YIELD POTENTIAL OF COTTON UNDER DRIP IRRIGATION IN SOUTH AFRICA

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Abstract

Regular droughts in southern Africa reduce the available water for irrigation of agricultural crops. Cotton in South Africa is mainly irrigated by centre pivot or other sprinkler type system whose efficiency in water distribution is poor under adverse conditions. The aim of this study was to evaluate the response of cotton to drip irrigation and intensive management practices. Three dripper line positions were compared in combination with two irrigation frequencies. The third factor was method of nitrogen and potassium applications. This factorial trial was conducted annually from 1987 to 1992 on a red clay soil which contained 54% clay and 450 mm m^{-1} total water at field capacity. Excessive vegetative growth was controlled with mepiquat chloride. Irrigation requirements were determined by daily monitoring of the soil water content with a neutron moisture probe.

The means for seed cotton yield varied from 7569 to 8781 kg ha^{-1} over seasons compared to a best commercial yield of 4500 kg ha^{-1}. The daily irrigated plots received 800 to 900 mm water over the growing season and those irrigated at five day intervals, 650 to 700 mm. There were no significant differences in yield with different placings of the dripper lines. Good lateral water movement was obtained and a single dripper line could supply water to two adjacent rows on the soil type used. The cotton roots withdrew water to a depth of 1200 mm. The fertilization practice had no significant effect on yield. However, fertigation with either nitrogen, potassium or phosphorus proved to be easy, accurate and labour saving.

Introduction

Drought in Southern Africa is a regular phenomenon and was experienced as recently as 1992. This emphasises the need for judicious water use, or even supplementary application of water, to enable crop production. To facilitate planning of dryland crop production and for planning the irrigation requirements of crops the Republic of South Africa (RSA) was classified into homogeneous rainfall zones by Welding and Havenga (1974), and recently by Dent *et al.* (1988). The occurrence and severity of droughts in the RSA was studied by Zucchini and Adamson (1984) to provide a means of assessing the risk of droughts in this hemisphere.

Mechanised irrigation systems gained popularity in the RSA during the early eighties, and the demand for, in particular, centre pivot systems reached a peak. Cotton in the RSA is mainly irrigated by means of sprinkler systems, while irrigation by flood, or furrow methods has declined to be only of importance in the Lower Orange river valley and the Griqualand-west cotton areas. Distribution of water by sprinkler equipment is disrupted by wind and evaporation from centre pivot systems is often extremely high. The efficient use of a limited water resource should be of high priority in the RSA. This can be achieved by means of drip irrigation, the advantages of which are well documented (Bucks and Davis, 1986). The main features of drip irrigation are uniform distribution of water, reduced total water applications and energy costs, and improved yields with many crops. However, the purchasing cost of drip irrigation systems is high and excellent management of equipment and crop production procedures is required in order to be financially successful.

The object of this study was to evaluate the response of cotton to intensive drip irrigation and management practices.

Experimental Procedures

Three dripper line positions were compared, namely on top of each crop row (P1), 25 cm beneath each ridge (P2), and one dripper line on top of a wide bed (800 mm) planted with two crop rows (P3). Daily irrigation to maintain the soil moisture regime close to field water capacity was compared with irrigation at five day intervals (Pentade). Conventional top dressing of 150 kg nitrogen and 57 kg potassium ha^{-1} (F1) applied at 6 and 10w after planting, was compared with the same levels by fertigation (F2). These treatment factors were arranged in a factorial trial, replicated four times in a randomised block design. Experimental plots consists of 6 rows of 12 m length. An analyses of variance over seasons was calculated and the least significant differences of Benferroni was used (Miller, 1966).

The trial site contained a red clay soil with 46% clay in the top soil to 54% in the subsoil, and the soil profile held 450 mm m^{-1} water at field capacity. The calcium and phosphorus status of the soil was supplemented by broadcasting 400 kg Ca and 80 kg P ha^{-1} respectively, and incorporating it into ridges, spaced at 1000 mm intervals.

The cotton cultivars Selati and Letaba, bred at this Institute, were planted during October each year from 1987 to 1990 at Rustenburg. Excessive vegetative growth was controlled by weekly applications of mepiquat chloride (Dippenaar *et al.*, 1990). Irrigation requirements were determined by daily monitoring of the soil moisture content with a neutron moisture probe. Total amounts of water applied including rainfall were calculated. Weekly scouting for insect populations determined the relevant insecticide which was applied with a tractor driven mist blower. Vegetative development of the cotton was described by measuring plant height and assessment of the number of branches on ten random plants per plot, at two weekly intervals. Seed cotton was hand picked four times to determine yield, and samples were taken to determine the fibre properties with a high volume instrumentation (HVI) system.

Results and Discussion

Seed cotton yield

Table 1 summarises the main effects and interaction (significantly at P=0.107) of fertilisation and irrigation levels during each season. A combined analyses of variance over the four growing seasons indicated that the yield was significantly lower during 1989/90 which was the result of a devastating hail storm on the 26th December 1989. The growing season was reduced by at least three weeks due to the loss of squares and bolls. The average lint yield for the other three seasons was 2879 kg ha^{-1}. Cotton under sprinkler irrigation yielded at the same trial site 2058 kg ha^{-1}, while under commercial farming condition a lint yield of 1575 kg ha^{-1} is considered as excellent. The two irrigation frequencies did not differ significantly. Differences between dripper line positions was less than 10 kg fibre ha^{-1} and non significant. The conventional application of potassium at planting, and nitrogen as a top dressing not later than 10 weeks after planting, out yielded the fertigation method by 72 kg ha^{-1}. The irrigation levels applied to achieve these lint yields, are summarised in Table 2. The daily irrigated plots received 631 to 866 mm water during the season and those irrigated at intervals of a pentade 465 to 848 mm applied in 19 to 22 irrigations. The latter practices made better use of the prevailing rainfall of 337 to 500 mm.

Vegetative development

Figure 1 demonstrates the rate of plant growth as increase in plant height. Cumulative day degrees (CDD) (Dippenaar and Human, 1992) were used to quantify the progression of the growing season after planting, instead of calender days. The increase in plant height was well described by equation 1.

Height= -308.6 + (1.52179 x CDD) - (0.000294 x CDD2) (1)
(R2adj= 0.9338; SE= 10.7262; df= 27)

A plant height of 1400 mm was reached although a weekly spray program with mepiquat chloride was applied. Rank growth, lodging and poor insect control would have been the result if no growth retardant was used. Plant heights from the 1987/88 season were excluded as insufficient mepiquat was applied to the cultivar Selati which is a tall growing type. The cultivar Letaba which has a more compact growth pattern was used during the other seasons.

Similarly the increase in the number of branches during the season was plotted against CDD and described by equation 2.

Branches= -5.888 + (0.02296 x CDD) - (0.00000506 x CDD2) (2)
(R2adj= 0.9025; SE= 1.6499; df= 25)

The first branch appeared after 323 CDD and increased by one with each 51.5 CDD. Continuous plant growth and increase in the number of sympodia, indicates the expansion of the frame work that carries the potential yield, on condition that insect populations are under control. The growth rate of these two measured parameters were the same and therefore collinear data. These regression curves serve as reference line to identify suboptimal growing situations.

Fibre properties

Fibre tenacity and micronaire for the first and second hand picking are presented in Table 3. Significant differences existed between seasons probably due to the cultivars used and the effect of the hail damage. Differences in fibre tenacity at both pickings, as effected by irrigation frequency or position of the dripper lines, was of no practical importance.

The interaction between dripper line position and irrigation frequency had a significant effect on the micronaire value of the fibre fineness but the order of this change was small (0.13 units).

Conclusion

Cotton responded very well under drip irrigation and yield was 24-65% higher than sprinkler irrigated cotton at the same site. The management inputs required for success were however also high.

On soils with similar lateral water movement characteristics as this clay soil, one dripper line can provide water for two cotton rows, and thus reduce the cost of the irrigation system by 40%. Due to the high water holding capacity of the trial site, irrigation at intervals of a pentade yielded the same as daily irrigated cotton. Fertigation of cotton was slightly inferior to the conventional fertilisation program. However fertigation with either nitrogen, potassium and phosphorus proved to be easy, accurate and labour saving. The affect of the applied treatments on fibre properties was small and over shadowed by seasonal effects.

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Table 1. Fibre yield (kg ha^{-1}) at two levels of irrigation and fertilisation during four growing seasons at Rustenburg, South Africa.

Seasons	Fertilisation				Mean seasons
	F1		F2		
	Irrigation daily	Frequency pentade	Irrigation daily	Frequency pentade	
1987/88	3462	3568	3477	3367	3468 c
1988/89	2646	2651	2602	2486	2596 b
1989/90	1858	1896	1867	1877	1875 a
1990/91	2816	2659	2630	2673	2694 b
Mean	2696	2694	2645	2601	2658
Mean fertilisation	2695 a		2623b		

LSD of Bonferroni (P=0.05) between and within seasons = 233
Interaction seasons x fertilisation x irrigation = 259
CV% = 8.0

(Dippenaar, M.C., Barnard, C. and Pretorius, M.M.: Tobacco and Cotton Research Institute, South Africa)

Table 2. Number of irrigations per seasons and mm water applied.

Season	Number of irrigations		Water applied	
	Daily	Pentade	Daily	Pentade
1987/88	77	22	866	648
1988/89	78	16	632	465
1990/91	93	19	823	568

(Dippenaar, M.C., Barnard, C. and Pretorius, M.M.: Tobacco and Cotton Research Institute, South Africa)

Table 3. Fibre tenacity (g tex^{-1}) and micronaire readings at first and second pickings at different placements of dripper lines and irrigation frequencies.

Dripper position	Irrigation frequency	Fibre tenacity		Micronaire readings	
		1st pick	2nd pick	1st pick	2nd pick
Mean	Daily	21.820	22.510	4.062	4.042
Mean	Pentade	21.712	22.433	3.994	4.074
P1	Mean	21.769	22.569	4.042	4.064
P2	Mean	21.545	22.553	4.025	4.066
P3	Mean	21.984	22.294	4.017	4.044
Mean seasons		21.766	22.472	4.028	4.058
CV%		5.1	4.7	6.3	5.8
LSD (P=0.05) interaction		1.155	ns	0.141	0.421

(Dippenaar, M.C., Barnard, C. and Pretorius, M.M.: Tobacco and Cotton Research Institute, South Africa)

Figure 1. Plant height and branches per plant under drip irrigation.