AGRONOMY AND SOILS

Optimum Irrigation Termination Timing in Furrow Irrigated Cotton

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ABSTRACT

Properly terminating furrow irrigation in mid-southern United States (U.S.) crops could reduce irrigation costs, the likelihood of adverse harvest conditions, and agricultural withdrawal from the Mississippi River Valley Alluvial Aquifer (MRVAA). This research was conducted to determine an optimum termination window for furrow-irrigated cotton (*Gossypium hirsutum* L.) in the mid-southern U.S. The effects of irrigation termination timing on cotton lint yield, net returns, and irrigation water use efficiency (IWUE) were evaluated on a Leeper silty clay loam (fine, smectitic, nonacid, thermic Vertic Epiaquepts) and on a Dundee silty clay (fine-silty, mixed, active, Typic Endoaqualfs). Neither terminating nor continuing to irrigate cotton from cutout (NAWF = 5) up to three weeks past first cracked boll had an effect on lint yield or fiber quality ($p \geq 0.6107$). Irrigation water use efficiency declined when water was applied past cutout ($p < 0.0001$). Results indicate that irrigation in cotton can be terminated at cutout without adversely effecting lint yield and fiber quality if soil water potential does not exceed -130 kPa prior to first cracked boll. Terminating irrigation in cotton at cutout could reduce late season irrigation cost and reduce water withdrawal from the MRVAA thus improving it sustainability.

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Cotton producers have the tendency to irrigate cotton after first cracked boll is observed. The ideology behind this method is to increase lint yield from upper fruiting positions on the plant; however, up to 75% of lint yield originates from lower fruiting branches (nodes 6-14) (Jenkins *et al*., 1990). Irrigation applied to cotton late in the growing season could result in several adverse effects such as hard lock and rotted bolls, unfavorable harvest conditions, added production costs, and increased withdrawal from the Mississippi River Valley Alluvial Aquifer (MRVAA). While adequate water to the plant either through rainfall or supplemental irrigation at the appropriate timing is crucial, irrigation termination timing is not well defined (Vories *et al*., 2011). A termination timing method based on crop growth, is needed to maximize lint yield, irrigation water use efficiency (IWUE), and net returns above irrigation costs while reducing the likelihood of adverse effects.

The alarming rate at which the MRVAA has declined due to agricultural withdrawal in the mid-southern United States (U.S.) has increased the need for ways to increase IWUE (Reba *et al*., 2014). A strategy to eliminate unnecessary water use would be to determine a time in which to terminate irrigation, therefore resulting in reductions in water use. Water savings up to 1 million ac-in could result by reducing one, 4 ac-in, irrigation event on the 250,000 acres of irrigated cotton in Mississippi alone (NASS, 2018).

Late season rainfall and irrigation in cotton can lead to increases in hard-locked bolls and boll rot. Environmental conditions that expose open bolls to increased humidity or water are factors that have contributed up to 35% hard-locked bolls and 4% boll rot in Georgia, resulting in more than $32 million dollars in lost revenue in 2003 (Williams-Woodward *et al*., 2003). Many agronomic practices such as reducing seeding rate, reducing nitrogen rate, selecting okra-leaf varieties, and use of fungicides have been evaluated to reduce the likelihood of hard-locked bolls and boll rot, however, annual losses vary (Andries *et al*., 1970; Marois *et al*., 2007). Reducing late season irrigation through proper termination timing could inhibit or abate conditions that promote hard-locked bolls and boll rot.

Terminating furrow irrigation in cotton has been determined by calendar date, plant growth stage, and use of growing degree days (GDDs). Silvertooth *et al*. (1996) suggested that furrow irrigation be terminated using GDDs, where the final irrigation application should not occur past 333 GDDs post-anthesis of harvestable bolls. Research from Bourland *et al*. (1992) and Vories *et al*. (2001) based irrigation termination on the number of nodes above the upper most first-position white flower (NAWF). Irrigation termination has also been determined by a combination of heat unit accumulation (GDDs) and crop development monitoring (NAWF), where irrigation termination occurs when 350 GDDs past cutout in northern Arkansas and 500 GDDs past cutout in southern Arkansas has elapsed (Reba, *et al*., 2012). While these methods may assist with irrigation termination decisions, relying on GDDs can be unreliable as temperatures decrease late in the season but cotton plants continue to mature.

Terminating irrigation based on weeks following cutout (NAWF =5) and first cracked boll could reduce unnecessary irrigation costs late in the growing season. The cost of a single furrow irrigation event, 2 to 4 ac-in, is $3.88 to $7.76/ac, therefore saving one event late season could increase the profit margin (Falconer *et al*., 2017). The incorporation of an irrigation termination timing in which soil water potential has no effect on lint yield or fiber quality, delaying crop maturity, or result in unfavorable field conditions at harvest would allow producers to schedule final irrigation (Vories *et al*., 2011).

Research relating irrigation termination timing in cotton to lint yield, fiber quality, and net returns is limited in the Mid-South. The objectives of this study were 1) to determine the optimum irrigation termination timing for furrow-irrigated cotton in the Mid-South that maximizes lint yield and fiber quality and 2) to determine an irrigation termination timing that reduces irrigation costs and water withdrawal from the alluvial aquifer. While maximizing lint yield is an important objective from a producer standpoint, understanding which termination timing is the most economical and provides efficient use of water is essential.

MATERIALS AND METHODS

Research was conducted at the R.R. Foil Plant Science Research Center near Starkville, MS (33.475396° N, 88.769066°W) on a Leeper silty clay loam (fine, smectitic, nonacid, thermic Vertic Epiaquepts) and at the Delta Research and Education Center near Stoneville, MS (33.436551° N, 90.910929° W) on a Dundee silty clay (fine-silty, mixed, active, thermic Typic Endoaqualfs) from 2015 through 2017. Cotton was planted at 45,000 seeds/ac and a depth of 1 inch (Table 1). Plots consisted of eight – 38-in rows that were 40-ft in length in Starkville, MS and four – 40-in rows that were 40-ft in length in Stoneville, MS. Furrow irrigation was applied using 15-in by 9-mil lay-flat polyethylene tubing (Delta Plastics, Little Rock, AR), with delivery optimized with the Pipe Hold and Universal Crown Evaluation Tool (PHAUCET version 8.2.20, USDA-NRCS, Washington, DC) (Kebede *et al*., 2014; Bryant *et al*., 2017). Flow rate at the field inlet was determined with a McCrometer flow tube with attached McPropeller bolt-on saddle flowmeter (McCrometer Inc., Hemet, California). Treatments were arranged in a randomized complete block design with four replications. Cotton was irrigated throughout the growing season based on current extension recommendations (Allen *et al*., 1998) until two weeks prior to first cracked boll which was based on growing degree unit accumulation (2150 DD_{60}) and overall crop condition (115 days after planting) (Ritchie *et al*., 2004). At two weeks prior to first cracked boll (Cutout), all plots were irrigated. On a weekly basis after the initial blanket irrigation, irrigation was terminated each week until three weeks after first cracked boll. Irrigation was therefore terminated at two weeks prior to first cracked boll, one week prior to first cracked boll, at first cracked boll and one, two, and three weeks after first cracked boll.

Management and Data Collection. Insect control, fertility, plant growth regulators, weed control, and harvest aids were applied based on Mississippi State University Extension recommendations (Bond *et al*., 2017; Catchot *et al*., 2017; Dodds, 2017; Dodds *et al*., 2017a). Data collection consisted of plant height and number of nodes at harvest, lint turnout, lint yield, and fiber quality. Cotton was harvested using a spindle picker modified for small plot research (Table 1). Lint turnout was determined by harvesting a 25-boll sample by hand and ginning on a 10-saw laboratory cotton gin (Continental Eagle Corp., Prattville, AL). Seed and lint were weighed, and lint turnout was calculated by dividing the weight of lint by the total weight of seed plus lint. Fiber quality was determined using a High-Volume Instrument (HVI®) at the Fiber and Biopolymer Research Institute, Lubbock, TX.

Table 1. Planting and Harvest Dates for Starkville and Stoneville, MS 2015–2017

	Starkville			Stoneville		
	–2015–	–2016–	–2017–	–2015–	–2016–	–2017–
Planting	May 8	May 7	May 7	May 5	May 10	May 8
Variety	ST 4946[z]	ST 4946	ST 4946	PHY 499[y]	DP 1639[x]	ST 4946
Harvest	Oct. 5	Oct. 24	Oct. 25	Sept. 30	Oct. 5	Oct. 3

[z] Stoneville 4946 GLB2

[y] Phytogen 499 WRF

[x] Deltapine 1639 B2XF

Economic Analysis. A partial budget was generated to assess the economic costs of irrigation setup and water application. Values were generated using the Mississippi State Cotton Planning Budgets from 2015-2017. Operation costs such as land planning, engine set up, ditching, rolling out pipe, applying water, picking up pipe, land forming, pumping, average labor and fuel costs were included in the analysis to determine net returns ($/ac). Net returns were determined by multiplying the average cotton lint price for each year, 2015–2017, by lint yield collected and subtracting irrigation costs (USDA, 2017).

Statistical Analysis. Data for this study was combined over years and analyzed using analysis of variance (ANOVA) with the PROC GLM procedure in SAS v.9.4 (SAS Institute, Cary, NC). Means were separated using Fisher's Protected LSD at the 0.05 level of significance.

RESULTS

Growing Season Rainfall and Irrigation. Rainfall varied over years, but every potential irrigation treatment was applied at least once over the course of the study (Table 2). In Starkville in 2015 and 2016, rainfall ranged from 24 and 67% below the 10-year average in August and September, respectively (Table 2). However, in 2017 rainfall in Starkville during August and September ranged 41 and 6% above the 10-year average, respectively (Table 2). In Stoneville in 2015, rainfall ranged from 73 and 78% below the 10-year average in August and September, respectively (Table 2). In 2016 and 2017, rainfall during August was 48 and 74% greater than the 10-year average, but September had 90 and 55% less rainfall, respectively (Table 2). Based on these weather conditions, less than average rainfall during the boll maturation and initial irrigation termination periods were observed in August and September in 2015 and 2016 in Starkville and 2015 in Stoneville.

Table 2. Rainfall amounts for trial locations in Starkville, MS and Stoneville, MS

Month	Week	Starkville			Stoneville		
		2015 Rainfall (in)	2016 Rainfall (in)	2017 Rainfall (in)	2015 Rainfall (in)	2016 Rainfall (in)	2017 Rainfall (in)
August	1	0.13	1.07	2.61	0.00	0.33	0.35
	2	0.85	1.68	4.57	0.00	0.81	7.73
	3	0.17	0.71	0.47	0.65	2.87	0.31
	4	0.81	0.00	0.05	0.08	1.47	2.35
September	1	0.05	0.00	2.77	0.09	0.30	1.70
	2	1.24	0.02	1.02	0.55	0.00	0.75
	3	0.03	2.73	0.63	0.12	0.04	0.91
	4	0.18	0.00	0.43	0.03	0.00	0.03
October	1	0.03	0.00	0.00	0.00	0.00	0.24
	2	0.42	0.00	0.67	0.21	0.00	0.07
	3	0.00	0.04	0.34	0.00	0.19	0.22
	4	2.02	0.00	1.18	5.28	0.01	1.37
Total		5.93	6.25	14.74	6.98	6.02	16.03

Termination Timing on Lint Yield, Fiber Quality, and Plant Growth Parameters. The primary hypothesis of this study is that producers should not irrigate past first cracked boll on Mid-South soils and that producers may be able to terminate irrigation earlier than first cracked boll. Irrigation termination timing did not impact cotton height at harvest, number of nodes at harvest, lint turnout, lint yield, micronaire, fiber length, fiber uniformity, fiber strength, or fiber elongation in any year or location ($p \geq 0.6107$) (Table 3). Previous research conducted in the mid-southern and southeastern U.S. by Vories *et al.* (2002) and Porter *et al.*, (2014) agrees with the findings of this research, where differences in lint yield for extended irrigation applications were variable and not reliable, and that neither lint yield or lint turnout was affected by irrigation termination timing. In addition, Vories *et al.* (2011) reported that no differences in fiber quality were observed due to varying irrigation termination timings and no consistent trend relating fiber quality to final irrigation was observed (Table 3). However, research conducted by Silvertooth *et al.* (2006) found that lint yield and micronaire values consistently increased with later irrigation termination dates. These results were derived from Arizona where supplemental irrigation is necessary to produce cotton, and rainfall is limited. Furthermore, Silvertooth *et al.* (2006) reported that irrigation termination after cutout provided the greatest lint yield and optimum micronaire. These results suggest that current recommendations of irrigation termination in Mississippi may be near optimum.

Though irrigation termination timing did not have an effect on plant growth parameters, lint turnout, lint yield, or fiber quality, these results suggest that when adequate rainfall in the mid-southern U.S. has occurred there is no additional benefit to irrigating beyond the current irrigation termination recommendation of first cracked boll (Table 4). Furthermore, these results suggest that irrigation could be terminated two weeks prior to first cracked boll (cutout) without observing a negative effect on plant growth, lint turnout, lint yield, or fiber quality. Typical furrow irrigation events apply between 2 and 4 in/ac of water. Irrigation costs associated with furrow irrigation in cotton are estimated at approximately $1.94 per ac-in. Therefore, by reducing one irrigation event at the end of the growing season, cost savings between $3.88 to $7.76 per acre could occur, Table 5 (Falconer *et al.*, 2017). Earlier irrigation termination may assist in the reduction of water withdrawal from the alluvial aquifer and reduce the likelihood of creating unfavorable harvest conditions while maintaining plant growth, lint yield, and fiber quality.

Table 3. Analysis of variance probability values for irrigation termination timing for Starkville and Stoneville, MS 2015-2017

	Ht. at Harvest[y]	Nodes at Harvest[x]	Turnout	Lint Yield	Mic,[w]	Leng,[v]	Unif,[u]	Stren,[t]	Elon,[h]	IWUE	Irrigation Cost	Net Returns
	----------------------------- p-values[z] -----------------------------											
Timing	**0.9945**	**0.9197**	**0.9755**	**0.7583**	**0.8178**	**0.9103**	**0.6107**	**0.7611**	**0.8406**	**<0.0001**	**<0.0001**	**0.8351**

[z] **Data pooled across year and location.**
[y] **Plant height at harvest.**
[x] **Total plant nodes at harvest.**
[w] **Micronaire.**
[v] **Fiber length.**
[u] **Fiber uniformity.**
[t] **Fiber strength.**
[s] **Fiber elongation.**

Table 4. Means for plant growth parameters, lint turnout, lint yield, and fiber quality for irrigation termination timing in Starkville, MS and Stoneville, MS 2015–2017

Timing[z]	Ht. at Harvest[y].	Nodes at Harvest[x]	Turnout	Lint Yield	Mic,[w]	Leng,[v]	Unif,[u]	Stren,[t]	Elon.[s]
	----- in -----	-- number --	----- % -----	---- lb/ac ----	---- mic ----	----- in -----	----- % -----	-- gram/tex --	----- % -----
2 Wk before CB	**40.6**	**19.8**	**0.420**	**1302**	**4.68**	**1.15**	**83.6**	**33.2**	**7.48**
1 Wk before CB	**40.6**	**19.5**	**0.421**	**1273**	**4.77**	**1.15**	**83.9**	**32.7**	**7.43**
Cracked Boll	**40.1**	**19.5**	**0.423**	**1220**	**4.74**	**1.15**	**83.4**	**33.3**	**7.56**
1 Wk after CB	**39.5**	**19.3**	**0.424**	**1273**	**4.82**	**1.15**	**83.8**	**33.3**	**7.48**
2 Wk after CB	**40.1**	**19.5**	**0.424**	**1321**	**4.78**	**1.15**	**83.7**	**33.1**	**7.50**
3 Wk after CB	**39.3**	**20.0**	**0.422**	**1338**	**4.72**	**1.15**	**83.5**	**33.1**	**7.63**

[z] **Data pooled across year and location.**
[y] **Plant height at harvest.**
[x] **Total plant nodes at harvest.**
[w] **Micronaire.**
[v] **Fiber length.**
[u] **Fiber uniformity.**
[t] **Fiber strength.**
[s] **Fiber elongation.**

Table 5. Irrigation water use efficiency (lb lint/ac-in) and net returns ($/ac) for 2015-2017

	IWUE	Irrigation Cost	Net Returns[a]
Termination Timing	--------- lb lint/ac-in ---------	-------------- $/ac --------------	-------------- $/ac --------------
Cutout	**372 a**	**6.79 f**	**868 a**
1 Wk after Cutout	**182 b**	**13.58 e**	**842 a**
Cracked Boll	**116 c**	**20.37 d**	**799 a**
1 Wk after CB	**91 cd**	**27.16 c**	**828 a**
2 Wk after CB	**76 de**	**33.95 b**	**853 a**
3 Wk after CB	**64 e**	**40.74 a**	**857 a**

CONCLUSION

The objective of this study were to determine the optimum irrigation termination timing for furrow irrigated cotton in the Mid-South that maximizes lint yield and fiber quality and reduces irrigation costs and water withdrawal from the alluvial aquifer. Terminating irrigation at cutout (two weeks prior to first cracked boll) when adequate soil moisture or rainfall is present maximized plant growth parameters, lint turnout, lint yield, and fiber quality. In this study, there was no benefit from terminating irrigation after cutout (two weeks prior to first cracked boll). Overall, irrigation termination timing should be based on specific environmental conditions, where factors such as soil moisture content and rainfall should be considered prior to irrigation termination timing. However, reductions in irrigation costs and reducing the likelihood of creating an environment favorable for adverse conditions may be observed with earlier irrigation termination timings.

REFERENCES

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration – Guidelines for computing crop water requirements – FAO irrigation and drainage paper 56. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/3/X0490E/X0490E00.htm (accessed 15 Dec. 2020)

Andries, J.A., J.E. Jones, L.W. Sloane, and J.G. Marshall. 1970. Effects of Super Okra Leaf Shape on Boll Rot, Yield, and Other Characters of Upland Cotton, Gossypium hirsutum L. Crop Sci. 10:403–407.

Bond, J.A., D.M. Dodds, B.R. Golden, J.T. Irby, E.J. Larson, B.H. Lawrence, D.B. Reynolds, and J.M. Sarver. 2018. 2018 Weed Management Suggestions for Mississippi Row Crops. Mississippi State University, Starkville, MS. Pub. 3171.

Bourland, F.M., D.M. Oosterhuis, and N.P. Tugwell. 1992. Concept for monitoring cotton plant growth and development using main-stem node counts. J. Prod. Agric. 5(4):532–538.

Bryant, C.J., L.J. Krutz, L. Falconer, J.T. Irby, C.G. Henry, H.C. Pringle III, M.E. Henry, D.P. Roach, D.M. Pickelmann, R.L. Atwill, and C.W. Woods. 2017. Irrigation water management practices that reduce water requirements for Mid-South furrow-irrigated soybean. Crop, Forage, and Turfgrass Management 3. doi:10.2134/cftm2017.04.0025

Catchot, A.L., C. Allen, J. Bibb, D. Cook, W. Crow, J. Dean, D. Fleming, J. Gore, B. Layton, N. Little, J. MacGown, F. Musser, S. Winter, D. Dodds, T. Irby, E. Larson, and S. Meyers. 2017. 2017 Insect Control Guide for Agronomic Crops. Mississippi State University, Starkville, MS. Pub. 2471.

Dodds, D.M. 2017. Cotton: Plant Growth Regulator Use. Mississippi Crop Situation. http://www.mississippi-crops.com/2017/07/07/cotton-plant-growth-regulator-use/ (accessed 15 Dec. 2020)

Dodds, D.M., D. Fromme, T. Cutts, T. Sandlin, T.B. Raper, and B. Robertson. 2017. 2017 Mid-South cotton defoliation guide. Midsouth Cotton Specialists' Working Group. http://news.utcrops.com/wp-content/uploads/2017/09/W376.pdf (accessed 15 Dec. 2020)

Falconer, L., D.M. Dodds, J. Bond, A.L. Catchot, D. Cook, B. Golden, J. Gore, L. Oldham, H.C. Pringle. 2017. Delta Planning Budgets – Cotton. Mississippi State University, Dept. of Agric. Econ. Report 2017-05.

Kebede, H., D.K. Fisher, R. Sui, and K.N. Reddy. 2014. Irrigation methods and scheduling in the Delta region of Mississippi: Current status and strategies to improve irrigation efficiency. Am. J. Plant Sci. 5:2917–2928. doi10.4236/ajps.2014.520307

Jenkins, J.N., J.C. McCarty Jr., and W.L. Parrott. 1990. Effectiveness of Fruiting Sites in Cotton: Yield. Crop Sci. 30:365–369.

Marois, J.J., D.D. Wright, B. Leite, D. Mailhot, and E. Osekre. 2007. Hardlock of Cotton: Historical Review and Perspectives. Proc. World Cotton Conf. 4. https://wcrc.confex.com/wcrc/2007/techprogram/P1837.HTM (accessed 15 Dec. 2020)

[NASS] National Agricultural Statistics Service. 2018. Planted Cotton Acreage. United States Department of Agriculture, Washington D.C. www.nass.usda.gov/statistics_by_subject (accessed 15 Dec. 2020)

Porter, W.M., G.D. Collins, S.A. Byrd, and J.L. Snider. 2014. Irrigation termination and fiber quality: subsurface drip irrigation versus overhead. www.uga.cotton.com/vault/file/2014RER-10282015.57-66.pdf (accessed 15 Dec. 2020)

Reba, M.L., T.G. Teague, and E.D. Vories. 2012. A review of irrigation termination practices in Northeast Arkansas. Arkansas Agricultural Experiment Station Research Series 610 41–44. http://arkansas-ag-news.uark.edu/pdf/610.pdf (accessed 15 Dec. 2020)

Reba, M.L., T.G. Teague, and E.D. Vories. 2014. A retrospective review of cotton irrigation on a production farm in the Mid-South. J. Cotton Sci. 18:137–144.

Ritchie, G.L., C.W. Bednarz, P.H. Jost, and S.M. Brown. 2004. Cotton growth and development. Univ. of Georgia, Tifton, GA. Coop. Ext. Serv. Bull. 1252.

Silvertooth, J.C., E.R. Norton, and P.W. Brown. 1996. Cotton growth and development patterns. In: Cotton, 75–97. Univ. of Arizona Rep. P-103. Tuscon, Ariz.: Univ. of Arizona.

Silvertooth, J.C., R. Tronstad, and A. Galadima. 2006. Evaluation of late season irrigation strategies. Proc. Beltwide Cotton Conf., San Antonio, TX. 3-6 Jan. 2006. Natl. Cotton Counc. Am., Memphis, TN.

[USDA] United States Department of Agriculture. 2017. 2013 Farm and Ranch Irrigation Survey. www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/ (accessed 15 Feb. 2020)

Williams-Woodward, J.L., P.Bertrand, P.Brannen, J. Fowler, R. Kemerait, D. Langston, A. Martinez, and J. Youmans. 2009. 2003 Georgia Plant Disease Loss Estimates. Univ. of Georgia. Bull. 41-06. https://athenaeum.libs.uga.edu/bitstream/handle/10724/12407/SB41-06.pdf?sequence=1&isAllowed=y (accessed 15 Dec. 2020)

Vories, E.D., R.E. Glover, N.R. Benson, Jr., and V.D. Wells. 2001. Identifying the optimum time for final surface irrigation on Mid-South cotton. ASAE Paper No. 012176. St. Joseph, Mich.

Vories, E.D. J.K. Greene, W. Robertson, T. Teague, B. Phipps, and S. Hague. 2002. Determining the optimal timing for final irrigation on Mid-South cotton. Proc. Beltwide Cotton Conf., Atlanta, GA. 8-13 Jan. 2002. Natl. Cotton Counc. Am., Memphis, TN.

Vories, E.D., P.L. Tacker, and R. Hogan. 2005. Multiple inlet approach to reduce water requirements for rice production. Appl. Eng. Agric. 21:611–616. doi:13031/2013.18571

Vories, E.D., J.K. Greene, T.G. Teague, J.H. Stewart, B.J. Phipps, B.C. Pringle, E.L. Clawson, R.J. Hogan, P.F. O'Leary, and T.W. Griffin. 2011. Determining the optimum timing for final furrow irrigation on Mid-South cotton. J. Applied Engineering in Agric. 27(5):737–745.