Nitrogen Fertility Management during Water Stress in Cotton

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ABSTRACT

Cotton is grown in a variety of climates where moisture stress is common. Stress may be chronic, occurring throughout the growing season, or acute, occurring at anytime during the season. Nitrogen management can have a significant impact on the effects of water stress. This paper presents the results of a three year study conducted in the San Joaquin Valley of California, USA. Differing levels of water stress and nitrogen fertility were imposed on moderate sized field plots of a determinate upland cotton (cv. Germains GC-510) in a replicated split plot trial. Measurements of growth, development, leaf area development, leaf water potential, soil water content, petiole nutrient concentrations, single leaf gas exchange, fruit retention patterns, lint yield and quality were made. Both water and nitrogen stresses were severe enough to reduce mainstem height. The highest level of nitrogen stress reduced mainstem height prior to first bloom. The addition of nitrogen reduced the effect of water stress from 73% of the unstressed control to 95%. Mainstem node development was not significantly decreased by water stress but water stress decreased the number of mainstem nodes required to produce 95% of the crop. Lint yield was significantly reduced by both water and nitrogen stress. The addition of nitrogen with the highest level of water stress increased lint yield from 58% to 76% of the unstressed control. Neither water nor nitrogen stress influenced fiber quality. Other physiological responses to nitrogen fertilization during water stress are discussed.

Introduction

Water stress is present in most cotton production environments. It can occur at anytime throughout the growing season and may either be chronic or acute. Research has been conducted for many years on the effects of water stress on cotton yields, growth and development (Grimes and El-Zik, 1990). However, relatively little work has been done on the nitrogen relations of water stressed cotton and less on the practical aspects of determining the optimum nitrogen management strategy for water stressed cotton (Zelinski, 1995). The purpose of this research was to study the response of water stressed cotton to various nitrogen fertilization rates and to determine appropriate nitrogen management recommendations.

Material and Methods

Cotton field trials were planted in early April in 1988, 1989, and 1990 at the University of California's Westside Field Station in the San Joaquin Valley of California, United States. Germains GC-510, a full season cultivar, was used each year. Plots in a split plot design with four replications with irrigation treatment as the main plots and nitrogen rate the split plots. The specific treatments for each year varied (Table 1).

Irrigation was applied in furrows using a time - volume method to determine depth applied. Table 2 summarizes the dates and amounts of each irrigation. Nitrogen fertilizer was applied as Ammonium Sulphate on May 25, 1988, May 19, 1989 and May 2, 1990 (Table 1). In addition, in 1988 the entire treatment area received 112 kg N/ha as Urea on Feb. 9. The row spacing was 1 metre and the plots were approximately 90 metres long, oriented in a north - south direction. Subplots were 4, 4, and 6 rows wide and main plots were 12, 20 and 18 rows wide in 1988, 1989, and 1990 respectively. There were between 4 and 6 buffer rows that received neither irrigation nor nitrogen between main plots.

Cotton growth, development and retention characteristics were determined through a combination of in-season and final plant mapping. Leaf water potential (LWP) was determined using a pressure chamber (Grimes and Yamada, 1982). Adjustments to raw LWP reading were made to compensate for abnormal temperatures on the day of the reading (Grimes, *et al.*, 1987). Soil Water Content (SWC) was determined with a neutron probe. Plots were harvested with a commercial two row cotton picker on Oct. 28, 1988, Oct 27, 1989 and Oct 19, 1990. Seedcotton samples were ginned to determine turnout and in 1988, lint samples were analyzed for length, strength, micronaire, elongation, reflectance, and yellowness at the USDA Cotton Research Station in Shafter, CA.

Results and Discussion

Effects on yield. The method of imposing water stress resulted in early season stress in 1988 (Table 3). Under these conditions, water stress in the absence of N fertilization reduced yields to 66 percent of the unstressed control but when N was added, lint yields were 76 percent of the unstressed control. This illustrates the interaction of water stress and nitrogen fertilization, the effects of early season water stress on lint yields being reduced by the addition of nitrogen fertilizers (Table 4). In 1989 and 1990, the method of imposing water stress simulated mid-season stress.

The addition of nitrogen to the high water stress treatments increased yields from 55% of the unstressed control to 76%, illustrating that under conditions where water stress is limiting yields in mid-season, the addition of nitrogen fertilizers can partially alleviate the effects. Since nitrogen can “substitute” for water (in a practical sense) an analysis of why it occurs is relevant.

Effects on growth and development. Cotton lint yields are partially a function of number of fruiting sites produced and the retention of fruit at those sites. The number of total mainstem nodes and the number of fruiting branches were reduced by water stress. The addition of nitrogen to water stress treatments increased both parameters (Tables 5 and 6). On average, the addition of nitrogen returned the mainstem nodes and the number of sympodial branches to the same values as the unstressed control. This finding helps explain the alleviating effect nitrogen has on water stressed cotton lint yields.

These results suggest that similar numbers of fruiting sites were produced in the unstressed control and the water stress + N treatments and that since the yields between these two treatments were so similar, an affect on fruit retention must have occurred.

Effects on fruit retention. The effect of water stress on fruit retention on all sympodial branches varied, with water stress increasing retention at position one in 1988 and reducing it in 1989 and 1990. The timing of water stress varied between 1988 and the other two years but this was probably not the cause since retention in the unstressed control was reduced in ‘89 and ’90 when the level and timing of both nitrogen and water stress should have been similar. In general, water stress had a limited effect on first position retention so additional nitrogen had little affect.

Though first position retention was not influenced by water stress, nor greatly changed with the addition of nitrogen, second position retention average across all sympodial branches was changed (Table 8). In all years, especially 1989 and 1990, water stress caused a large reduction in retention at the second position. The addition of nitrogen partially alleviated this effect.

Fruit retention at the second position was closely correlated with yield, explaining approximately 65 percent of the variation over the three years (Fig. 1). These data support the contention that second position boll development is more sensitive to stress because it is less favourably positioned for nutrient supply.

Conclusions

Water stress early or mid season has a big impact on cotton yields. The addition of nitrogen fertilizer can significantly alleviate this effect. The improvement in yields cannot be explained by increases in nodes, in sympodial branches, or in first sympodial fruiting site retention. Nitrogen fertilization appears to improve retention mainly at the second sympodial fruiting position. Percent retention at this position is closely correlated with yield.

References

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Table 1. Irrigation and nitrogen treatments in 1988, 1989 and 1990.

Year	Main Plot (Irrigation Timing)	1st / Subsequent MPa or Date	Split Plot (Nitrogen Rate)	kg/ha
1988	Low	-1.3 / -1.6	I	0
	Moderate	-1.5 / -1.9	II	85
	High	-2.0 / -2.3	III	170
1989	Low	June 1 / -1.5	I	0
			II	30
	Moderate	June 1 / -1.8	III	55
			IV	110
	High	June 1 / -2.1	V	220
1990	Low	June 4 / -1.5	I	0
	Moderate	June 4 / -1.8	II	110
	High	June 4 / -2.1	III	220

Table 2. Irrigation dates and amount applied.

Treatment		PrePlant	1st	2nd	3rd	4th	5th	6th	Total
1988	I	Feb 18	Jun 6	Jun 27	Jul 15	Jul 29	Aug 11	Aug 23	
amount (mm)		350	100	120	90	100	85	50	895
	II	Feb 18	Jun 27	Jul 19	Aug 1	Aug 26			
		350	120	110	105	60			745
	III	Feb 18	Jul 11	Aug 11					
		350	130	105					585
1989	I	Jan 25	Jun 1	Jul 3	Jul 17	Aug 2	Aug 21		
amount (mm)		320	160	130	190	130	100		1,030
	II	Jan 25	Jun 1	Jul 14	Aug 4				
		320	160	190	130				800
	III	Jan 25	Jun 1	Jul 28					
		320	160	150					630
1990	I	Feb 1	Jun 4	Jun 22	Jul 3	Jul 20	Aug 3		
amount (mm)		315	140	130	140	160	130		1,015
	II	Feb 1	Jun 4	Jul 3	Jul 27				
		315	140	140	130				725
	III	Feb 1	Jun 4	Jul 20					
		315	140	160					615

Table 3. The interactions of water stress and nitrogen fertilization on cotton lint yield (kg/ha) in 1988. Values in parenthesis are yields expressed as a percent of the unstressed control, considered to be the low water stress - maximum N rate treatment.

Water Stress	N Rate (kg/ha)		
	0	110	220
Low	1383 (84)	1644 (101)	1626 (100)
Moderate	1321 (80)	1544 (94)	1556 (95)
High	1088 (66)	1160 (71)	1248 (76)

Table 4. Interaction of water stress and nitrogen fertilization on average cotton lint yields (kg/ha) in 1989 and 1990. Values in parenthesis are yields expressed as a percent of the unstressed control, considered to be the low water stress - maximum N rate treatment.

Water Stress	N Rate (kg/ha)		
	0	110	220
Low	958 (62)	1463 (95)	1543 (100)
Moderate	892 (58)	1381 (89)	1438 (93)
High	852 (55)	1132 (73)	1175 (76)

Table 5. Effect of water stress and nitrogen on number of mainstem nodes.

Year	Unstressed Control	Water Stress	Water Stress + N
1988	22.4	22.9	23.6
1989	25.7	22.9	24.3
1990	22.8	20.0	23.0
Average	23.6	21.9	23.6

Table 6. Effect of water stress and nitrogen on number of sympodial nodes.

Year	Unstressed Control	Water Stress	Water Stress + N
1988	15.1	15.6	16.2
1989	19.0	16.4	18.2
1990	17.7	14.9	17.8
Average	17.3	15.6	17.4

Table 7. Effect of water stress and nitrogen on percent retention at position one averaged across all sympodial branches.

Year	Unstressed Control	Water Stress	Water Stress + N
1988	63.2	73.1	65.0
1989	37.0	33.3	35.0
1990	42.5	40.3	33.5
Average	47.6	48.9	44.5

Table 8. Effect of water stress and nitrogen on percent retention at position two averaged across all sympodial branches.

Year	Unstressed Control	Water Stress	Water Stress + N
1988	20.3	14.7	16.3
1989	15.5	3.0	6.8
1990	14.8	8.8	10.5
Average	16.9	8.8	11.2

Figure 1. Relationship between percent retention on the second fruiting position average across all sympodial branches and lint yield of upland cotton.