UPLAND AND PIMA SOIL WATER UPTAKE PATTERNS FROM A DEEP, WELL-DRAINED SOIL

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Abstract

Water extraction patterns of Pima S7 and Acala Maxxa were compared in order to identify any gross differences in water uptake patterns that may necessitate the development of alternative irrigation guidelines for this relatively new San Joaquin Valley cotton type. Substantial water extraction by Acala and Pima cotton occurred at depths to 8 feet (2.4 meters), for irrigation treatments below optimum levels. Under this high water stress regime, average water extraction between the 6 and 8-foot depths was 9 percent for Pima S7 and 14 percent for Acala Maxxa during the three years of study. Irrigation treatments that optimized yield experienced water extraction values above 20 percent to the four-foot depth under Acala Maxxa and five-foot depth under Pima S7, also indicating a preference for Pima to take up water from more shallow depths. Generally, Acala Maxxa also proved to be more capable of extracting deep soil water compared to Pima S7 for severely drought impacted treatments. Despite the Acala's ability to forage successfully for deep soil water, these studies demonstrate that yield optimization in Maxxa must include more frequent irrigation and less cumulative water stress compared to Pima S7.

Introduction

Improved soil water management practices using more precise irrigation scheduling techniques, can lead to enhanced water use efficiency, irrigation efficiency, reduced costs and higher yield for the cotton producer. Current yields for Pima cotton in the San Joaquin Valley typically range from 90 to 100 percent of the commonly grown Acala and non-Acala Upland varieties. This indicates a strong competitive advantage of Pima in this region and the high likelihood that this unique cotton will continue to be grown competitively in the near future.

Water continues to be one of the most valuable inputs to the cotton production system with water prices steadily increasing and ranging from 50 to more than 200 dollars per acre-foot. Properly managed fields have minimal deep percolation and nutrient removal, while maintaining some degree of leaching fraction in the regions salt affected soils. Since Pima cotton's re-introduction to California's San Joaquin Valley in the late 1980's, information has been needed on soil water extraction patterns and crop water consumption of this indeterminate cotton type. Recent studies have shown Pima cottons tendency to set a larger proportion of fruit later in the season than the current Upland cottons, with a fruit set period of 40 to 50 days compared to a 28 to 34 day period more typical for the Upland cotton varieties. The extended reproductive season, coupled with delayed senescence characteristics, has lead growers and researchers to question the current seasonal cotton water use information for Pima cotton.

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Materials and Methods

Replicated irrigation trials were conducted in 1998, 1999, and 2000 at the University of California, West Side Research and Extension Center in Five Points, CA. These trials consisted of four different irrigation treatments ranging from zero irrigation to three irrigations in 1998, and one to five in-season irrigations in 1999 and 2000. Three different varieties of Pima Cotton: S7, DP-HTO, and Phy-57 along with Acala Maxxa were grown, and there were three replications in each trial. Four row 280-foot plots were developed for each of the four varieties within an irrigation main plot, and four row guards were constructed for each irrigation treatment.

Neutron Probe access tubes were installed and were monitored every 7 to 10 days with readings initiated at first square. Readings were taken to a depth of eight feet at one-foot intervals, and calibration curves were developed for each of the trial sites. Leaf water potential readings using a pressure chamber were also monitored throughout the season to determine plant water status and also to assist with irrigation timing decisions. Detailed final season plant mapping was conducted during late September; crop yield data were collected from each plot, as were cotton sub-samples for fiber quality analysis and gin turnout.

Each field was pre-irrigated in January with adequate moisture to produce an eight-foot soil profile at field capacity. The crop was planted April 22, 1998, April 14, 1999, and April 4, 2000. Neutron probe access tubes were installed to eight feet on two of the three Pima S7 and Acala Maxxa replicates for each irrigation treatment. A Cambell-Pacific 503 Hydroprobe was used to determine volumetric soil water content at 7- to 10-day intervals throughout the growing season. A nine-inch reading was made to represent soil moisture storage at the one-foot depth while an 18-inch reading was used to represent second foot soil moisture; 12-inch increments were used thereafter to represent corresponding depths to eight feet for soil moisture content. Neutron probe calibration was conducted independently at each site for each year of the study; these curves were developed by taking 50cc soil samples, determining volumetric soil moisture, and correlating it with neutron probe counts taken from the same tube and depth.

Plant populations were 25k/Acre in 1998, and 40k/Acre in 1999, and 45k/Acre in 2000. Nutrition, insect, and defoliation management were optimized both years of the study. In-season plant mapping was conducted every two weeks until peak bloom with a final plant map occurring in early September each year. Plant height, total node number, fruiting node number, and height to node ratio were evaluated at each plant map with nodes above white flower monitored following first bloom.

Each of the four row treatments were spindle picked and weighed in harvest trailers with 5 to 7 lb. sub-samples collected for each plot to determine lint turnout and HVI fiber quality parameters.

Results and Discussion

Soil water uptake properties are transient in nature and depend partially on antecedent soil moisture conditions, soil structure and soil mineralogy. On the well-watered plots a general trend was observed for reduced cumulative infiltration throughout the irrigation season, Table 1. Early season irrigation events allowed 5.4 to 7.9 inches of water to be applied to the 280-foot runs, while late season irrigation events tended to allow 3.5 to 5.5 inches of applied water per irrigation indicating a general breakdown of soil structure through the season. Total applied water generally ranged from 0 to 7 inches for the most stressed treatments (treatment 1), and 16 to 26 inches for the well-watered treatments (treatment 4). Cool early and mid-season conditions in 1998 created a lower overall water requirement for all cotton varieties, shifting optimum production from three to two in-season irrigation events.

Plant water extraction data were used to estimate rooting depth and activity, which was dynamic in nature both within season and between seasons. We found that effective rooting depth increased at a rapid rate during the 120-day period following sowing, but then slowed dramatically during the last 45 days leading up to defoliation, figure 1. This rate of root growth was lower in early 1998 with July 1 rooting depth at two feet while the 1999 and 2000 seasons produced a 3 and 4-foot root zone on this same date. The warm spring of the 2000 season resulted in above average early crop development and an extensive soil volume with which to extract water for crop evapotranspiration. Despite variations in annual weather, late season root water extraction depths were consistent on these clay loam soils with root activity observed between the 7 to 8-foot zone. Plant water extraction patterns also varied depending on the water regime that was imposed.

Plant water extraction in the vertical soil moisture profile was more uniform on low water application treatments for Pima S7 and Acala Maxxa cotton, figure 2. Pima and Acala cultivars both demonstrated a 15 to 25 percent seasonal extraction, depending on depth, in volumetric moisture. Water extraction at the 7 and 8-foot depth was particularly significant for Acala cotton plots having one or two seasonal irrigation events, but as irrigation frequency increased, a corresponding reduction in deep water extraction was observed. Under water regimes typical of grower practices (three to five irrigation events), whole season water extraction from the 8-foot depth was less than 7 percent for Acala cotton and less than 5 percent for Pima cotton. Irrigation frequency also influenced the proportion of water extracted from surface layers. Both Acala and Pima cottons experienced a 60 percent cumulative water extraction in the first foot for the high frequency irrigation treatment with large cumulative values being maintained for the top four feet of soil for the Pima cotton and top 5 feet for the Acala.

End of season plant height measurements, table 2., show the impacts of the various irrigation regimes. Yield differences from all three years of the study are shown in table 3.

Table 1. In-season irrigation dates and amounts and total amount applied for the various irrigation regimes.

	1st Irrig.	2nd Irrig.	3rd Irrig.	4th Irrig.	5th Irrig.	Total Applied
1998	7/10					
	5.4"					5.4 Ac/in
	7/10	8/7				
	5.4"	4.8"				10.1 Ac/in
	7/2	7/30	8/24			
	5.4"	6.1"	4.1"			15.6 Ac/in
1999	7/8					
	7.9"					7.9 Ac/in
	6/16	7/15				
	7.5"	7.4"				14.9 Ac/in
	6/16	7/15	8/13			
	7.5"	7.4"	4.6"			19.5 Ac/in
	6/3	6/25	7/15	8/13	9/2	
	5.9"	5.1"	7.4"	4.6"	3.5"	26.5 Ac/in
2000	6/28					
	6.8"					6.8 Ac/in
	6/15	7/19				
	5.6"	6.2"				11.8 Ac/in
	6/15	7/19	8/17			
	5.6"	6.2"	5.5"			17.3 Ac/in
	5/26	6/28	7/19	8/17	9/8	
	7.3"	6.8"	6.2"	5.5"	3.9"	29.7 Ac/in

Table 2. End of season plant height measurements.

	Number of In-Season Irrigations			
	1	**2**	**3**	**5**
98' Pima	36.9	33.9	35.6	-
98' Acala	37.9	38.5	38.6	-
99' Pima	32.8	40.9	47.1	43.1
99' Acala	29.8	38.3	40.5	44.6
00' Pima	24.6	29.0	29.6	37.5
00' Acala	29.3	32.1	33.3	41.9

Table 3. Yield (pounds of lint/acre).

	Number of In-Season Irrigations			
	1	**2**	**3**	**5**
98' Pima	1066	1324	1313	-
98' Acala	893	1154	1134	-
99' Pima	1537	2089	2006	1996
99' Acala	1510	1759	1971	1920
00' Pima	1258	1695	1848	1767
00' Acala	1487	1653	1761	1865

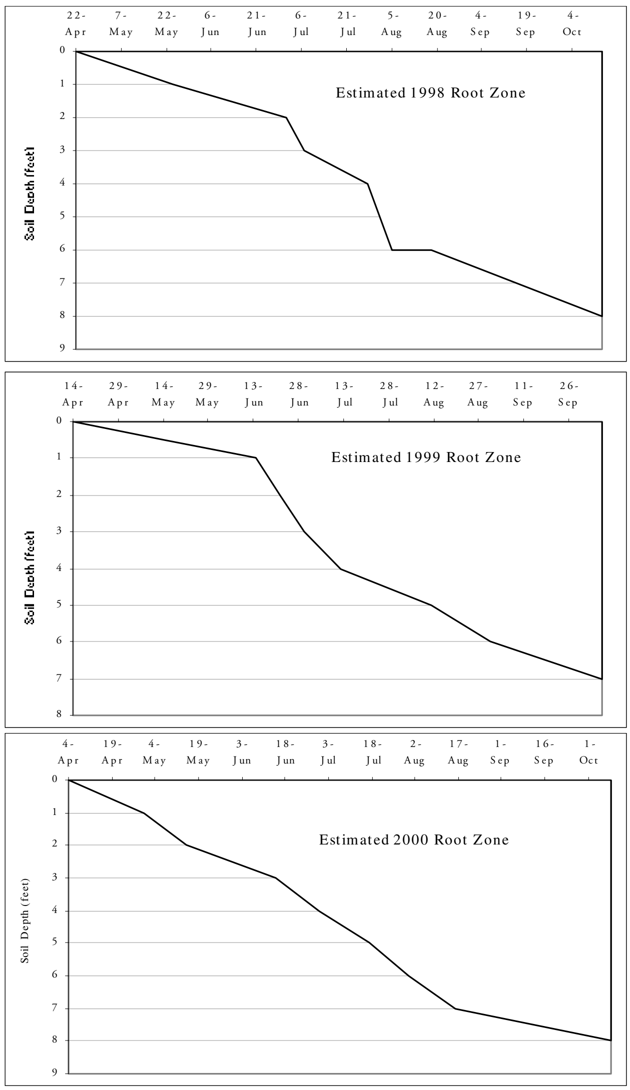

Figure 1. Rooting depth estimates based on neutron probe moisture depletion measurements.

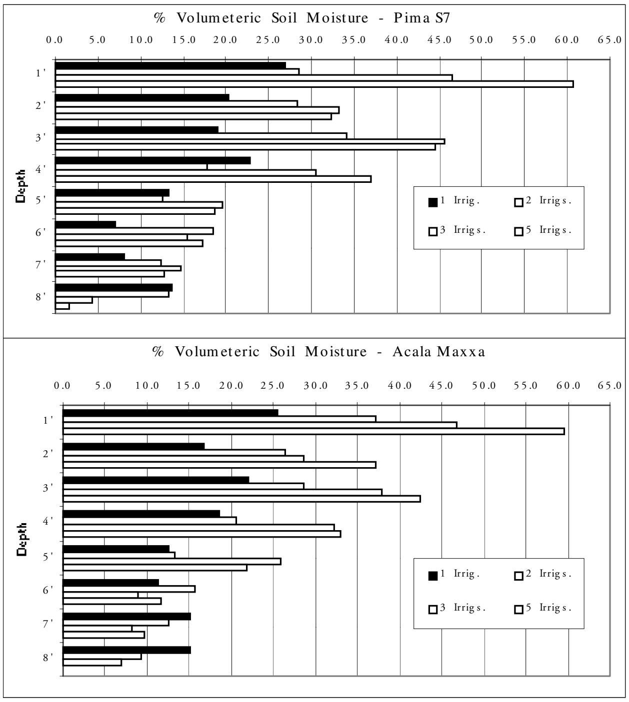

Figure 2. Volumetric soil moisture depletion in the vertical soil profile from May 3 to October 9, 2000.