Maize under sprinkler, drip & furrow irrigation

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IN A NUTSHELL

- Sprinkler, subsurface drip and furrow irrigated maize were compared side-by-side on a difficult, variable soil at the Coleambally Demo Farm in 2004–05
- Subsurface drip irrigated maize out-performed sprinkler and furrow irrigated maize in terms of yield, net irrigation water use and net irrigation water productivity
- Crop performance and water use efficiency under all irrigation systems could be improved by better irrigation management, shallower furrows and smaller siphons to improve subbing, and increased nitrogen rates

A large-scale demonstration at Coleambally has provided interesting and useful results comparing three different irrigation systems. This article reports on the maize crop grown at the site in 2004–05.

A 20 ha water use efficiency (WUE) site at the Murrumbidgee Shire Community Experimental Demonstration Farm (Demo Farm) allows side-by-side comparison of crops grown with overhead sprinkler (sprinkler), subsurface drip (drip) and conventional furrow (furrow) irrigation. The project was set up by Coleambally Irrigation in cooperation with the Demo Farm committee and volunteers in 2002.

The site

The site was undeveloped grazing land until 1998 when it was set up for border check irrigation and subsequently grew three winter crops. In 2002, beds (1.8 m centres) were formed using GPS, a subsurface drip system was installed in the middle block, and a lateral move sprinkler irrigator was set up on the eastern block. Soybeans were grown in 2002–03, followed by wheat in 2003 and maize in 2004–05.

The soil

The soil is a highly variable gilgai complex of red-brown loam (mostly Wilbriggie) and brown self-mulching clay (Yooroobla). Wilbriggie soils have a poorly structured, shallow (5–10 cm) red-brown loam topsoil over a heavy clay subsoil. They are hard setting with poor infiltration (subbing). Yooroobla clay is a well-structured soil with uniform high clay content to depth, lime throughout the profile, and good subbing properties.

The pH of the topsoil was around neutral and salinity throughout the profile was low. Organic carbon and total nitrogen were also very low in the topsoil. The furrow irrigated block had much higher organic carbon and lower pH and salinity than the drip and sprinkler blocks. Average plant available soil water holding capacity in the top metre of the profile is relatively low (95 mm), suggesting that irrigation is needed after about 50 mm of crop water use, when starting with a full profile.

Irrigation & surface drainage systems

Sprinkler system – a two-span Lindsay-Zimmattic lateral move irrigator was installed to irrigate the sprinkler block from a supply channel running along the edge of the WUE site. The travelling speed was adjusted to complete one pass (490 m) in 24 hours, resulting in an application rate of 15 mm (0.15 ML/ha) per pass.

Drip system – 25 mm drip tape was installed 20 cm below the centre of 72 beds in the drip block in October 2002. The theoretical application rate was equivalent to 1.25 mm/h (0.3 ML/ha/d).

Furrow system – irrigated using 50 mm (2 inch) siphons. Irrigation applications were measured using an ultrasonic Mace Agriflo meter in the supply pipe.

Drainage – each irrigation block had a separate drainage outlet, and surface drainage was measured using an Agriflo meter in each drainage pipe.

Site management

The paddock history and 2004–05 crop management for the site are summarised in Table 1.

In March 2004, the site was irrigated to wet the wheat stubble to allow it to start to breakdown. The sprinkler system had a real advantage over the other systems, as it only took 0.15 ML/ha (followed by a very timely 15 mm of rain) to wet the surface sufficiently. The drip system required 0.77 ML/ha and it took 1.9 ML/ha to wet up the top of the beds in the furrow irrigated plots because the soil was very dry and cracked.

Soil water

The soil profile in the sprinkler block was dry to depth at sowing, and much drier than in the drip and furrow irrigated blocks. The top few centimetres of soil in the drip and furrow irrigated blocks was dry, but there was plenty of moisture below.

Shortly after harvest the soil water content to 0.9 m was generally similar in all blocks, but slightly higher in the drip block at 5–35 cm depth.

Comparing the change in soil water between sowing and harvest, the sprinkler block was slightly wetter (by 0.2 ML/ha) at harvest, drip was 0.5 ML/ha drier at harvest and furrow was 0.8 ML/ha drier (Table 2).

Irrigation management

The crop in the sprinkler block was established with four passes of the lateral move irrigator (total irrigation of 52 mm) to try and build up soil water content. There were 38 sprinkler irrigations during the season. Sprinkler applications were guided by the scheduling for the furrow irrigated block, using MaizeMan software.

The drip and furrow blocks were irrigated five days after sowing to germinate the seed. However, much of the seed in these blocks started to germinate prior to irrigation due to placement of the seed in the moist soil below the surface.

The drip system was run for about 60 hours to wet up the soil for germination, and thereafter generally supplied 14–20 mm per irrigation and there were 27 irrigation events. We used tensiometers in the beds to guide irrigation management, with the goal to keep the soil in the top 0.4 m wetter than -50 kPa.

Irrigations in the furrow block were scheduled when simulated plant available soil water content fell to 40%, using the MaizeMan software. In retrospect, we believe that the crop suffered from soil water deficit and that we should have used a higher cut-off (50%).

Total irrigation applications were 6.2 ML/ha (sprinkler), 5.1 ML/ha (drip) and 6.0 ML/ha (furrow), and there was a total of 144 mm of rain (Table 2). Simulated crop water use (whole of season evapotranspiration (ET) totalled 707 mm) closely matched total water input, but was much less than the theoretical ET of about 1100 mm if the crop had been grown under perfect management.

Crop performance

The crops on the furrow and drip blocks emerged a few days earlier than on the sprinkler block because they had been sown into residual moisture and irrigated several days earlier. Crop establishment was generally very good with all irrigation systems (~8.3 plants/m^2), however it was much more even in the sprinkler block. Patchiness in the drip and furrow irrigated blocks was due to poor subbing in places.

The crop grew well in all treatments (Figures 1 and 2), with no visible signs of stress at any stage until premature

Table 1
Paddock history and maize management details

2004–05	Paddock/crop management
15 Feb	Sprayed with Roundup® Max. @1.2 L/ha
9 Mar	Wheat stubble mulched (5 t/ha)
12 Mar	Poultry manure (dry) spread @ 5 t/ha
23 Mar	Irrigation to provide moisture for stubble breakdown
26 Apr	Furrows cleaned out and soil dropped on top of beds/straw
9 Jun	Sprayed weeds with Roundup (1 L/ha) and Cadence® (250 g/ha) - volunteer wheat, especially on drip and flood irrigated blocks
6 Sep	Sprayed weeds with Roundup and Cadence
20 Sep	Fertiliser 32:10:00 @ 500 kg/ha (160 kg N/ha, 50 kg P/ha) 15 cm under plant rows (2 rows/bed)
26 Sep	Sprayed Gessaprim® @ 6 L/ha, Dual® @ 2 L/ha
27 Sep	Broadcast gypsum @ 2 t/ha
28/29 Sep	Beds power harrowed
8 Oct	Pioneer 3153 @ 82,000-84,000 seeds/ha, @ 5 cm with Counter®; seeds were also dressed with Gaucho®; seed sown with Gaspardo precision planter
12 Oct	Furrow and drip irrigation commenced
16 Oct	Sprinkler irrigation commenced
9 Nov	Aerial sprayed Cadence 50 L/ha water & 400 g/ha Cadence for Bathurst burr
Nov/Dec	100 kg N/ha as urea applied in 5 (flood, sprinkler) or 10 irrigations (drip)
28 Feb	Last flood irrigation
1 Mar	Last drip irrigation
2 Mar	Last sprinkler irrigation
8 Apr	Baited for mouse control - Mouseoff ® (zinc phosphide) @ 1 kg/ha
26 Apr	Header harvest

senescence started to appear in patches within each irrigation block in late January. Filling to the tip of the cob was incomplete, especially in the areas that senesced prematurely, indicating the crop had suffered stress during the reproductive stage.

Yield variability was high within all irrigation treatments and generally ranged from about 7–14 t/ha. Figure 3 shows the yield map of the experimental site. In the sprinkler block, yields were highest at the bottom. In the drip block, yields were lowest in the bottom portion, perhaps due to lower irrigation rates towards the bottom, which would again also mean lower nitrogen application during fertigation. Within the furrow block, yields were highest in the top and bottom sections, possibly due to longer irrigation time (due to backing up of drainage water), which would have increased water availability (and nitrogen supply during fertigation).

Grain yield

Average grain yield (12% moisture) was highest with drip (11.5 t/ha) and least with furrow irrigation (9.9 t/ha), while the sprinkler yielded 10.3 t/ha (averaged over the total area which included unplanted beds for wheel tracks, and the western edge which received less water due to wind drift) (Table 2). Potential yield for Pioneer 3153 with 80,000 plants/ha sown on 8 October for the 2004–05 weather was estimated to be 16.8 t/ha (12%) moisture, using MaizeMan.

Net irrigation water

Net irrigation water application during the season was highest in sprinkler (6.1 ML/ha) and least in drip (4.8 ML/ha) (Table 2).

Net irrigation water productivity for drip (2.4 t/ML) was about 33% higher than sprinkler and furrow, due to both higher yield and lower quantity of irrigation water applied. When the autumn 2004 irrigation is also taken into consideration, net irrigation water productivity declines to 1.3 t/ML in furrow, compared with 1.7 ML/ha in sprinkler and 2.1 ML/ha in drip.

Table 2
Water inputs, crop water use, yield and water productivity of maize under three irrigation systems (12 October 2004 to 28 April 2005)

Irrigation system	Change in soil water[A]	Rain	Irrigation	Surface drainage	Net irrigation	Total water use[B]	Yield 12% moisture	Net irrigation water productivity	Total water productivity
	dSW	R	I	SD	I-SD	T= I+R-SD-dSW	Y	Y/(I-SD)	Y/T
	ML/ha						t/ha	t/ML	
Sprinkler	0.2	1.4	6.2	0.1	6.1	7.4	10.3	1.7	1.4
Drip	-0.5	1.4	5.1	0.3	4.8	6.7	11.5	2.4	1.7
Furrow	-0.8	1.4	6.0	0.5	5.5	7.8	9.9	1.8	1.3

[A] difference in soil water content over the root zone (0.0–0.9 m) between sowing and harvest – negative values mean the soil was drier at harvest, positive values indicate wetter soil at harvest than at sowing

[B] assumes no deep drainage losses below 0.9 m during the maize season

Figure 1 *Calibration of the sprinklers on the lateral move irrigator - and excellent crop establishment.*

Figure 2 *Soil water monitoring in the bed – right tensiometers, left Enviroscan*

Total water productivity

Taking into account all sources of water (irrigation, rain, and soil water depletion between sowing and harvest), total crop water use in was highest in furrow (7.8 ML/ha) and least in drip (6.7 ML/ha).

Total water productivity in sprinkler and furrow was similar (1.3–1.4 t/ML), while total water productivity in drip was about 40% higher (1.7 ML/ha), due to both higher yield and lower water use in the drip.

How to improve

We expect to be able to improve crop performance under all systems by improving irrigation system and soil management, and by increasing nitrogen application rate. Given the site has only been recently developed, we consider that growing more crops, stubble retention and minimum tillage will help to improve soil structure, subbing and soil water holding capacity in all systems over time.

Shallower furrows and smaller siphons should improve subbing into the furrow irrigated beds, and scheduling irrigations at 50% plant available water (rather than 40%) should reduce soil water deficit stress.

In the drip irrigated block, we need to further investigate soil moisture variability down the subsurface drip lines, and manage irrigations so that the bottom quarter of the field receives adequate water.

The use of beds with sprinkler irrigation appears to be questionable, due to high runoff from the beds, forcing the crop to extract water from the furrows, which are compacted by trafficking, instead of from the non-trafficked beds. Runoff from the beds was probably exacerbated once the plants became large enough to intercept most of the water from the sprinklers, which then ran down the stems in concentrated streams.

Conclusions

We achieved higher yield and water productivity of maize with sub-surface drip irrigation compared with furrow and sprinkler irrigation, with real savings in both irrigation and total water use. However, the results indicate that there is plenty of scope to improve crop performance by improving irrigation and other management in all systems. Given the increasing price and reduced availability of water for irrigation, further evaluation of alternative methods for irrigating maize and other broadacre crops is warranted. This should include evaluation of management options and development of guidelines for maximising yield and water productivity, together with economic evaluation of the different systems. We plan to grow maize at the site again in 2005–06 and introduce some of the improvements discussed above.

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Further information

Information about the project and a detailed report on the study are available from

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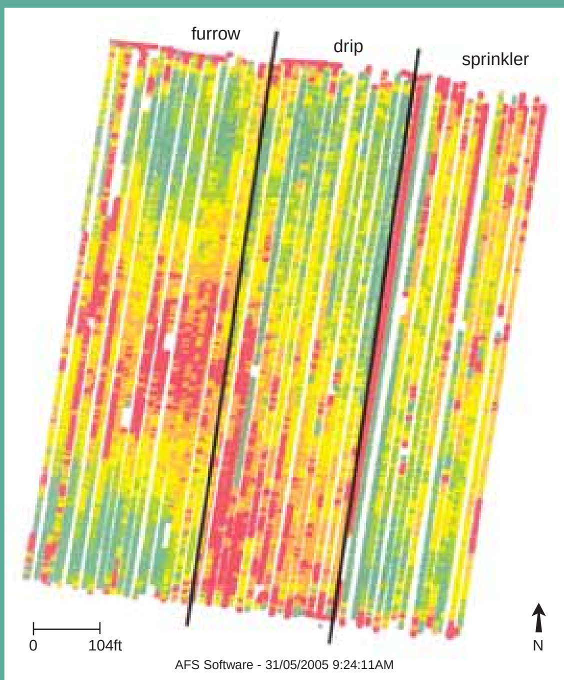

Figure 3 *Yield map of the 2004–05 maize crop.*

Sprinkler - red <9.5 t/ha, dark green >12.1 t/ha
Drip - red <9.1 t/ha, dark green >12.1 t/ha
Furrow - red < 7.8 t/ha, dark green > 10.8 t/ha

The thick white strips running from top to bottom in the sprinkler block are non-planted wheel pads; the poor western edge of the sprinkler block is also clearly visible as a red strip running the length of the field.