Soil and water management for irrigated crops on a red-brown earth soil

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Summary. Four soil management treatments: hill/furrow, cultivated bay, `no till' beds and direct drill into ex-pasture, were compared for sunflower and maize using surface irrigation (either flood or furrow), and drip irrigation. Hill/furrow yielded most dry matter from each crop over both irrigation methods. Yields of sunflower seed and maize dry matter from beds were similar to hill/furrow. Direct drill yields were equivalent to cultivated bays. Waterlogging retarded growth following the first surface irrigation. Direct drill was affected worst and sunflower more than maize. Drip irrigation produced 47% more dry matter and 23% more seed than surface irrigation for sunflower, and 35% more dry matter for maize, over all soil managements. These results demonstrate the importance of good soil-water relations for irrigated crops on red-brown earth soils and the potential for direct drilling.

Introduction

Many irrigated crops are sown into cultivated seedbeds and flood irrigated. This practice is detrimental to soil structure and will therefore reduce yield capability of future crops. Although furrow irrigation reduces the inundation of soil aggregates and assists aeration of the surface root zone, the need to cultivate seedbeds for crops is being increasingly questioned and direct drilling continues to expand. There has been little comparative research into direct drilling of crops under flood or furrow irrigation, particularly on dense soils such as predominate in the irrigation areas of southern Australia. This experiment, conducted at the Kyabram Research Institute, compared direct drilled and cultivated seed beds for sunflower, *Helianthus annuus,* and maize, *Zea mays,* under both surface (flood or furrow) and drip irrigation.

Methods

The soil type at the experimental site was Lemnos loam, a duplex red-brown earth with 150 mm of hard setting loam topsoil with a bulk density (bd) of 1.5 g/cm^3 over a massive clay subsoil (bd 1.6 g/cm^3). The surface slope was 0.13% and the prior history was three years of sub clover pasture.

A split plot design with three replicates was used to compare two irrigation methods (surface and drip) as main treatments and four soil managements (sub treatments). Sunflower was grown in year 1 (1989-90), maize in year 2 (1990-91).

The four soil managements were: (i) hill/furrow - seedbed cultivated then hilled for furrow irrigation; (ii) cultivated bay - seedbed cultivated then smoothed for flood irrigation; (iii) beds - `no till' raised beds with furrows 1.5 m apart established under barley in 1989, all traffic confined to furrows, sown by direct drilling; (iv) direct drill - sown into uncultivated ex-pasture soil, grazed short then killed by spraying.

The two irrigation methods were: (a) surface irrigation either by furrow (soil managements (i) and (iii)) or flood (soil managements (ii) and (iv)). Interval for surface irrigation was based on a cumulative evaporation of 75 mm after crop canopy closure. (b) Drip irrigation; using `trickle' tape along each crop row to supply water on demand and avoid both waterlogging and water stress associated with normal irrigation cycles. Tensiometers were installed at depths of 200 mm and 500 mm in the 'trickle' irrigated treatments. Water lost by evapotranspiration was replaced after a maximum deficit of 25 mm so that soil water tension did not exceed 80 kPa at 200 mm, and to permit some periodic drying from saturation at 500 mm to prevent waterlogging of the subsoil. The drip irrigation treatment was designed to remove any constraints to yield caused by soil-water supply and thus separate the effects of soil management from those of water supply, as well as indicating potential crop yield.

Three aluminium access tubes per plot were installed to a depth of 1.0 m to monitor soil water storage and extraction with a neutron moisture meter. Plot size was 60x20 m for surface irrigated plots, which were used to measure total crop-water use, and 60x10 m for drip irrigation.

Crops were planted with a precision seeder at 750 mm row spacing. Direct drilling was achieved using narrow rotary hoes to cultivate a 50x50 mm slot in front of each sowing boot.

Year 1. Sunflower

Cultivar Suncross 363 was planted on 29 November 1989 at approximately 100,000 seeds/ha, following irrigation. At planting 40 kg/ha of phosphorus (P) and 36 kg/ha of nitrogen (N) were banded and 60 kg N/ha was applied 25 days after emergence. Sprayseed (Paraquat 125 g/1.-., Diquat 75 g/L) at 2.5 L/ha was applied pre-planting to direct drill treatments to desiccate the annual pasture, and Stomp (Pendimethalin 330 g/L) at 4 L/ha to all treatments post-planting. Sunflower heads were protected from birds to measure seed yield; 240 plants per plot were selected at random and covered with nylon mesh bags after pollination. Dry matter yield was measured at 45 days after sowing and at final harvest. An oat crop was planted in April 1990 and harvested for silage in October.

Year 2. Maize

Cultivar C 76 was planted into the same plots using the same treatments as for sunflower on 28 November 1990 following irrigation. Fertiliser banded at planting was 40 kg P and 36 kg N/ ha with an additional 175 kg N/ha for surface irrigation or 250 kg N for drip irrigation, plus 20 kg P and 18 kg sulfur (S) applied subsequently through the irrigation water. The non-cultivated plots were sprayed with Sprayseed at 3 L/ha prior to planting. Stomp was applied post-planting at 4 L/ha to all treatments, and atrazine (500 g/L) post emergent at 5 L/ha to the direct drill treatment to control *Echinochloa crus-galli.* Yield was measured as dry matter at 45 days by cutting four 1.5 m^2 strips from each plot, and then at 125 days when the whole plot was harvested with a forage harvester 100 mm from ground level except for two border rows each side.

Results and discussion

Year 1 Sunflower

Yields of seed and dry matter for sunflower are presented in Table 1. There was no significant difference ($P>0.05$) in seed yield between soil managements, but a highly significant difference ($P<0.01$) between irrigation methods. Drip irrigation produced 23% more seed on average than surface irrigation (flood or furrow) and for direct drill under flood 43% more. When data from both irrigation methods were combined, hill/furrow produced significantly more dry matter than the other soil managements. Drip irrigation produced 47% more dry matter than the surface irrigation treatments. There was no interaction between soil management and irrigation method either for seed yield or dry matter yield ($P>0.05$).

Harvest index for surface irrigation was 0.43 but for drip irrigation it was 0.36. This indicates that sunflower was not able to convert the additional growth provided by improved soil water relations to seed yield at a constant ratio, thus diminishing the commercial advantage of the improved water management.

Direct drill treatments achieved equivalent plant populations and seedling growth for the first 10 days, to cultivated seedbeds. The first irrigation for flood or furrow treatments 15 days after emergence, despite being completed in six hours, had a severely detrimental effect on crop growth due to waterlogging of the root zone. The tap root system was destroyed on most of the flood irrigated plants. Direct drilled plots were most severely affected, as the seeding slots acted as small reservoirs which extended the period of waterlogging. Furrow irrigated treatments also received a noticeable setback but drip irrigated plots continued to thrive with frequent small applications of water. The superiority of drip irrigation for early crop development was shown at 45 days when there was 45% more dry matter under drip than surface irrigation. Most plants damaged by this waterlogging event re-established their root system by growing new roots from the stem just below the soil surface. These roots did not succumb at

subsequent irrigations and crop recovery was remarkably good. Seed yields between soil managements were not significantly different (P>0.05) but the furrow irrigated plots ((i) and (iii)) appeared superior to surface flooded treatments ((ii) and (iv)) throughout the season and had a mean yield 15% higher.

Table 1. Seed yield and dry matter yield for sunflower grown under four soil management systems using two irrigation methods.

Soil management		Seed yield (t/ha)			Dry matter yield (t/ha)		
		Surface irrigation	Drip irrigation	Mean	Surface irrigation	Drip irrigation	Mean
(i)	Hill/furrow	4.5	5.7	5.1	11.6	15.6	13.6
(ii)	Cultivated bay	4.2	4.9	4.5	8.9	14.3	11.8
(iii)	Beds	4.6	5.0	4.8	8.5	14.0	11.6
(iv)	Direct drill	3.7	5.3	4.5	10.0	13.6	11.3
l.s.d. (P=0.05)		--	--	--	--	1.7	

l.s.d. (P=0.05) between irrigation methods = 0.3 (seed) and 0.6 (dry matter).

Final yields of direct drill showed the potential for this technique to be excellent, however sunflower demonstrated that it is very vulnerable to seedling waterlogging on dense soils with slow surface drainage.

Year 2 Maize

Yields of dry matter for maize are presented in Table 2. For surface irrigation, hill/furrow soil management gave a significantly higher yield than both flood treatments ((ii) and (iv)). The yield of beds was marginally lower than hill/furrow. Drip irrigation produced 35% more dry matter than surface irrigation, (l.s.d. P=0.05 = 4.2). When both irrigation methods were combined in the analysis, hill/furrow was again greater (P<0.05) than flood treatments (ii) and (iv) and there was no difference between the other three treatments. There was no interaction between soil management and irrigation method (P>0.05).

Maize also suffered a set back in growth following the first irrigation. The negative effect on growth from waterlogging of seedlings was least severe on hill/furrow and worst with direct drill. Yields from surface irrigation relative to drip irrigation for the four soil managements at 45 days were: hill/furrow 76%, beds 63%, cultivated bays 55% and direct drill 51%.

Table 2. Final dry matter yield for maize grown under four soil management systems using two irrigation methods.

Treatment		Dry matter yield (t/ha) Surface irrigation	Drip irrigation	Mean
(i)	Hill/furrow	21.7	27.9	24.8
(ii)	Cultivated bay	18.3	24.1	21.2
(iii)	Beds	19.5	25.4	22.5
(iv)	Direct drill	18.2	26.9	22.5
l.s.d. (P=0.05)		2.2	--	1.34

Final yield of direct drill under drip irrigation was equivalent to any other management, which indicates that the density of the surface soil did not limit growth when soil water supply was optimised. Under flood irrigation the direct drill treatment produced a similar yield to the cultivated seedbed, showing that where satisfactory crop establishment, weed control and surface drainage are achieved, direct drilling can he an equivalent commercial option to cultivation even in dense soils.

Soil-water relations

For surface irrigation, hill/furrow management provided the closest soil-water relationship to drip irrigation. The hills wet thoroughly during irrigation and drained quickly. This treatment was superior even under drip irrigation which may be explained by better drainage after rainfall events when the profile was full. Beds grew an equivalent yield of sunflower seed to hill/furrow but their maize yield may have been reduced by the prior barley crop, independent of their soil-water status.

Measurement of soil water intake and extraction showed that the `no-till' beds were wetting well after two years and held more water than cultivated treatments following the final irrigation. Water intake and storage patterns under direct drill showed more water held below 0.4 m and greater water extraction between 0.6 m and 1.0 m than with cultivated seedbeds, indicating good intake characteristics.

The experiment has shown that if soil and water management is able to provide excellent soil-water relationships, crop yields may be increased by 23-47% on this soil. Direct drilling can be successful if crop establishment, surface drainage and weed control are adequate.