



Subsurface drip superior to sprinkler & furrow - again!

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in a nutshell

- Sprinkler, subsurface drip and furrow irrigated maize were compared in 2005–06 at the community farm at Coleambally – a repeat of 2004–05 comparisons
- Once again, subsurface drip (11.2 t/ha) out-yielded sprinkler (9.7 t/ha) and furrow (8.6 t/ha) irrigated maize in terms of yield by 16 and 31%, respectively
- Subsurface drip again had higher net irrigation water productivity (2.0 t/ML compared with 1.7–1.8 t/ML for sprinkler and drip) and higher total water productivity (1.3 t/ML compared with 1.1 t/ML)
- Financial analysis is needed to determine whether the increased yield and irrigation water productivity with subsurface drip is financially beneficial to farmers

The performance of maize grown with sprinkler, subsurface drip and furrow irrigation was compared in 2005–06 on the Water Use Efficiency block at the community farm at Coleambally.

The work was essentially a repeat of the 2004–05 maize trial reported in the IREC Farmers' Newsletter No. 170, 2005, where details of the site and irrigation systems are also provided. The main differences in 2005–06 were different seasonal conditions (crop established on rain, very hot weather during silking and grain filling), and some changes in irrigation system and nitrogen management to try to improve crop performance in all three irrigation systems.

Crop management

Maize (Pioneer® 33T39; CRM 113) was sown on 18 October 2005 and harvested between 30 March and 3 April 2006. Crop management is summarised in Table 1.

A total of 276 kg N/ha was applied at sowing, and this was topped up to 358–378 kg N/ha with urea applied through each irrigation system. Thus the crop is unlikely to have suffered from nitrogen deficiency, in comparison with 2004–05 when the total application was only 242–262 kg N/ha.

Table 1: 2005–06 crop management of the trial site

1 June 2005	Mulched stubble from 2004–05 maize
8 September 2005	Sprayed with Roundup® Max @ 1L/ha & Surpass® @ 1 L/ha
22 September 2005	Maize stubble burnt
13 October 2005	Fertiliser: 535 kg/ha of urea + 268 kg/ha Granulock 10Z® banded at 15 cm under the plant lines – total application 276 kg N/ha, 56 kg P/ha, 9 kg S/ha, and 3 kg Zn/ha
17 October 2005	Beds rotary hoed, furrows cleaned out and beds shaped
17 October 2005	Primextra® @ 2 L/ha and Dual® @ 2 L/ha incorporated with the bed shaper
18 October 2005	Pioneer® 33T39 @ 86,000 seeds/ha @ 5 cm with 2 kg/ha of Counter®
24 November 2005	First irrigation for all systems
28 November 2005	Aerial application of Cadence® @ 400 g/ha and wetting agent BS1000 @ 0.1%
December - January	Water run urea applied in all systems: 90, 82 & 102 kg N/ha for sprinkler, drip and furrow
18 January 2006	Hail storm strafed the crop, uniform damage over the entire crop
09 February 2006	Final irrigation for all systems
30 March 2006 to 3 April 2006	Header harvest



Irrigation management

The crop was sown into moist soil, and 18 mm of rain fell over the first three days after sowing, followed by another 56 mm of well-distributed rain between 24 October and 9 November. Therefore irrigation in all three systems did not commence until 24 November.

Irrigation of the sprinkler and furrow systems was scheduled using the MaizeMan software, whenever simulated plant available water fell below 50%. Irrigation of the drip was scheduled using tensiometers, as MaizeMan cannot simulate subsurface drip irrigation.

Sprinkler irrigation

There were 30 sprinkler passes during the season. Generally, a 36 hour pass applying 20–25 mm was followed immediately by a 24 hour pass applying 15–20 mm. This was a change from the management in the first year, when there were usually three consecutive 24 hour passes. We changed to a slower first pass to increase the application rate to try to push water deeper into the beds. Net irrigation was 5.6 ML/ha, 0.5 ML/ha less than in the previous season due to the facts that the soil profile was wetter in the sprinkler block at the time of sowing in 2005–06, in-season rainfall was higher, and crop duration was shorter by 32 days.

Drip irrigation

Drip irrigations commenced with 10-hour applications of approximately 11 mm. In late December, irrigation management was changed to pulse irrigation. Two or three hour irrigations were scheduled four times per day (from 5 am to 8 pm) depending on soil water content and crop stage. Tensiometers at 0.1, 0.2 and 0.4 m depth placed between the centre of the bed and plant line (0.1 m from the plant line) were used to guide irrigation scheduling, with the aim of keeping the soil in the top 0.4 m around field capacity (ie, between -10 and -40 kPa). A total of 5.5 ML/ha was applied to the crop in the subsurface drip block between sowing and physiological maturity. Net irrigation was about 0.5 ML/ha higher than in the previous season, despite the higher rainfall and shorter crop duration in 2005–06, because we were trying to avoid soil water deficit right to the bottom of the block, as emitter flow rate declined with distance down the beds. Between maturity and harvest, an additional 0.8 ML/ha was accidentally applied to the drip

due to failure of a solenoid valve when an adjacent field was being irrigated.

Furrow (flood) irrigation

There were 12 furrow irrigations, applying an average of 48 mm per irrigation, and a total of 5.7 ML/ha for the season. As in the previous year, irrigations generally took about seven hours, and the drainage outlet was shut overnight to allow the water to back up the furrows about 50 m to try to hold the water in the furrows and increase subbing. Net irrigation was about 0.6 ML/ha less than in 2004–05 due to the higher rainfall and shorter crop duration.

Soil water

At the time of sowing, soil water content in the top 0.9 m was similar in all three irrigation blocks in both the beds and furrows (Figure 1). The soil was drier at harvest than at sowing in all three blocks, by an average of 0.8–1.2 ML/ha (Figure 1), but the beds in the drip block at harvest were much wetter than in the sprinkler and furrow blocks due to the accidental irrigation after maturity.

Crop establishment, growth & development

Crop establishment was excellent and very uniform in all three blocks (Figures 2 and 3), aided by timely rains after sowing. The plant population averaged 84,000 plants per hectare. The very even establishment across all three blocks was in contrast with the previous year, when establishment was much less uniform on the furrow and drip irrigated blocks due to variable subbing.

The crop grew well in all treatments and showed no indication of water or nitrogen stress, despite consistently high temperatures from silking to end of grain filling. The crop reached silking around 2 January and physiological maturity around 12 February.

Crop disease was almost completely absent in all treatments, with only a small number of cobs affected by boil smut and Fusarium ear rot.

A severe hail storm hit the site on 18 January 2006. Damage was even across the whole paddock and affected the top half of the canopy, with many leaves shredded (strafed) and some loss of leaf area (Figure 4).

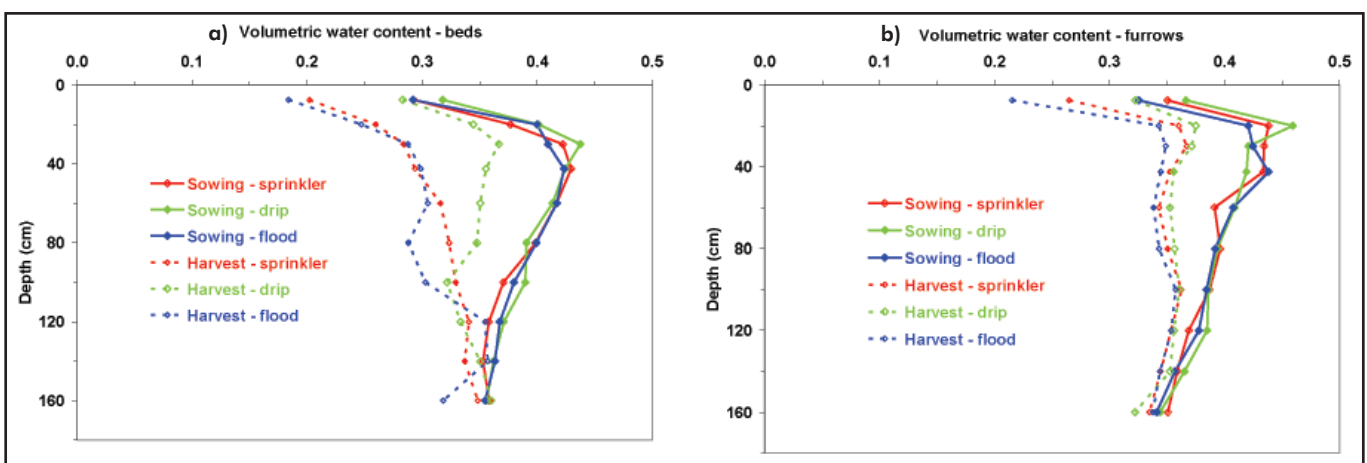


Figure 1: Soil water content at the times of sowing and harvest under the beds (a) and furrows (b) in the three irrigation systems. A volumetric water content of 0.2 means 20% of the soil volume is water, 0.3 means 30% is water and so on.



About two weeks after the hail storm, the furrow and drip irrigated blocks experienced a severe mite infestation, which hastened senescence in comparison with the sprinkler block, where the mite infestation was 1–2 weeks later. It is likely that frequent sprinkler irrigations kept washing the mites off the leaves and drowned them.

Mean total above ground biomass was similar in all irrigation systems (22 t/ha). Total biomass was similar in the drip in 2004–05, but lower in the furrow (19 t/ha) and sprinkler (21 t/ha).

Grain yield

As in 2004–05, grain yields were highest in the drip, and least with furrow irrigation, however the differences were much greater in 2004–05, probably because of improved management of the drip and sprinkler systems in 2005–06. Average grain yield (14% moisture) was 11.2 t/ha in the drip, 31% higher than with furrow irrigation (8.6 t/ha), and 16% higher than yield of the sprinkler block (9.7 t/ha, which includes the unplanted area for wheel tracks,

or approximately 10.2 t/ha excluding the wheel pads). Grain yields in all systems were lower in 2005–06 than the previous year, particularly in the furrow-irrigated block. This was probably largely due to the very hot weather from silking to maturity in 2005–06. The duration of this growth period was about 57 days in 2004–05 compared with only 43 days in 2005–06.

Yield variability was again high in all systems, with yields at a spatial scale of 4 beds x 2.5 m ranging from less than 7.5 t/ha to more than 14 t/ha (Figure 5). The furrow block had the highest variability, and the drip the least. Yield was less variable in the drip and sprinkler blocks when compared with the 2004–05 crop. In 2004–05, yield declined towards the bottom end of the drip-irrigated beds, which was associated with lower emitter flow rates with distance from the supply end. In 2005–06 we kept the soil much wetter to try to avoid water deficit stress towards the bottom end. Conversely, in 2004–05 yield of the sprinkler system increased from the top (irrigation start) to bottom end. We suspect that applying a higher application rate in



Figure 2: Crop establishment and Chris O'Neill taking neutron counts for determining soil water content

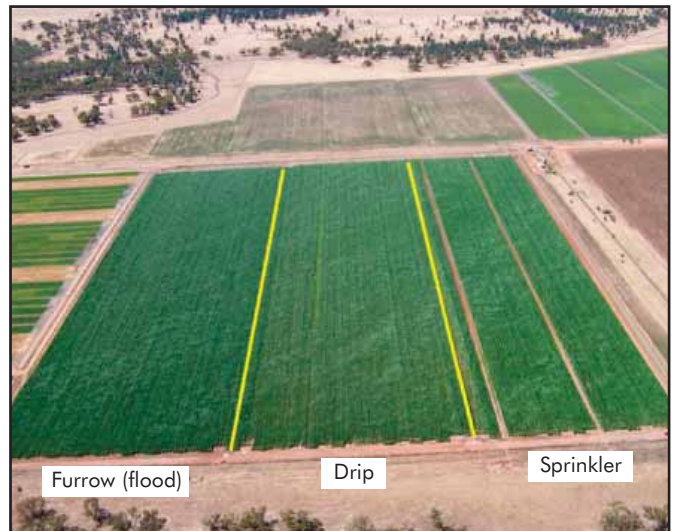


Figure 3: Aerial view of the 3 irrigation blocks on 19 Dec 2005



Figure 4: Damaged leaves and severed plant material on the ground after the 18 January hail storm

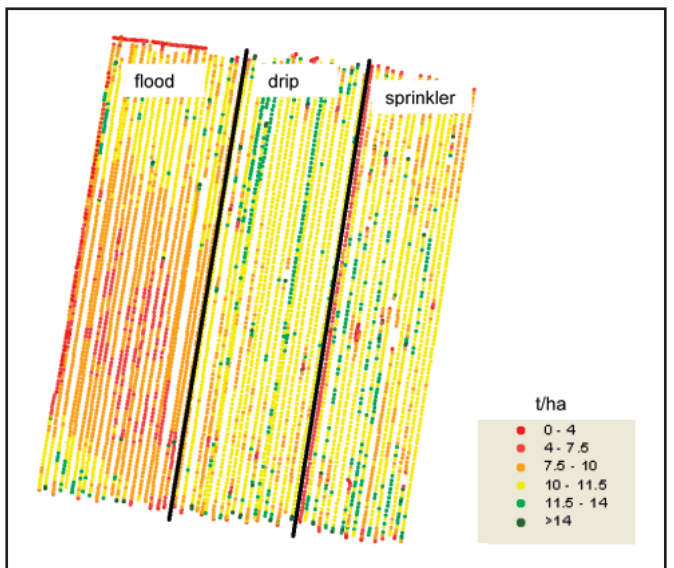


Figure 5: Yield map for maize grown using the three irrigation systems in 2005–06



2005–06 (20–25 mm) with the first irrigation reduced water deficit stress at the top end by pushing more water into the soil and reducing the proportion lost by non-productive soil evaporation. Similar management of the furrow block in both years led to a similar yield pattern, with yields highest at the top and bottom, probably due to longer irrigation contact time at the supply end, and backing up of the drainage water at the bottom end. We also suspect that higher nitrogen rates in all three blocks eliminated nitrogen deficiency as a potential source of yield variability, in comparison with the 2004–05 season where nitrogen may have been limiting.

Water productivity

As in 2004–05, the drip system produced the highest *net irrigation water productivity* (2.0 t/ML), due to higher yield, and despite higher *net irrigation* compared with the furrow block (Table 2). *Net irrigation water productivity* of the sprinkler and furrow irrigated blocks was similar to values in the previous season, but was lower in the drip in 2005–06 when compared with the 2004–05 result due to lower yield and higher irrigation application in 2005–06.

Total water productivity was much lower (by up to 26%) than in 2004–05 due to the lower yields in all treatments, and probably also due to higher soil evaporation and transpiration due to the more generous irrigation management during 2005–06. As in 2004–05, *total water productivity* of the sprinkler and furrow blocks was similar (1.1 t/ML), while it was about 11% higher in the drip (1.3 t/ML).

General discussion

Subsurface drip irrigated maize outperformed sprinkler and furrow irrigated maize in two consecutive seasons in terms of yield, *irrigation water productivity* and *total water productivity*.

The lower yields on the furrow system occurred despite irrigation every 5–6 days during the major part of the growing season each year (total 12–13 irrigations). However subbing into the beds was generally poor, and each year yields were poorer towards the middle of the block where the irrigation contact time was least.

The yield advantage of drip over furrow was greater in 2005–06 (31%) than 2004–05 (16%), which may be due to improved management of the subsurface drip system using pulse irrigation (four irrigations per day) and keeping the root zone moist at all times, in the second year.

In both years the yield with sprinkler irrigation was also higher than with flood, by 4% in 2004–05 and by 13% in 2005–06. The relative improvement of the sprinkler in the second year is possibly due to changing the irrigation management to a slower (~36 hour) heavier application (20–25 mm) for the first pass followed immediately by a quicker (~24 hour, 15–20 mm) application.

Total irrigation applications in both seasons were similar, with 5.5–5.9 ML/ha in all systems in 2005–06, compared with 5.1 ML/ha in the drip and 6.0 and 6.2 ML/ha in the furrow and sprinkler in 2004–05. These amounts are lower than the amount generally considered typical for well-managed maize crops in this region. However, the volume applied was measured at the entrance to each block, by a different method for each system, and the sprinkler and drip flow meters were calibrated each year against volumetric measurements in the field. Our irrigation measurements are supported by the values with sprinkler and border check determined by Greenwood *et al* (2006) for maize grown near Kyabram, and by the fact that a 20.5 t/ha maize crop was grown using 7.5 ML/ha of irrigation water at Boort in 2004–05 (Birch *et al* 2006).

Future work & recommendations

After maize harvest in early April 2006, the site was sown to barley, with the intention of evaluating barley yield, water use and water productivity in the three irrigation systems. The irrigation plots were split in half, and the maize stubble was burnt in one half block in each system. Barley was sown with the Combo+ Happy Seeder, reported in the IREC *Farmers' Newsletter*, No. 172, 2006, in the burnt plots and in the standing maize stubble in the third week of May. Unfortunately, CSIRO will be withdrawing from all this water use efficiency and stubble management work by the end of 2006, due to changing research priorities.

Table 2: Water inputs, crop water use, yield and productivity of all irrigation systems for 2005–06

Irrigation system	Change in soil water ^A ΔSW	Rain R	Irrigation I	Surface drainage SD	Net irrigation I - SD	Total water use ^B T = I + R - SD - ΔSW	Yield 14% moisture Y t/ha	Net irrigation water productivity ^C Y/(I-SD) t/ML	Total water productivity Y/T t/ML
Sprinkler	-1.0	1.9	5.9 ^C	0.3	5.6 ^C	8.5	9.7	1.7	1.1
Drip	-0.8	1.9	5.5 ^C 6.4 ^D	0.0	5.5 ^C 6.4 ^D	9.0 ^D	11.2	2.0	1.3 ^D
Furrow	-1.2	1.9	5.7 ^C	1.0	4.7 ^C	7.7	8.6	1.8	1.1

^A difference in soil water content in the root zone (0.0 - 0.9 m) between sowing and harvest. Negative value means the soil was drier at harvest than at sowing. The bigger the negative number, the greater the drying


^B assumes no deep drainage losses below 0.9 m during the season

^C between sowing and physiological maturity

^D between sowing and harvest – includes accidental irrigation after maturity



The performance of a range of crops needs to be compared with the three irrigation systems, under a range of seasonal conditions, as there are no data available in the southern Murray-Darling Basin for broadacre crops other than maize and perennial pasture. Validated simulation models, such as MaizeMan, the CERES crop models and APSIM, could be used with historical weather data to compare yields, water use and water productivity, as affected by management, seasonal and site conditions, for sprinkler and furrow irrigation. However, none of these models are currently able to simulate crop performance and water use with subsurface drip irrigation.

Management guidelines for growing broadacre crops under high pressure irrigation systems are also needed, drawing on the experience of growers using these systems as well as the results of field research and modelling studies. Financial analysis of the different irrigation systems, taking into account crop performance and water use as affected by the irrigation system and management, is urgently needed to help growers determine whether investment in subsurface drip or sprinkler irrigation systems is financially beneficial for broadacre crops. 

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Further reading

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