S85\994 D √ 8/83 - 6(87) 1987|DAN10L 99

RURAL INDUSTRY RESEARCH FUNDS
FINAL REPORT

Authorised Body: COTTON RESEARCH COUNCIL

Project Number: DAN 10L

Project Title: AN EVALUATION OF DRIP IRRIGATION IN COTTON

Field of Research: Agronomy Field code: 2.2

Organisation: Department of Agriculture, NSW

Address: P O Box K220
Haymarket 2000

Project supervisor: Dr E C Wolfe, Regional Director of Research
Tel: 067-679300
Mr A Seberry, Director Plant Production Research
Tel: 02 -2175063

Research staff: Dr G A Constable and Dr A S Hodgson
Agricultural Research Station
PMB Myall Vale
Narrabri 2390 Tel: 067-931105

Administrative contact: Mr G M Mohr, Research Co-ordinator
Tel: 02 -2175130

Commencement and completion dates: August 1983, June 1987

OBJECTIVES

* To make a direct and impartial yield comparison between two types of drip irrigation and standard furrow irrigation. This study should determine whether drip irrigation is a viable alternative to traditional methods.

* To use a drip irrigation facility as a research tool to study waterlogging, nutrient uptake, water relations, physiology of fruiting and root distribution.

* To determine new cultivar suitability for drip irrigation.

BUDGET SUMMARY

	1983/84	1984/85	1985/86	1986/87	
Salaries	3500	3850	3850	1840	
Operating	2000	2500	2500	1200	
Capital	20600	1950	1300	-	
Total	26100	8300	7650	3040	45090

SUMMARY OF RESULTS

Surface (SD) and buried (BD) methods of drip irrigation were compared with furrow irrigation (F) over four seasons on a cracking grey clay soil. Drip irrigated treatments were watered to maintain a deficit of 45 mm; while F was watered on a deficit of 90 mm. Nitrogen fertilizer was applied weekly to drip irrigated treatments during watering over the first half of the season; and to F as one application before sowing.

Emergence was slower for seeds sown in a SD system than for BD or F. This delay was associated with slower sorption of water from drip laterals located in the furrow to seeds sown in the top of ridges.

In two hot seasons there was heavier yield from SD and BD irrigation than from F; in one wet season the yields were the same; and in another season there was a slight reduction in yield with drip irrigation. Average lint yields for cultivar Deltapine 61 over the four seasons were: 1633, 1736 and 1676 kg/ha for SD, BD and F, respectively. The cultivar Siokra had more stable performance under drip irrigation than Deltapine types. Both types of drip laterals were capable of maintaining a consistent output of water and fertilizer over the 200 m long field. Drip irrigation generally delayed maturity, which was associated with delayed nitrogen uptake and reduced fibre micronaire when compared to F. Fibre length and strength were generally not affected by method of irrigation.

It was concluded that the performance of drip irrigation did not justify the high economic outlay to grow cotton on this soil type, especially in cool or wet seasons.

ACHIEVEMENT OF AIMS

All objectives were achieved. Good results were obtained on the relative yield potential of drip and furrow irrigation at this site. Recommendations can be made for a range of circumstances regarding whether drip irrigation would be economic.

The drip irrigation facility was a valuable research tool. We have used the experiment for a number of projects including waterlogging, nitrogen uptake, trace element uptake, mapping of fruit initiation and survival, and root distribution studies.

The locally bred cultivar 'Siokra' was better adapted to drip irrigation than Deltapine types. This difference was due to disease resistance and to more open canopy growth characteristics.

DIFFICULTIES

The major difficulty with this type of experiment is the inability to test the technology rapidly on a range of soil types. The approach taken was to establish principles at one central location, then to extrapolate these principles to other situations.

In common with commercial drip irrigators, we occasionally had difficulty obtaining spare parts from distributors. This aspect highlights one of the problems with drip irrigation: with the necessity to irrigate in small amounts frequently, breakdowns can have catastrophic consequences. If spares take more than three days to arrive, the crop can experience water stress before repairs are done.

RECOMMENDATIONS FOR FUTURE RESEARCH

The only issue not explored in depth in our research was irrigation frequency. If drip irrigation was more economic, there could be some value in examining different irrigation frequencies, particularly during early growth. This type of experiment could be done in small plots, rather than the 200m x 16 row plots in this experiment.

APPLICATION OF RESULTS TO INDUSTRY

The most positive information to come from this experiment is the timing of N fertilizer uptake in relation to crop growth stage. This knowledge allows us to accurately recommend N fertilizer application strategies in order to obtain maximum benefit from the fertilizer. These recommendations will benefit cotton grown under all types of irrigation management.

We have the intensive data to allow us to recommend that drip irrigation is not economic on grey clays developed for flood irrigation. For new country where drip irrigation may be economic, we have established some management principles, particularly for nitrogen, which should maximise crop performance. The practice of applying nitrogen through boll filling is inefficient.

LIST OF PUBLICATIONS

Extension. Preliminary results of these experiments were presented at the last two ACGRA research conferences. An Agfact on drip irrigation of cotton is being prepared in conjunction with the Special Agronomist (Irrigation).

Research. Three scientific papers are being prepared for submission to *Irrigation Science*.

DETAILED REPORT

INTRODUCTION

Nir (1982) reviewed the potential of drip (trickle) irrigation and noted that: soil water can be maintained at a constant, optimum level in the root zone; there are minimum losses of water from deep percolation, evaporation and runoff; water application is uniform even with variable slope and soil texture; problems with salinity of soil or water are minimised; and the system facilitates the automation of water and fertilizer application. Drip irrigation has gained wide acceptance for irrigating orchards, vineyards and vegetable crops, particularly where water is expensive, scarce or of marginal quality (Howell et al., 1980). Drip irrigation cut water use by up to 50% and raised lint yield by up to 670 kg/ha in California, (Wilson et al., 1984). Returns were 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.

More than 90% of cotton in Australia is grown under furrow irrigation on slowly permeable clay soils. Under this system, cotton plants experience waterlogging at each irrigation or heavy rain, which decreases lint yield by at least 220 kg/ha in most seasons (Hodgson 1982; Hearn and Constable 1984). Avoidance of waterlogging by an alternative irrigation method such as drip, could therefore potentially improve yields. Several other factors of cotton production in Australia do not favour drip irrigation: water is relatively cheap (although sometimes scarce); the climate can be mild and wet; and there are few problems with salinity of soils or water.

In 1982, low water supplies and high cotton prices prompted interest in drip irrigation in Australia; and two commercial blocks were established. Despite claims of heavy yields under drip irrigation, interest has since waned because of better water supplies, fluctuating cotton prices and the high cost of installation ($4000/ha). Impartial, replicated experiments comparing drip with the standard furrow system were required to accurately determine the costs and advantages of drip irrigation on cotton and to establish optimum management practices.

METHODS

The climate at this locality is semi-arid, but variable. Table 1 summarises rainfall and temperature for the four seasons of this project. The most noteable features were the wet, cool season in 1983-84 and the dry, hot seasons in 1984-85 and 1985-86.

Standard soil preparation and crop agronomy were used where possible within the constraints of the experimental treatments. Trifluralin herbicide was incorporated before sowing in October each season on 1 m rowspacing and a density of 100,000 plants/ha was established. The crops were sprayed by air for insect pests as required.

Three methods of irrigation were arranged in four randomised complete blocks and imposed in each of the summer crop seasons 1983-84, 1984-85, 1985-86 and 1986-87. Plot size was 16 rows x 200 m. The irrigation treatments were:

Conventional furrow irrigation (F). One 50 mm diameter siphon was run per two furrows until the full length of the field had been watered.

Surface drip irrigation (SD). Drip laterals (Netafim 'Gadash' or Humes 'Drip-In') were laid in every second furrow after sowing each season. Emitter spacing was 1 m. This system was operated at a pressure of 172 kPa, providing 1.4 mm/hour.

Buried drip irrigation (BD). Drip laterals (Hardies 'Bi-Wall') were laid at 0.2 m depth under every crop row in September 1983; and remained in place permanently. Emitter spacing was 0.3 m and this system was operated at a pressure of 83 kPa, providing 1.7 mm/hour.

Surface drip irrigation is portable, since the lines can be rolled up at the end of one season and moved elsewhere in the following season. This enables crop rotation in cotton fields, a practice which can improve soil stucture and fertility. We made use of this ability by sowing wheat after cotton in SD and F treatments in the first season. In the second season, these treatments were located in an adjacent field, which had been fallowed after wheat. The BD treatment remained at the original site and was analysed separately in that season (1984-85). In the third and fourth seasons, SD and F treatments returned to the original plots.

Nitrogen fertilizer scheduling.

Total N fertilizer rates for each treatment in each season followed optimum rates determined in previous experiments (Constable and Rochester 1988). Nitrogen fertilizer rates reflected the crop history: in the first three seasons SD and F were sown into fallow soil; in the last three seasons BD was sown after the proceding cotton crop into permanent hills. The total rates for each season were:

Treatment	1983/84	1984/85	1985/86	1986/87
F	91	87	89	150
SD	93	82	89	152
BD	93	143	148	151

In treatment F, all N was applied as anhydrous ammonia 0.2 m below each row, one to two months before sowing. For the drip irrigation treatments, N was applied in the irrigation water with a hydraulic pump (T.M.B.) as urea or a urea/ammonium nitrate solution.

Irrigation scheduling

The optimum irrigation strategies established for this location were followed; using neutron measurements from two access tubes placed in each plot. Treatment F was irrigated before planting when necessary, and subsequent irrigations were scheduled to coincide with 50% (or 90 mm) of available water depletion. Treatments SD and BD were watered after sowing if necessary to initiate germination and thereafter maintained at a deficit of 45 mm. A summary of total irrigation amounts to each treatment is shown in Table 2.

Cultivars

Four cultivars were compared in all but the first season in sub-plots 4 rows x 20 metres in each main plot. These cultivars were: Deltapine 61, Deltapine 90, Sicot 3 and Siokra.

Root sampling

Soil cores were sampled to a depth of 120cm in one season. The roots from these cores were washed out and their length measured.

Harvest

Yield was measured by mechanical harvest of ten two-row x 20 m sub-plots along the field. After weighing the seed cotton, a sample was taken for ginning in a 20-saw gin. Lint yields were obtained from ginning percentages calculated from these data.

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 inches), 3.2 mm stelometer fibre strength and micronaire.

RESULTS AND DISCUSSION

Emergence

Emergence was strongly influenced by rainfall. In 1983-84 and 1986-87, winter and spring rainfall was sufficient to fully wet the profile (Table 1) and germinate the seed. Consequently, all irrigation treatments emerged at a similar rate (Table 3). In 1984-85, irrigation was necessary before sowing F plots and water was applied to SD and BD plots after sowing. The slow sorption of water from the drip laterals in the furrow to the seeds delayed emergence in SD compared to F and BD. In 1985-86, rain two days after sowing ensured uniform emergence in all treatments.

The uneven germination in the dry season (1984-85) may have been minimised by having wide beds (2 m) with a lateral on the flat bed-tops, instead of in furrows. In this way, sorption of water could have been improved.

N uptake

Total N uptake for each treatment ranged from 100 kg/ha in 1983/84, to 160 kg/ha in 1984/85. Maximum rate of N uptake occurred between 900 and 1000 day degrees from sowing (about 3 kg N/ha/day) although actual values varied due to fluctuating temperature, solar radiation or waterlogging. Based on these values, fertilizer recovery was similar for all treatments, except in 1985/86 when SD had a greater N uptake than F, even with the same amount of N fertilizer applied.

The pattern of N uptake for each treatment is shown in Figure 1. There was always some part of the early season when either SD and BD (or both) were delayed in N fertilizer uptake. This delay could be attributed to different placement (SD - in every second furrow), or timing (SD and BD - as late as boll filling). The firm conclusion is that N uptake is restricted during boll filling. A similar hypothesis was proposed by Crowther in 1924.

Root distribution

Figure 2 shows the distribution of roots with depth for each treatment. BD had more surface roots - in keeping with good soil condition (minimum tillage) and ideal N fertilizer placement. F had the most roots at depth - in keeping with longer irrigation intervals, where moisture had to be extracted from deeper in the profile.

Yield

Table 4 shows total lint yield of each treatment and a summary of mean yields across seasons. The low yields in 1983-84 and 1986-87 were associated with cool temperatures (Table 1), which are unfavourable for rapid boll setting.

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

In 1984-85, SD yielded 6% more than F (P<.01), while BD was 1% more than F. These differences were evident in all cultivars, where DP90 had the heaviest yield. There were only small differences in maturity, with SD being slightly delayed in comparison with F.

In 1985-86, BD yielded 12% more than F (P<.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. Drip irrigation clearly delayed maturity, especially in SD.

In 1986-87, SD yielded 10% (P<.01) and BD yielded 5% (P<.05) less than F. This trend was evident in all cultivars, where Siokra had the heaviest yield. There was a delay in maturity with drip irrigation, particularly for BD.

On a three year average, Siokra under drip irrigation yielded 7% more than F; while the four year average with DP61 showed smaller and less consistent differences. The leaf shape of Siokra apparantly enabled greater light penetration through the heavy leaf canopies in drip irrigated treatments. The delayed maturity with drip irrigation treatments in most seasons was consistent with delayed nitrogen fertilizer uptake.

The drip laterals appeared to maintain uniform water and fertilizer output for their full 200 m length because the relative yield of each treatment was maintained at all positions in the 200 m length of run in every season. The bottom 20 m of the field averaged 9% less yield and can be attributed to inherant 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 5). 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 (Table 1). This adverse effect of cool temperature on fibre development is well documented.

Fibre quality was not greatly influenced by irrigation method, but there was a general trend towards a reduction in micronaire with drip irrigation - consistent with delayed maturity in all but the first season.

GENERAL DISCUSSION

Drainage, disease incidence and N uptake patterns were the main factors which affected the relative performance of these irrigation treatments. The slope on this site was 1:812, generally allowing good drainage of F irrigation and after heavy rain. In 1986/87, F was affected the most by waterlogging from 80 mm of rain which fell after the first irrigation. Despite this fact, F had 5 to 10% greater yield than SD and BD (Table 4) in that season.

There was a greater incidence of Bacterial Blight in SD and BD in the two seasons when this disease was assessed. These treatments had taller leafier canopies which appeared to favour the disease. In addition, BD had a greater incidence of Verticillium Wilt than SD and F because of a different crop rotation.

N uptake was generally delayed in SD (Figure 1). This factor accounts for the delay in maturity and lower micronaire (Table 5) in this treatment and may have limited yield to some degree. N fertilizer application to drip irrigation should include about 30% before sowing, with the rest applied before the end of December. This schedule should avoid delayed uptake at early flowering, as well as late uptake during boll opening. There was no indication that higher N rates were required for drip irrigation.

There have been few randomised and replicated experiments such as ours which compare drip irrigation with furrow irrigation. Most reports compare results from drip irrigated fields with adjacent furrow irrigated fields. Soil type and crop history may be different in these situations, so comparisons may not be valid. Wilson et al., (1984) reviewed both types of comparisons and concluded that yield increases with drip irrigation are obtained in medium to coarse textured soil and in hot dry climates. This is consistent with our results, since we obtained lint yield increases even on heavy clay soil of up to 150 kg/ha in 1984-85 and 220 (DP90) to 322 (Siokra) kg/ha in 1985-86 (Table 4). These seasons were much warmer and drier than average (Table 1). In cooler and wetter seasons, there was negligible difference in yield between methods of irrigation. The yield advantage of drip irrigation would not repay the installation cost of S4000/ha within ten years, even with high lint prices.

REFERENCES CITED

Constable, G.A. and Rochester, I.J. (1988), N application to cotton on clay soil: timing and soil testing. *Agron.J.* , in press.

Hearn, A.B. and Constable, G.A. (1984). Irrigation for crops in a sub- humid environment VII. Evaluation of irrigation strategies for cotton. *Irrig. Sci. 5*, 75-94.

Hodgson, A.S. (1982). The effects of duration, timing and chemical amelioration of short-term waterlogging during furrow irrigation of cotton in a cracking grey clay. *Aust. J. Agric. Res. 33*, 1019-1028.

Howell, T.A., Bucks, D.A. and Chesness, J.L. (1981). Advances in trickle irrigation. In Irrigation, challenges of the 80's. St. Joseph, Michigan; American Society of Agricultural Engineers p69-94.

Nir, D. (1982). Drip irrigation. In CRC Handbook of irrigation technology. Volume 1(Edited by Finkel, H.J.) Boca Raton, Florida; CRC Press p247-298.

Wilson, P., Ayer, H. and Snider, G. (1984) Drip irrigation for cotton. Implications for farm profits. *Agricultural Economic Report, Economic Research Service, US Department of Agriculture* No. AER-517.

Table 1. Meteorological data recorded at Narrabri Agricultural Research Station in the four seasons compared with long term means at the same site. Day degrees are a heat unit sum with a base of 12°C.

Season	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
				Day degrees per month					
1983/84	81	160	223	260	364	342	346	326	207
1984/85	89	115	230	307	404	464	389	372	225
1985/86	88	138	212	305	384	399	406	406	272
1986/87	88	161	187	305	369	455	413	328	244
26 year mean	100	149	223	308	403	430	390	355	228
				Rainfall per month (mm)					
1983/84	53	45	93	90	48	219	120	27	61
1984/85	12	30	54	55	19	18	59	19	21
1985/86	83	18	58	27	71	64	14	0	25
1986/87	27	92	47	38	44	120	24	60	1
26 year mean	38	38	51	58	55	104	57	50	29

Table 2. Summary of water application to each treatment.

Irrigation Method	Season	Irrigation mm	Effective rain mm	Total mm
Surface drip	1983/84	122	448	570
	1984/85	497	123	620
	1985/86	616	114	730
	1986/87	507	158	665
Buried drip	1983/84	149	448	597
	1984/85	524	123	647
	1985/86	585	114	699
	1986/87	497	158	665
Furrow	1983/84	115	448	563
	1984/85	598	123	721
	1985/86	662	114	776
	1986/87	n.a.	158	n.a.

Table 3. Seedling emergence in three seasons. Standard error of means are shown in parentheses.

Treatment	Emergence (%)			Speed of emergence (days)		
	1984/85	1985/86	1986/87	1984/85	1985/86	1986/87
F	77(4)	67(3)	90(3)	9.1(.3)	11.6(.5)	8.0(.2)
SD	73(4)	82(3)	83(3)	17.2(.3)	12.3(.5)	8.5(.2)
BD	90(4)	77(3)	82(3)	8.3(.2)	11.7(.5)	8.0(.2)

Table 4. 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.

		Irrigation method		
Season	Cultivar	SD	BD	F
			kg/ha	
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 to 86-87				
	DP61	1615	1759	1694
	DP90	1773	1805	1770
	Sicot 3	1618	1671	1690
	Siokra	2042	2036	1910
1983-84 to 86-87				
	DP61	1633	1736	1676

Table 5. 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 (+, o, -) refer to an increase (+), no effect (o) or decrease (-) in the fibre quality parameter ($P<.05$) compared to furrow irrigation in the four successive seasons of the experiment.

Effect		Length	Strength	Micronaire
		inches	g/tex	
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,-,-

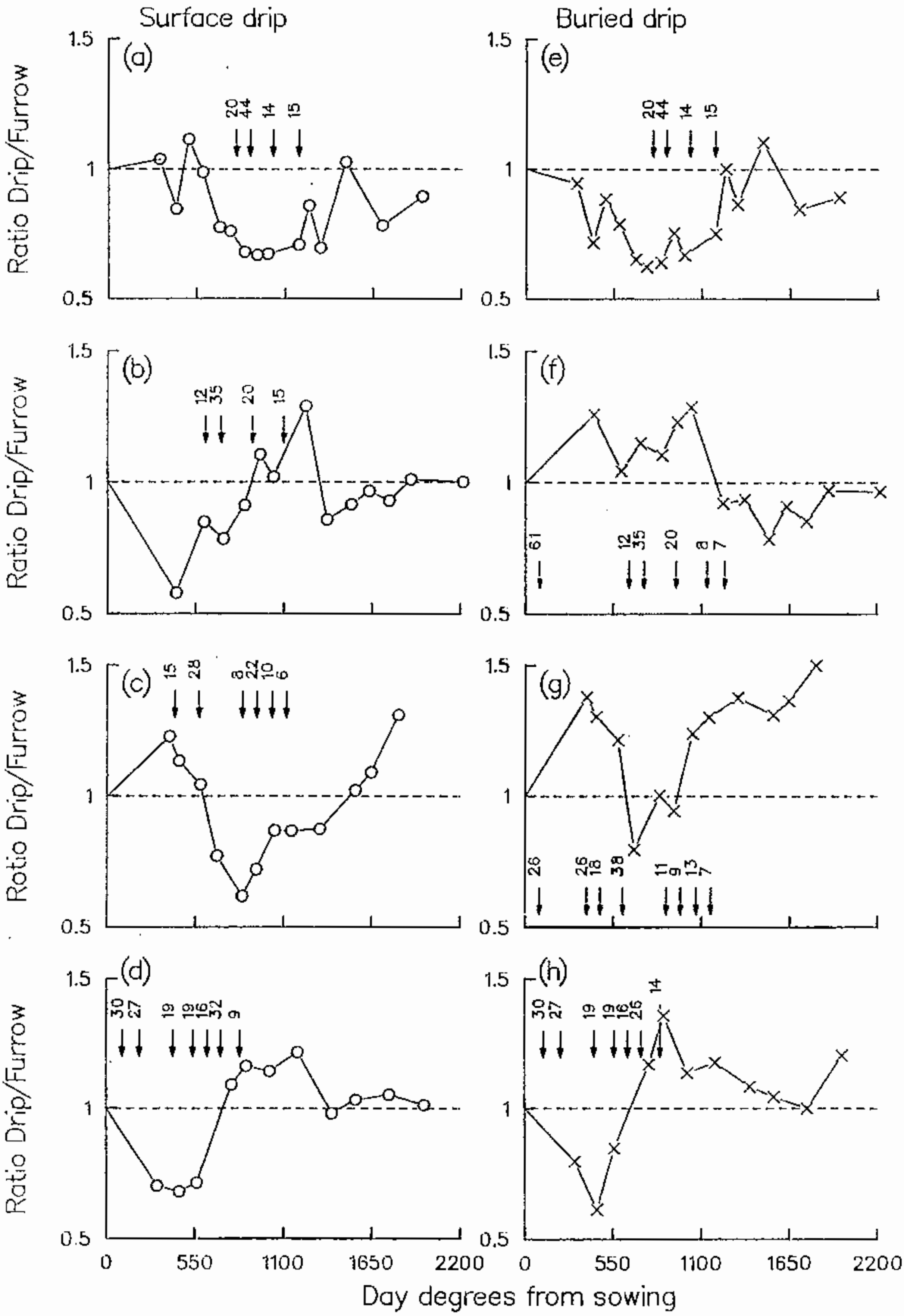

FIGURE 1: The relative pattern of N uptake for each drip treatment in 1983/84 (a & e); 1984/85 (b & f); 1985/86 (c & g) and 1986/87 (d & h).

Each plot is the ratio of drip to furrow N uptake in kg/ha thoughout each season.

Arrows denote timing and weekly totals of N fertiliser application in kg/ha.

FIGURE 2: Root length density profiles for furrow irrigation (F), surface drip irrigation (SD) and buried drip irrigation in the 1986/87 season.