Lint Yield Response to Varied Levels of Water Stress and Consumptive Water Use Requirements of Upland Cotton

F. Metzler, S. Husman, and R. Wegener
University of Arizona, Maricopa County Cooperative Extension

Abstract

Lint yield response to varied Management Allowed Depletion Levels (MADL), and consumptive water use rates were determined for four upland cotton varieties (D&PL 5415, D&PL NuCotn 33B, D&PL 5816, and STV 474) at the Maricopa Agricultural Center. Four irrigation treatments based on MADL of 35% (Very Wet), 50% (Wet), 75% (Medium) and 90% (Dry) of available moisture were used to schedule irrigations after May 16. The Very Wet and Wet treatments showed statistically similar yields which were much greater than the Medium and Dry treatments. Irrigation return intervals of six to ten days from early June thru late July appeared to provide the greatest lint yields. Consumptive water use appears to reach its maximum during the peak bloom period of the fruiting cycle. Following peak bloom, water use gradually diminishes.

Introduction

The Phoenix Active Management Area of the Arizona Department of Water Resources has provided two years of funding to measure the consumptive water use requirements of medium maturity determinate upland cotton varieties. Another aspect of the research is to determine the relationship between Management Allowed Depletion Levels (MADL) and lint yield response. MADL is the percentage of the available soil moisture that should be depleted from the active root zone before an irrigation is necessary. What is the optimum MADL which will provide the best yields while avoiding unnecessary irrigations? One school of thought is that whereas the older less determinate upland varieties were more forgiving of plant water stress (allowing for a higher MADL), the newer more determinate varieties are very sensitive to water stress during the fruiting cycle which may result in fruit shed and significant yield losses.

Research Objectives

- Assess the lint yield response to varied levels of water stress of three medium maturity Upland cotton varieties (D&PL 5415, D&PL Nu Cotn 33B, STV 474) compared to a less determinate variety (D&PL 5816).

- Determine the consumptive water use requirements of those varieties.

Materials and Methods

The test was laid out in a replicated, randomized complete block split plot design on Field 10A at the University of Arizona Maricopa Agricultural Center. There were four irrigation treatments consisting of Very Wet (35% MADL), Wet (50%), Medium (75%) and Dry (90%) irrigation regimes. Each treatment consisted of all four varieties in test plots approximately .24 acres in size. Total test area was approximately 5 acres. Row spacing was 40 inches. The test was planted to moisture on April 2, 1996. Following an irrigation on May 16, all treatments were irrigated based on measured soil moisture depletion.

Fifty-six neutron probe access tubes were installed to a depth of six feet throughout the field and were used to schedule irrigations and determine consumptive water use rates. Probe readings were taken in the first foot and at 8 inch intervals thereafter to beneath the active root zone. Irrigation regimes of 35%, 50%, 75%, and 90% MADL were established. "Available water" was defined as 66% of the field capacity of the sandy loam soils in the test. For example, if the average field capacity was 2.6" per foot of soil, then there would be 1.7" of available water per foot. In the Very Wet Treatment (35% MADL), irrigations were initiated when 35% of the 1.7" per foot had been depleted (or 0.6 inches per foot) within the active root zone. Probe readings were taken three days after an irrigation (to allow drainage of excess water from the profile) and then as frequently as necessary to schedule the next irrigation. The "active root zone" was defined as running from the first foot to the lowest interval which indicated an average of at least .05 inches of depletion since the last irrigation.

Cutout occurred across all treatments by late July, and all irrigations were terminated no later than August 10. The test was defoliated on September 5, and harvested on September 18 using a two row plot picker.

Results and Discussion

Table 1 summarizes the lint yield results obtained by treatment and variety. Averaging all varieties within each treatment, there was statistically significant separation between the Dry, Medium and Wet treatments. The Very Wet treatment was similar (and slightly lower) in yield to the Wet treatment. The most significant result of this test was the 50% reduction in yield between the Wet (1438 lint lbs/ac) and Medium (713 lint lbs/ac) treatments. This reduction in yield occurred between a 50% and 75% MADL irrigation regime. In terms of irrigation return intervals, this is a difference of irrigating every 6 to 10 days as compared to irrigating every 17 to 24 days (see Table 2). Obviously the difference in the duration of return intervals is large, therefore the authors plan to modify the MADL's to 35%, 50%, 65% and 80%. Somewhere between the 50% and 75% MADL lies a critical level of plant water stress which may cause severe reductions in yields.

The very short return intervals in early to mid June are more a reflection of the shallower root zones and rapid surface evaporation than of rapid consumptive use. However, plant mapping data indicates that by June 17 the treatments had already begun to differentiate in terms of plant height, HNR and fruit retention. In other words, the early to mid June irrigations were already setting the stage for the plants before heavy fruiting had occurred. It should also be stressed that the irrigation intervals are specific to the soil moisture holding characteristics of the soils in this test. Heavier soils would naturally have longer return intervals, as lighter soils would require more frequent irrigations.

Consumptive water use (CU) was calculated using neutron probe data. The season total observed CU figures are summarized in Table 3. There was no significant difference in water use rates or total CU across the four varieties tested. The Very Wet treatment had the highest CU (27.3"), followed closely by the Wet treatment (25.4") The Dry treatment (17.4") actually had a higher CU than the Medium (16.3"), but both treatments were severely stressed throughout the growing season. The CU figures derived do not include evaporation directly from the soil surface immediately following an irrigation. Measurement of this component of CU is not possible with the neutron probe. As a result, CU rates would be slightly higher than the values provided herein, particularly before the crop canopy had closed.

Figure 1 provides a comparison between the observed CU from the 1996 test (Wet treatment only), and predicted CU based on crop coefficient curves developed by Paul Brown, Extension Biometeorologist (labeled AZSCHED MOD), and Leonard Erie et al (1981) in the late 1950's and early 1960's (labeled Erie). As the figure shows, observed CU rates fit nicely with the Brown curve from early June into early July , and then they begin to gradually drop off. The peak or spike in CU rates from mid June to early July corresponds directly to the early bloom through peak bloom stages of the fruiting cycle. This relationship helps emphasize the absolutely critical importance of avoiding water stress during the fruiting cycle when water demand is at its highest. It is also interesting to note the significantly higher CU rates of both the Observed CU and Brown CU over the Erie CU. This discrepancy may be explained by the fact that the more indeterminate varieties tested by Erie et al did not experience the onset of the fruiting cycle as rapidly as today's more determinate, shorter-season varieties.

Another reduction in CU occurs in mid August after irrigation termination. This test was designed to focus on the primary fruiting cycle and the authors did not attempt to carry the crop beyond this point. It is possible that CU rates may continue at the mid to late July levels beyond the first fruiting cycle if the crop is managed with that intent.

Summary

Results from the first year showed a strong statistical relationship between irrigation thresholds and lint yield response. The 50% reduction in lint yield response between the Wet and Medium treatments indicates that somewhere between the 50% and 75% MADL lies a critical irrigation threshold that should be identified. Plant water demand appears to be highest during the peak bloom period of the fruiting cycle. Proper irrigation intervals must be maintained during this period. The statistically similar yields from the Wet and Very Wet treatments highlight the importance of maximizing irrigation scheduling efficiency while avoiding unnecessary irrigations. The relatively close correspondence between the Brown curve and the observed CU rates (in June and early July) indicates existing crop coefficient curves can be used for irrigation scheduling purposes. However, there may be potential for a lengthening of irrigation intervals and reduction of irrigations following cessation of the primary fruiting cycle.

References

Brown, P. (1995). Personal correspondence, University of Arizona Cooperative Extension.

Erie, L.J., French, O.F., Bucks, D.A., and Harris, K. (1981). "Consumptive Use of Water by Major Crops in the Southwestern United States." USDA-ARS. Conservation Research Report No. 29. 40 pp.

Table 1. Lint Yields (lint lbs/Ac) by Variety and Irrigation Treatment

Treatment Variety	Very Wet	Wet	Medium	Dry
D&PL 5415	1420 ab	1545 a	778 c	374 d
STV 474	1540 a	1503 ab	673 c	279 d
D&PL NuCotn 33B	1414 ab	1447 ab	701 c	335 d
D&PL 5816	1120 b	1254 b	701 c	328 d
Average Yield	1374 a	1438 a	713 c	329 d
Means followed by the same letter are not significantly different at P<.05 using a Fishers' LSD. *LSD = 262.36 OSL= 0.0458 C.V.= 19.12*				

Table 2. Irrigation Histories by Treatment, Irrigation Amounts & Return Intervals

Very Wet		Wet		Medium		Dry	
Date irrigated	Amount & Return Interval	Date irrigated	Amount & Return Interval	Date irrigated	Amount & Return Interval	Date irrigated	Amount & Return Interval
March 12* (preirrigate)	6.5 "	March 12* (preirrigate)	6.5 "	March 12* (preirrigate)	6.5 "	March 12* (preirrigate)	6.5 "
May 16	4"	May 16	4"	May 16	4"	May 16	4"
May 30	2" / 14						
June 6	2" / 7	June 6	3" / 21				
				June 8	3" / 23		
June 11	2" / 5	June 12	3" / 6				
June 14	2" / 3						
June 19	3" / 5	June 19	3" / 7			June 19	5" / 34
June 25	3" / 6			June 25	5" / 17		
		June 27	5" / 8				
July 2	3" / 7						
July 9	3" / 7	July 9	4" / 12				
July 15	3" / 6						
		July 18	4" / 9				
				July 19	5" / 24	July 19	5.5" / 30
July 23	3" / 8						
		July 29	4" / 11				
July 31	3" / 8						
				August 6	5" / 17		
August 8	3" / 8	August 8	4" / 10				
14 irrig.	42.5"	10 irrig.	40.5"	6 irrig.	28.5"	4 irrig.	21"

Table 3. Total Water Applied and Observed Consumptive Use by Treatment.

Irrigation Treatment	Total Water Applied (inches)	Observed Consumptive Use (inches)
Very Wet (35% MADL)	42.5	27.3
Wet (50% MADL)	40.5	25.4
Medium (75% MADL)	28.5	16.3
Dry (90% MADL)	21	17.4

Figure 1.Consumptive Water Use Comparison