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# A comparison of drip and furrow irrigated cotton on a cracking clay soil

## 3. Yield and quality of four cultivars

**G.A. Constable and A.S. Hodgson**

NSW Agriculture and Fisheries, Agricultural Research Station, Narrabri, 2390 N.S.W. Australia

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**Summary.** The relative yield potentials of surface (SD) and buried (BD) methods of drip irrigation and furrow irrigation (F) of cotton were compared over four seasons. Drip-irrigated treatments were maintained at a deficit of 45 mm below the fully-irrigated soil water content, while F was irrigated when the deficit reached about 90 mm. Nitrogen fertilizer was applied weekly to drip-irrigated treatments during irrigation over the first half of the season and to F as one application before sowing. Emergence of cotton was slower in a SD system than for BD or F. This delay was associated with slower sorption of water from SD laterals in the furrow to seeds sown in the top of ridges. In two seasons there was heavier yield from SD and BD irrigation than from F; in one season the yields were the same; and in one season there was a small reduction in yield with drip irrigation. Average lint yields for cultivar Deltapine 61 over the four seasons were 1633, 1736 and 1676 kg ha$^{-1}$ for SD, BD and F, respectively. The yield of cultivar Siokra was higher and more stable than Deltapine types under drip irrigation. Drip irrigation delayed maturity by two to nine days, an effect associated with reduced fibre micronaire when compared with F. The relative yield of each treatment was maintained at all positions along the 200 m length of field. Therefore both drip systems must have maintained a consistent output of water and fertilizer over the length of drip laterals. Fibre length and strength were generally not affected by method of irrigation. It was concluded that even though the drip irrigation system had a higher yield potential, the performance of the system did not justify the high economic outlay to grow cotton at this site, especially in cool or wet seasons.

Drip irrigation reduced water use of cotton in California by up to 50% and raised lint yield by up to 670 kg/ha (Wilson et al. 1984) when compared with furrow irrigation. Therefore profit was greatest where pumping costs were high, where soil texture was medium to coarse and where the climate was hot and dry. The main disadvantages were the high cost, the uncertainty of yield increases and the rapid onset of water stress when irrigation was delayed. Recent experience in Arizona also shows improved water use efficiency of drip compared with furrow irrigation (Hofman et al. 1988). Our own experiments suggest a potential improvement in water use efficiency for drip irrigation, mainly through reduced losses from the supply channel and tail drain (Part 2, Hodgson et al. 1990).

Cotton in Australia is grown under furrow irrigation on slowly permeable clay soils with limited slope. Cotton plants therefore experience waterlogging at each irrigation or after heavy rain, decreasing lint yield by about 200 kg ha$^{-1}$ in most seasons (Hodgson 1982; Hearn and Constable 1984; Hodgson and MacLeod 1987). Avoidance of waterlogging by drip irrigation could potentially improve yields.

This paper presents yield, fibre quality and cultivar interactions in experiments comparing two methods of drip irrigation with furrow irrigation over four seasons. Components of yield differences are discussed in relation to all measurements taken from these experiments (Part 1, Constable et al. 1990; Part 2, Hodgson et al. 1990).

## Methods

Details of the experiments are given in Part 1. Three methods of irrigation were arranged in four randomized complete blocks and imposed in each of the sumer cropping seasons of 1983/84, 1984/85, 1985/86 and 1986/87. Plot size was 16 rows × 200 m. The irrigation treatments were: conventional furrow irrigation (F), surface drip irrigation (SD) and buried drip irrigation (BD). Both drip systems were supplied from the same pump and filtration system, with operating pressures, backflushing, chlorination and acidification as recommended by their manufacturers. Details of N fertilizer and irrigation schedules are presented in companion papers (Parts 1 and 2).

*Offprint requests to:* G.A. Constable

### Cultivars

Four cultivars were compared in the last three seasons in sub-plots 4 rows × 20 metres in each main plot. These cultivars were:

Deltapine 61 (DP61). Medium maturity, commercial cultivar before 1985.
Deltapine 90 (DP90). High quality, medium maturity, commercial cultivar since 1985.
Sicot 3. Locally bred line combining frego bract and glabrous leaf for resistance to *Heliothis* (Reid and Thomson 1984).
Siokra. Locally bred cultivar combining okra leaf shape, resistance to bacterial blight and improved fibre quality when compared with Deltapine 61. This cultivar occupied 60% of the Australian cotton area in the 1987/88 season.

### Emergence

Emerged seedlings were counted in the last three seasons in an area of 5 $m^2$ in each main plot, three times per week until emergence was complete. Speed of emergence was calculated from these data as the number of days from sowing to 80% of final percentage emergence (E80) after Anderson (1971).

### Harvest

Yield was measured by machine picking ten two-row × 20 m sub-plots along the rows in each plot. In the last three seasons, the middle four sub-plots contained the cultivars listed above. The first three and last three sub-plots (60 m) were the control cultivar (DP61 in 1983/84 and 1984/85; DP90 in 1985/86 and 1986/87). After weighing the seed cotton, a sample was taken for ginning in a 20-saw gin. Lint yields were obtained from the ginning percentages of these samples. Maturity was measured by hand-picking 1 m of row of the control cultivar in each main plot at approximately ten day intervals between first and last boll opening. The date when 60% of the final yield was pickable was calculated from these data and used as an index of maturity date. Fibre quality was measured on a 30 g sample from each plot in a 'Spinlab' high-volume instrument at the CSIRO Division of Textile Industries. Measurements included 2.5% span length (still measured in non-SI units of inches), 3.2 mm stelometer fibre strength and micronaire value (a measure of fibre fineness).

## Results and discussion

### Emergence

Emergence was strongly influenced by rainfall. In 1983/84 (emergence data not collected) and 1986/87, winter and spring rainfall was sufficient to fully wet the profile and germinate the seed. Consequently, all irrigation treatments emerged at a similar rate (Table 1). In 1984/85, irrigation was necessary before sowing F plots and SD and BD plots were irrigated after sowing. The slow sorption of water from the drip laterals in the furrow to the seeds sown in the tops of the ridges delayed emergence in SD compared with F and BD. In 1985/86, rain two days after sowing ensured uniform emergence in all treatments. The uneven germination with SD in the dry season (1984/85) may have been minimized by having wide beds (2 m) with a lateral on the flat bed-tops, instead of in alternate furrows.

### Yield

Table 2 shows total lint yield of each treatment and a summary of mean yields across seasons, while Table 3 shows the date when 60% of lint was picked – an indica-

**Table 2.** Effect of cultivar and irrigation method on total lint yield of cotton in four seasons. Standard error of difference between means are shown in parentheses

| Season | Lint yield kg ha$^{-1}$ | | | |
|---|---|---|---|---|
| | Cultivar | SD | BD | F |
| 1983/84 | DP61 | 1686 | 1669 | 1620 |
| | | (41) | (41) | (41) |
| 1984/85 | DP61 | 1937 | 1886 | 1877 |
| | DP90 | 2109 | 1996 | 1964 |
| | Sicot 3 | 2047 | 1871 | 1932 |
| | Siokra | 1995 | 1917 | 1846 |
| | | (64) | (65) | (64) |
| 1985/86 | DP61 | 1667 | 2039 | 1765 |
| | DP90 | 1923 | 2092 | 1872 |
| | Sicot 3 | 1654 | 1882 | 1797 |
| | Siokra | 2261 | 2274 | 1952 |
| | | (82) | (82) | (82) |
| 1986/87 | DP61 | 1242 | 1351 | 1440 |
| | DP90 | 1287 | 1327 | 1474 |
| | Sicot 3 | 1152 | 1259 | 1340 |
| | Siokra | 1871 | 1916 | 1932 |
| | | (54) | (54) | (54) |
| 1984/85–86/87 | DP61 | 1615 | 1759 | 1694 |
| | DP90 | 1773 | 1805 | 1770 |
| | Sicot 3 | 1618 | 1671 | 1690 |
| | Siokra | 2042 | 2036 | 1910 |
| 1983/84–86/87 | DP61 | 1633 | 1736 | 1676 |

**Table 1.** Seedling emergence for different irrigation methods in three seasons (SD-surface drip; BD-buried drip; F-furrow irrigation). Standard error of means are shown in parentheses

| Treatment | Emergence (%) | | | Days to 80% of final emergence | | |
|---|---|---|---|---|---|---|
| | 1984/85 | 1985/86 | 1986/87 | 1984/85 | 1985/86 | 1986/87 |
| SD | 73 (4) | 82 (3) | 83 (3) | 17.2 (0.3) | 12.3 (0.5) | 8.5 (0.2) |
| BD | 90 (4) | 77 (3) | 82 (3) | 8.3 (0.2) | 11.7 (0.5) | 8.0 (0.2) |
| F | 77 (4) | 67 (3) | 90 (3) | 9.1 (0.3) | 11.6 (0.5) | 8.0 (0.2) |

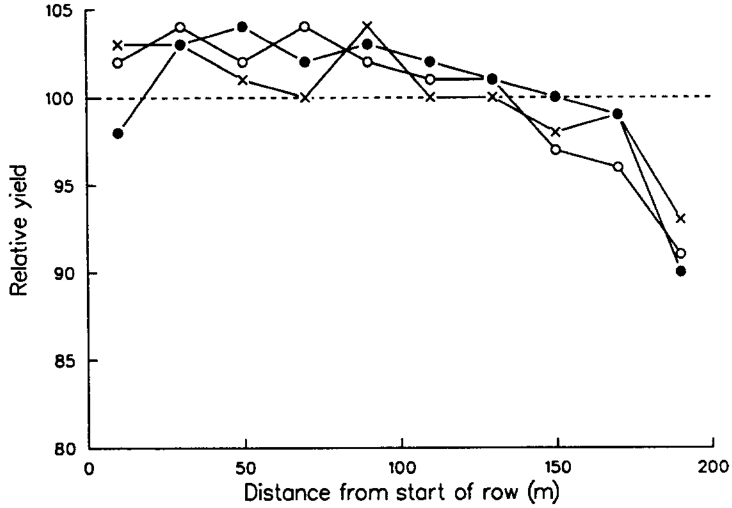


**Fig. 1.** The lack of interaction between irrigation treatment and position along a length of row. Values are lint yield of each sub-plot as a percentage of that treatment mean. Mean of four seasons. Symbols: o – Surface drip; x – Buried drip; • – Furrow

**Table 3.** Effect of irrigation method on crop maturity (days from sowing to 60% of crop harvestable) of cotton in four seasons. Data calculated from regular hand picks of 1 m in each main plot. Standard errors of differences between means are shown in parentheses

| Season | Cultivar | Maturity (days) | | |
|---|---|---|---|---|
| | | SD | BD | F |
| 1983/84 | DP61 | 157.3<br>(2.2) | 162.8<br>(2.2) | 157.1<br>(2.2) |
| 1984/85 | DP61 | 144.8<br>(2.4) | 140.0<br>(3.8) | 140.1<br>(2.4) |
| 1985/86 | DP90 | 154.4<br>(1.8) | 152.0<br>(1.8) | 146.6<br>(1.8) |
| 1986/87 | DP90 | 169.3<br>(3.2) | 173.1<br>(3.2) | 162.5<br>(3.2) |
| Mean | | 156.5 | 157.0 | 151.6 |

**Table 4.** Main effects of cultivar and season and a summary of the relative effects of irrigation method on fibre length, fibre strength and micronaire in each season. Abbreviations (+, 0, −) refer to an increase (+), no effect (0) or decrease (−) in the fibre quality parameter ($P<0.05$) compared with furrow irrigation in the four successive seasons of the experiments

| Effect | | Fibre property | | |
|---|---|---|---|---|
| | | Length inches | Strength g tex$^{-1}$ | Micronaire |
| Cultivar | DP61 | 1.15 | 24.8 | 4.67 |
| | DP90 | 1.13 | 28.0 | 4.45 |
| | Sicot 3 | 1.13 | 24.4 | 4.53 |
| | Siokra | 1.14 | 25.7 | 4.28 |
| Season | 1983/84 | 1.13 | 21.5 | 3.93 |
| | 1984/85 | 1.09 | 25.1 | 4.84 |
| | 1985/86 | 1.13 | 26.2 | 4.53 |
| | 1986/87 | 1.16 | 26.1 | 4.40 |
| Irrigation | SD | 0, 0, +, 0 | 0, 0, −, 0 | +, −, −, − |
| | BD | 0, 0, +, 0 | 0, 0, 0, 0 | +, 0, −, − |

tion of relative maturity in each treatment. The cool temperatures in 1983/84 and 1986/87 (Part 1) were partly responsible for lower yields (Constable et al. 1976). Boll size was measured on the hand pick data: there was no significant difference between irrigation treatments in any season (data not shown).

In 1983/84, SD and BD yielded 3 to 4% more than F. This difference was not statistically significant. The maturity of BD was slightly delayed when compared with SD and F.

In 1984/85, SD yielded 6% more than F ($P<0.01$), while BD yielded 1% more than F. Irrigation treatment differences were the same in all cultivars; DP90 had the heaviest yield. Crop maturity of the SD treatment was slightly delayed when compared with F.

In 1985/86, BD yielded 12% more than F ($P<0.01$), while SD was 2% more than F (n.s.). These differences were dependant on cultivar, with Siokra yielding 16% more under SD and BD than F, whereas Sicot 3 and DP61 had 6 to 8% lower yield in SD than F. Both drip irrigation treatments were later in maturity than F.

In 1986/87, SD yielded 10% ($P<0.01$) and BD yielded 5% ($P<0.05$) less than F. This trend was evident for all cultivars. Siokra had the heaviest yield. There was a delay in maturity with drip irrigation, particularly for BD.

On a three year average, Siokra yielded 7% more under drip irrigation than F; while the four year average with DP61 showed smaller and less consistent differences. The slight delay in maturity (about 5 days – Table 3) with drip irrigation treatments was consistent with delayed nitrogen fertilizer uptake; the consequences of this difference are discussed in Part 1.

The relative yield of each treatment was maintained at all positions in the 200 m length of run in every season (Fig. 1). Therefore the drip laterals maintained uniform water and fertilizer output for their full length. The bottom 20 m of the field averaged 9% less yield in all treatments, an effect that can be attributed to soil differences created by levelling and/or to poor drainage following heavy rain.

*Fibre quality*

The effect of cultivar on fibre quality was consistent and highly significant each season (Table 4). The higher fibre strength of DP90 over other cultivars was a noteable feature and is one of the reasons why the Australian cotton industry rapidly adopted this cultivar in 1985. Season had a large effect on micronaire, in keeping with temperatures experienced during fibre development. Lowest micronaire was obtained in 1983/84, which had the coolest temperatures during boll filling (Part 1). This adverse effect of cool temperature on fibre development is well documented (Gipson and Joham 1968; Hesketh and Low 1968; Wanjura and Barker 1985). Fibre quality was not greatly influenced by irrigation method, but there was a general trend towards a reduction in micronaire with drip irrigation (Table 4), consistent with delayed maturity (Table 3).

## General discussion

Although drip irrigation produced higher yields than furrow irrigation in some seasons, we have shown that well-managed furrow irrigation is capable of high yields in this environment.

Surface and buried drip irrigation had similar yields overall (Table 2). The SD system has the advantage of being portable – allowing crop rotation and more efficient management of weed, disease and fertility problems. The BD system produces better germination, fertilizer placement and mechanical weed control. The choice of a system should be based on the potential magnitude of these factors at each site, as well as cost. Henggeler (1988) arrived at a similar conclusion in Texas.

Slope is an important factor affecting waterlogging (Hodgson 1982) and many local commercial fields have slopes of approximately 1:2000. The slope on this site was 1:812, allowing good surface drainage during furrow irrigation and heavy rain. It is likely that a site with less slope would experience more waterlogging at each furrow irrigation. In that case, drip irrigation might have a more favourable comparison than found in these experiments. Heavy rainfall during the season is not likely to favour either drip or furrow irrigation in the long term, because there is a similar chance of either system having a wetter soil profile than the other at the time of rain.

Drip irrigation may provide conditions more favourable for disease. Humid conditions in the canopy associated with regular irrigation of SD and BD appeared to favour bacterial blight (*Xanthomonas campestris*) infection of bolls in susceptable cultivars (SJ Allen pers. comm.). In addition, BD had a greater incidence of verticillium wilt (*Verticillium albo-atrum*) (SJ Allen pers. comm.), than SD and F because continuous cotton encourages the disease. The rotation with wheat employed in the second season with SD and F, probably reduced soil inoculum levels of the fungus (Evans et al. 1967; El-Zik 1985).

N uptake was generally delayed in SD (Part 1). This factor almost certainly accounts for the delay in maturity (Table 3) and lower micronaire (Table 4) in this treatment and possibly reduced yield of some cultivars in 1985/86. Recommendations for better timing of N fertilizer applied to drip irrigation on these clay soils are presented in Part 1.

Okra leaf strains of cotton have shown some promise in past research, particularly in humid environments (Andries et al. 1969; Thomson 1972; Rao and Weaver 1976; Constable 1977). The combination of open canopy, early maturity and bacterial blight resistance gave the cultivar Siokra a clear superiority at this site. Average yield of Siokra was 8% more than Deltapine 90 under furrow irrigation and 14% more under drip irrigation (Table 2).

There have been few randomized and replicated experiments which compare drip irrigation with furrow irrigation (Wilson et al. 1984). Most reports compare results from drip-irrigated fields with adjacent furrow-irrigated fields. Wilson et al. (1984) reviewed all types of comparisons and concluded that yield increases with drip irrigation are obtained in medium to coarse textured soil and in hot dry climates. We obtained lint yield increases of up to 150 kg $ha^{-1}$ in 1984/85 and 220 (DP90) to 322 kg $ha^{-1}$ (Siokra) in 1985/86 (Table 2) on heavy clay soil. These two seasons were much warmer and drier than average (Part 1). In cooler and wetter seasons, there was negligible difference in yield between methods of irrigation. With a cotton price of \$A2 $kg^{-1}$, a consistent yield advantage of 200 kg $ha^{-1}$ is required to repay an installation cost of \$A4000 $ha^{-1}$ within ten years. Therefore in the long term, the 129 kg $ha^{-1}$ average yield advantage (Table 2 – Siokra) of drip irrigation at this site would not be economic. Sites with variable soil texture, slope, or other factors which render them unsuitable for flood irrigation, may give a profitable return on investment under drip irrigation, depending on land cost, development cost and yield level.

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