrigation methods with increasing N up to the maximum 150 lb N/acre, though not all differences were significant. Additionally, plant height and plant maturity were also significantly affected by N-fertilization treatments (data not shown).

PRACTICAL APPLICATIONS

Irrigated cotton generally produced higher yields than cotton grown under dryland conditions, but the highest yielding irrigation method depended on the yearly climate effects. Cotton yield response to residual soil N from previous N-fertilization treatments tended to decline with time. Residual soil N was sufficient the first year (2002) to produce relatively high yields when previous N-fertilization rates were high and cotton was irrigated. After three growing seasons (2000, 2002, and 2003) and one fallow season (2001), cotton yield response in 2003 to residual soil NO_3-N was negligible for irrigated cotton with only the dryland block producing seedcotton yields that increased as previous N rate increased. Resumption of N fertilization treatments in 2004 immediately resulted in significant yield increases.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fee.

LITERATURE CITED

Bondada, B.R., D.M. Oosterhuis, R.J. Norman, and W.H. Baker. 1996. Canopy photosynthesis, growth, yield, and boll ^{15}N accumulation under nitrogen stress in cotton. Crop Sci. 36:127-133.

Guinn, G., J.R. Mauney, and K.E. Fry. 1981. Irrigation scheduling effects on growth, bloom rates, boll abscission and yield of cotton. Agron. J. 73:529-534.

Jordan, W.R. 1986. Water deficits and reproduction. pp. 63-72. *In:* J.R. Mauney and J. McD. Stewart (eds.). Cotton Physiology. The Cotton Foundation, Memphis, Tenn.

Maples, R., and J. G. Keogh. 1971. Cotton fertilization studies on loessial plains soils of eastern Arkansas. University of Arkansas Agricultural Experiment Station Bulletin 825. Fayetteville, Ark.

McConnell, J.S., and W.H. Baker. 1998. Yield and petiole nitrate responses of cotton (*Gossypium hirsutum* L.) to foliar nitrogen fertilization. J. of Cotton Sci. 2:143-152.

McConnell, J. S., B. S. Frizzell, R. L. Maples, and G. A. Mitchell. 1988. Relationships of irrigation methods and nitrogen fertilization rates in cotton production. University of Arkansas Agricultural Experiment Station Report Series 310.

Radin, J.W., and J.R. Mauney. 1984. The nitrogen stress syndrome. *In:* J.R. Mauney and J.M. Stewart (ed.), Cotton Physiology. p. 91-105. The Cotton Foundation, Memphis, Tenn.

Wanjura, D.F., J.R. Mahan, and D.R. Upchurch. 1996. Irrigation starting time effects on cotton under high-frequency irrigation. Agron. J. 88:561-566.

Table 1. Duration, tensiometer thresholds and depths, and water application rates for three irrigation methods used in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark., since 1993.

Irrigation		Tensiometer		Water
methods	Duration	Threshold	Depth	applied[z]
		-(cbar)-	-(in.)-	-(in.)-
High frequency	Planting to P.B.[y]	35	6	0.75
center-pivot	P.B. to Aug. 15	35	6	1.00
Furrow flow	Until Aug. 15	55	12	Not precise
Dryland	Not irrigated	--	--	--

[z] Water application rate per irrigation.
[y] P.B.=Peak bloom

Table 2. Nitrogen (N) fertilization treatments and application timings for the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark.

Total N-Rate	Pre-plant	First square	First flower
- (lb N/acre) -	---------------------- (lb N/acre)	----------------------	
150	75	75	0
150	50	50	50
150	30	60	60
120	60	60	0
120	40	40	40
90	45	45	0
90	30	30	30
60	30	30	0
30	15	15	0
0	0	0	0

Table 3. Residual nitrate-nitrogen (NO_3-N) to a depth of five feet in six-inch increments from five N-fertilization rates (Table 1, split applied, half pre-plant and half at first square) under three irrigation methods in the McConnell-Mitchell study in Spring, 2000.

Soil	Irrigation method and total N-fertilizer rate																	
	Furrow irrigated						Dryland						High-frequency center-pivot					
depth	0	30	60	90	120	150	0	30	60	90	120	150	0	30	60	90	120	150
(in.)	(lb residual NO_3-N/acre)																	
0- 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
0 - 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
6 - 12	2	2	1	2	2	2	5	9	6	33	108	102	1	1	2	3	3	5
12 - 18	2	3	3	2	3	4	4	6	5	35	138	135	2	1	3	3	3	11
18 - 24	3	3	3	2	4	7	4	5	6	36	125	111	2	1	2	1	2	20
24 - 30	3	3	3	3	4	7	4	4	6	31	91	104	2	3	2	2	3	18
30 - 36	2	3	3	3	5	6	3	3	5	22	58	68	2	3	1	3	4	10
36 - 42	3	3	3	3	4	7	3	3	4	12	54	37	2	2	2	3	4	7
42 - 48	3	2	3	2	4	9	2	3	3	7	37	21	2	2	3	3	6	6
48 - 54	3	3	3	3	4	8	3	3	4	6	21	15	2	3	2	3	6	4
54 - 60	2	2	3	2	7	6	13	6	30	2	33	57	6	4	2	2	5	7
Mean	2	3	3	2	4	6	5	5	8	21	75	71	2	2	2	3	4	9

Table 4. Residual nitrate-nitrogen (NO_3-N) to a depth of five feet in six-inch increments from five N-fertilization rates (Table 1, split-applied, half pre-plant and half at first square) under three irrigation methods in the McConnell-Mitchell study in Spring, 2004.

Soil	Irrigation method and total N-fertilizer rate																	
	Furrow irrigated						Dryland						High-frequency center-pivot					
depth	0	30	60	90	120	150	0	30	60	90	120	150	0	30	60	90	120	150
(in.)	(lb residual NO_3-N/acre)																	
0- 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
0 - 6	3	2	1	2	4	2	4	4	4	3	6	4	2	3	3	4	2	3
6 - 12	1	1	2	2	2	2	4	4	4	3	4	6	2	1	3	2	2	3
12 - 18	2	2	2	5	2	2	5	5	5	5	6	8	2	2	3	2	2	2
18 - 24	4	3	3	3	3	3	5	5	5	5	12	9	2	2	3	2	2	2
24 - 30	3	2	3	4	3	3	5	5	6	6	13	41	2	2	3	2	3	2
30 - 36	3	3	3	3	3	3	5	4	6	9	19	52	2	2	3	2	3	2
36 - 42	3	2	3	3	3	3	5	4	6	12	37	80	3	2	3	2	3	2
42 - 48	2	2	3	3	2	3	5	5	7	17	54	89	3	2	3	3	3	3
48 - 54	2	2	3	3	3	3	5	5	7	17	64	89	3	2	3	3	3	3
54 - 60	2	2	2	3	3	3	5	6	7	10	41	79	2	3	3	3	3	3
Mean	3	2	2	3	3	3	5	5	6	9	26	45	3	2	3	2	3	3

Table 5. Seedcotton yield response to residual N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2002 in the McConnell-Mitchell plots at the Southeast Branch Experiment Station near Rohwer, Ark.

	N-rate and timing[z]			Irrigation method			
Total N rate	PP	FS	FF	High frequency	Furrow irrigated	Dryland	N-rate mean
	------------- (lb N/acre) -------------			---------------------- (lb seedcotton yield/acre[y]) --------------------			
150	75	75	0	3847	3413	2901	3379
150	50	50	50	3900	3464	3114	3485
150	30	60	60	3864	3369	3202	3470
120	60	60	0	3692	3466	2998	3378
120	40	40	40	3886	3214	3391	3489
90	45	45	0	3733	3342	3204	3419
90	30	30	30	3616	3330	3245	3395
60	30	30	0	4041	3146	3056	3407
30	15	15	0	3602	3037	3297	3304
0	0	0	0	3481	2867	2886	3071
To compare N-treatment means within irrigation method LSD(0.05) = 340							
To compare N-treatment means between irrigation methods LSD(0.05) = 493							
Irrigation method mean yield				3766	3265	3128	

[z] N application times; PP, preplant; FS, first square; and FF, first flower.
[y] Lint yield may be estimated by dividing the seedcotton yield by 3.

Table 6. Seedcotton yield response to residual N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2003 in the McConnell-Mitchell plots at the Southeast Branch Experiment Station near Rohwer, Ark.

	N-rate and timing[z]			Irrigation method			
Total N rate	PP	FS	FF	High frequency	Furrow irrigated	Dryland	N-rate mean
	------------- (lb N/acre) -------------			---------------------- (lb seedcotton yield/acre[y]) --------------------			
150	75	75	0	1833	1406	2568	1936
150	50	50	50	1873	1463	2659	1998
150	30	60	60	2244	1412	2246	1967
120	60	60	0	2045	1646	2671	2120
120	40	40	40	2003	1271	2678	1983
90	45	45	0	1882	1353	1815	1677
90	30	30	30	1780	1426	2344	1852
60	30	30	0	1770	1493	1507	1593
30	15	15	0	1805	1381	1905	1697
0	0	0	0	1796	1284	1237	1439
To compare N-treatment means within irrigation method LSD(0.05) = 397							
To compare N-treatment means between irrigation methods LSD(0.05) = 472							
Irrigation method mean yield				1904	1413	2169	

[z] N application times; PP, pre-plant; FS, first square; and FF, first flower.
[y] Lint yield may be estimated by dividing the seedcotton yield by 3.

Table 7. Seedcotton yield response to N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2004 in the McConnell-Mitchell plots at the Southeast Branch Experiment Station near Rohwer, Ark.

	N-rate and timing[z]			Irrigation method			
Total N rate	PP	FS	FF	High frequency	Furrow irrigated	Dryland	N-rate mean
	------------- (lb N/acre) -------------			---------------------- (lb seedcotton yield/acre[y]) --------------------			
150	75	75	0	3320	3870	3277	3476
150	50	50	50	3134	4042	3930	3690
150	30	60	60	3049	4467	3691	3710
120	60	60	0	2948	3829	3413	3396
120	40	40	40	3008	3888	3821	3562
90	45	45	0	2756	3761	3098	3205
90	30	30	30	2749	3697	3323	3241
60	30	30	0	2730	3037	2563	2777
30	15	15	0	2077	2974	2425	2475
0	0	0	0	1757	2224	1048	1676
To compare N-treatment means within irrigation method LSD(0.05) = 412							
To compare N-treatment means between irrigation methods LSD(0.05) = 663							
Irrigation method mean yield				2753	3563	3058	

[z] N application times; AE, after emergence; FS, first square; and FF, first flower.
[y] Lint yield may be estimated by dividing the seedcotton yield by 3.