Decline in Water Uptake by Irrigated Cotton During Boll Filling, and its Amelioration by Daily Drip Irrigation

John W. Radin, Jack R. Mauney, and Peter C. Kerridge

Abstract

In 1984, 1985, and 1986, leaf water potentials of irrigated cotton declined markedly as the crop approached cutout. Midday transpiration rates also declined, indicating a water-stressed condition. The water stress occurred despite the fact that measurements were made only when the soil was fully charged with water. In 1986, plant hydraulic conductances were estimated. The conductance was high early in the season, declined to a low value during cutout, and increased during regrowth to the high value of the early season. It is suggested that root length and efficiency of water uptake, or both, decrease during boll filling as most assimilates are partitioned into the bolls. Daily drip irrigation prevented this susceptibility to stress during boll filling. In 1984 and 1986, drip irrigation decreased the length and severity of cutout, resulting in an increased boll load at the end of the season.

Introduction

Drip irrigation in Arizona is believed to increase yields over conventional irrigation methods (biweekly furrow or flood irrigation), but the reasons for a yield increase are not understood. Here we report the results of a three-year study of cotton water relations on biweekly (furrow or flood) or daily (drip) irrigations.

Results and Discussion

The 1984 and 1985 tests were at the Maricopa Agricultural Center, and the 1986 test was at the Western Cotton Research Lab, Phoenix. In all three years, plant water potentials (measured with a pressure chamber) of furrow-irrigated or flood-irrigated cotton went to low values (more negative) as the crop acquired a heavy boll load (Table 1). This was true even though measurements were made only after the crop had been irrigated, indicating that the crop was unable to take up the water available to it. Drip-irrigated plants grown in adjacent fields showed no such inability to take up water (Table 1).

A LiCor LI-1600 porometer was used to measure stomatal diffusive conductances in 1984 and single-leaf transpiration rates in 1986. In both cases the midday values were low in the furrow-irrigated plants during rapid boll-filling. Again, this indicates that the plants were water-stressed despite having ample moisture available in the soil (Table 2). The drip-irrigated plants maintained a higher stomatal conductance in 1984 and a higher transpiration rate in 1986 during cutout. Differences between the furrow-irrigated and drip-irrigated crops before and after cutout were considerably smaller than they were during cutout (Table 2).

In 1986, the relationship between water potential and transpiration rate was determined by measuring each over a period of several hours, beginning predawn. The slope of a plot of transpiration against water potential is an indicator of the plant's hydraulic conductance (ability to transport water efficiently). In the flood-irrigated plants, hydraulic conductance was high initially, but it decreased to a low value as the boll load increased. Late in the season, during the second flush of growth, the hydraulic conductance was again high (Table 3). In the drip-irrigated plants, the hydraulic conductance was high throughout the season. In particular, the value during cutout was much higher than in the flood-irrigated plants.

In 1984 and 1986, boll loading patterns reflected the fact that the furrow-irrigated crop was subject to water stress. In 1984, drip irrigation delayed cutout; the longer period of boll loading resulted in about 20% more bolls per plant (Fig. 1). In 1986, the crop emerged from cutout much earlier, resulting again in a larger boll load per plant (Fig. 1). In both cases, if this boll load were carried to maturity, it would result in an increased yield in the drip-irrigated crop. In 1985, there was no advantage to drip irrigation, however.

We interpret these results in the following way. As the furrow-irrigated crop acquires a large boll load, most of the photosynthates are diverted into the growth of the bolls, leaving very little for the support of the root system. Thus, if a 2-week irrigation cycle results in a very mild water stress toward the end of the cycle, the root system will deteriorate and be unable to recover. Such behavior of the root system is not seen when the plant is able to partition photosynthates to the root system, allowing it to regrow rapidly after a stress. It is limited to the short period of the year when the boll load is too heavy to allow proper root recovery. The susceptibility to stress during this period can limit the plant's ability to support bolls and therefore lead to early and more severe cutout. Where drip irrigation is used successfully, this is the typical pattern that is seen, i.e., drip irrigation delays cutout.

These preliminary results do not tell us whether it is possible to overcome the root system decline apparently suffered by furrow-irrigated crops without resorting to a drip irrigation system. However, if the process is indeed triggered by very mild end-of-cycle stresses, then a small supplemental irrigation at the appropriate time may help prevent the decline. Experiments will be continuing with supplemental irrigations scheduled by boll counts on the plants, to see whether the beneficial effects of drip irrigation can be reproduced without use of a drip system.

Table 1. Midday plant water potentials of drip- and furrow-irrigated cotton.

Treatment and Year	Water Potential (bars)		
	Pre-cutout	Mid-cutout	Post-cutout
Furrow-irrigated			
1984	-15.4±0.3	-19.5±0.4	-16.7±0.9
1985	-15.9±0.5	-22.8±0.8	-19.5±0.6
1986	-16.6±1.1	-24.1±0.8	-23.9±0.7
Drip-irrigated			
1984	-14.9±0.9	-15.3±0.3	-17.5±1.7
1985	-15.1±0.3	-20.1±0.9	-17.6±0.4
1986	-14.8±0.7	-16.5±0.6	-15.8±1.0

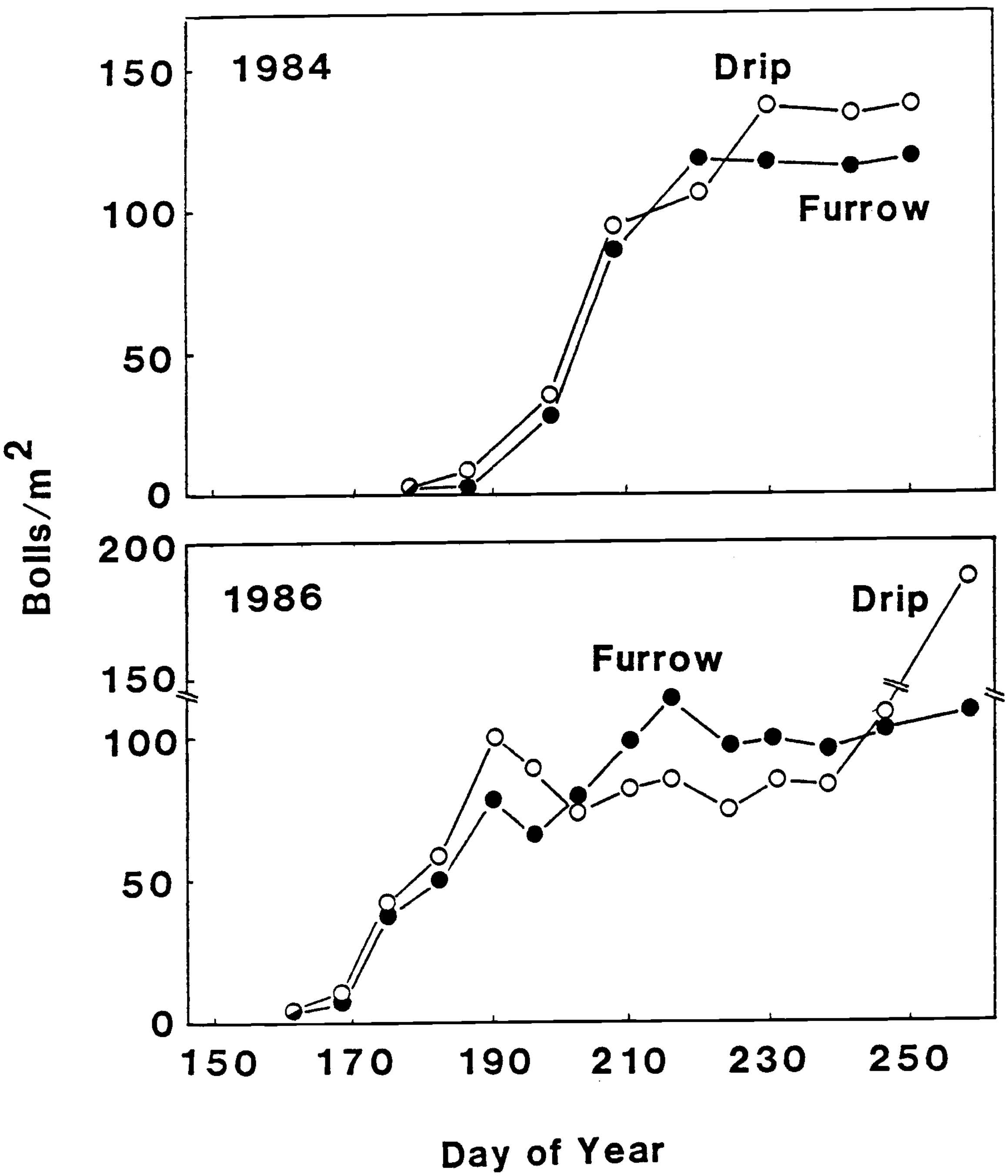
Table 2. Midday transpiration rates of single leaves, 1986.

Treatment	Transpiration rate ($g/dm^2 \cdot hr$)		
	Pre-cutout	Mid-cutout	Post-cutout
Furrow-Irrigated	23.4±1.1	17.3±0.7	16.6±0.7
Drip-Irrigated	25.6±0.4	20.7±0.2	17.1±0.5

Table 3. Plant hydraulic conductances, 1986.

Treatment	Hydraulic Conductance ($g/dm^2 \cdot hr \cdot bar$)		
	Pre-cutout	Mid-cutout	Post-cutout
Furrow-Irrigated	2.28	0.94	2.61
Drip-Irrigated	3.94	3.46	2.23

Figure 1.


1984
Drip
Furrow
1986
Drip
Furrow
150
100
50
0
200
150
100
50
0
Bolls/m2
150
170
190
210
230
250
Day of Year