IMPROVING THE WATER USE EFFICIENCY OF RICE

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ABSTRACT

The cost of irrigation water accounts for 20-30% of the total variable costs of rice production in the Murrumbidgee and Murray Valleys. Rice production consumes a substantial proportion of the available supply of irrigation water. Any agronomic/water management practice that has the potential to reduce water use should be investigated.

Research in the Burdekin River Irrigation Area indicated that crop water use of rice grown on raised beds was 32% less than when grown using conventional permanent flood. Whilst recognising that there are likely to be agronomic constraints to rice production on raised beds in the Riverina, investigations into potential water savings, were investigated in this project.

The project evaluated the water use efficiency of rice grown on a raised bed layout on two of the principal soil types used for rice production (four experiments). This layout was compared with the now traditional aerial sown fully ponded flat layout. The opportunity to explore water management options on the raised bed layout was also undertaken in three of the experiments. Water use was quantified and agronomic performance of the rice crop monitored.

Maintaining water in the furrows all season reduced grain yield by an average of 10% (range 7-20). In three of the four experiments harvest index was lower where water was maintained only in the furrows. Moisture stress during panicle development and grain filling may have contributed to this result. Although sterility was not measured, no affected panicles were observed.

Water use, where water was maintained in the furrows, was reduced by 14% (range 7-18). Water use efficiency increased on two occasions but decreased on one. Efficiencies for the two irrigation layouts by water management treatments of most interest (water maintained in the furrows; fully ponded flat) ranged only from 7.1 to 8.1 kg/ha/mm of water used by the crop.

Despite an apparently similar soil type across the experimental areas, considerable variation in water use between plots with the same water management was measured. When attempting to measure water use in 'small plots' it is recommended that there be a minimum of four replications and/ or differences in water management between treatments be substantial.

This project demonstrated that rice can be successfully grown on the raised bed layout (yields > 10 t/ha). Reductions in water use will not be as substantial as those reported from Queensland. Where water 'subs' readily to the centre of the raised bed grain yield, water use and water use efficiency are all likely to be similar to the traditional fully ponded flat layout.

BACKGROUND

The cost of irrigation water accounts for 20-30% of the total variable costs of rice production in the Murrumbidgee and Murray Valleys (1995/96 water prices; Curthoys, 1995). Rice production consumes a substantial proportion of the available supply of irrigation water. Any agronomic/water management practice, that has the potential to reduce water use, should be investigated. As well as a direct economic benefit, there may be a reduction in accessions to the watertable.

Research in the Burdekin River Irrigation Area indicated that crop water use of rice grown on raised beds was 32% less than when grown using conventional permanent flood (Borrell et al, 1997). Whilst recognising that there are likely to be agronomic constraints to rice production on raised beds in the Riverina, investigations into potential water savings should be undertaken.

A preliminary experiment, funded by the RIRDC Rice R&D Committee, was undertaken at NSW Agriculture's Murray Valley Field Station in 1996/1997. The soil type was a transitional red-brown earth. Plots combine sown on raised beds were compared with the aerial sown fully ponded 'flat' layout. One of the raised bed plots, where irrigation water subbed readily to the centre of the bed (presumably because of a subtle difference in soil type), and water was ponded ten days before panicle initiation (PI) produced the highest biomass and grain yield. It used as much water as the fully ponded control plots. The remaining three plots on the raised bed layout did not sub as well (one was ponded ten days before PI), used less water, but still yielded as well as the controls.

Although the yields were only based on quadrat samples, and sowing method may have confounded the result, the experiment demonstrated that rice could be grown successfully on the raised bed layout.

1 OBJECTIVES

The project aims to investigate opportunities to improve the water use efficiency of the rice crop by comparing the raised bed layout with conventional aerial sowing on a flat layout. Water use of short season varieties will also be measured.

The project will evaluate the water use of rice grown on a raised bed layout on two of the principal soil types used for rice production – a transitional red-brown earth and a grey cracking clay. A replicated comparison with the now traditional aerial sown fully ponded crop will be undertaken.

Water use will be quantified and agronomic performance monitored.

2 METHODOLOGY

Replicated field experiments were conducted over four growing seasons, 1997/1998 to 2000/2001. Also in 2000/2001, a four hectare bay with a raised bed layout, on a commercial property was monitored for crop growth.

3.1 Plot size and replication

Plot size was approximately 12 x 65 m in 1997/1998; 12 x 40 m in1998/1999; 24 x 100 m in 1999/2000 and 2000/2001. A randomised block design was used with four replicates at Deniliquin and three at 'Old Coree'.

3.2 Crop agronomy

3.2.1 Sowing rate

The sowing rate was as recommended in NSW Agriculture's Ricecheck publication (range 125-145 kg/ha).

3.2.2 Weed and pest control

Weed control was accomplished using herbicides as per NSW Agriculture's Ricecheck recommendations. Insect pests (bloodworms) were also controlled as recommended in Ricecheck.

3.3 Measurements

3.3.1 Water use

Water use was measured either by change in bay water level (irrigation water applied by syphon) or by flowmeter (irrigation water applied by pumping through aluminium pipeline). Rainfall was measured on site. Soil moisture was measured prior to the initial ponding or first flushing irrigation. The surface area of each plot was adjusted (increased) when deep water was applied to protect the rice from cold temperature during microspore development. When the water level was raised the banks separating the plots became damp and water evaporated from the soil surface. Thus, the values for water use provided in the results section include adjustments for antecedent soil moisture, rainfall, and adjusted surface area whilst deep ponded water was on the plots.

3.3.2 Crop phenology

All experiments were inspected at least twice weekly and crop phenology was recorded as necessary.

3.3.3 Dry matter production

Samples for dry matter production were taken at PI, flowering and physiological maturity. In 1997/1998 samples were also taken on two occasions prior to PI. Usually, for the aerial sown treatments the sample size was $1m^2$. For the raised bed plots the sample size was 1 m of row x the width of the bed (furrow to furrow). The bed width was 1.6 m at Deniliquin, 2.0 m at ‘Old Coree’ and 1.8 m at ‘Zennor’. All samples were dried at 80^oC until constant weight was achieved.

Harvest index was measured on the samples taken at physiological maturity.

3.3.4 Grain yield

Grain yields were obtained using a ‘small plot’ header. Header width was 1.8 m and there were usually two strips 10-20 m in length harvested from each plot. Grain moisture content was measured (using Sunrice equipment located at the Deniliquin mill) on a sub-sample from each plot and grain yields are reported as tonnes/ ha at 14 % moisture.

3.4 Site specific experimental details

3.4.1 Experiment 1 (1997/1998)

Location: NSW Agriculture’s Murray Valley Field Station, Deniliquin.
Soil type: Transitional red-brown earth.
Variety: Namaga; Jarrah was used for the late sown treatments.
Sowing date: combine sown – 3rd October; aerial sown – 15th October; aerial sown (late) – 12th November.
Nitrogen fertiliser rate: 120 kg N/ha (as urea) pre-plant plus topdressing at (PI) as recommended by the rice NIR tissue test.

Treatments
1. Flat layout; aerial sown; ponded (control).
2. Flat layout; combine sown; ponded at 3 leaf stage.
3. Raised bed layout; combine sown; water maintained in the furrows all season.
4. Raised bed layout; combine sown; water maintained in the furrows; ponded at PI.
5. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf stage.
6. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf stage; ponded again at PI.
7. Flat layout; aerial sown (late); ponded.
8. Raised bed layout; aerial sown (late); water maintained in the furrows all season.

3.4.2 Experiment 2 (1998/1999)

Location: NSW Agriculture’s Murray Valley Field Station, Deniliquin.
Soil type: Transitional red-brown earth.
Variety: Namaga; Millin for early sown treatment.
Sowing date: 16th October; early sowing – 28th September.

Nitrogen fertiliser rate: 150 kg N/ha (as urea) pre-plant. The rice NIR tissue test recommended no topdressing.

Treatments

1. Flat layout; aerial sown; ponded (control).
2. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf stage.
3. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf stage; ponded again at PI.
4. Flat layout; aerial sown; ponded; early sowing.

3.4.3 Experiment 3 (1999/2000)

Location: McCaughey Memorial Institute, ‘Old Coree’, Jerilderie.
Soil type: grey cracking ‘heavy’ clay.
Variety: Opus.
Sowing date: 31st October.
Nitrogen fertiliser rate: 100 kg N/ha (as urea) preplant. The rice NIR tissue test recommended no topdressing.

Treatments

1. Flat layout; aerial sown; ponded (control).
2. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf stage and then maintained in furrow for the remainder of the season.
3. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf stage; ponded at PI.

3.4.4 Experiment 4 (2000/2001)

Location: McCaughey Memorial Institute, ‘Old Coree’, Jerilderie
Soil type: grey cracking ‘heavy’ clay.
Variety: Amaroo
Sowing date: combine sown – 11th October; aerial sown –19th October.
Nitrogen fertiliser rate: 100 kg N/ha (as urea) pre plant. The raised bed treatment received another 75 kg N/ha, as urea, at PI (as recommended by the rice NIR tissue test).

Treatments

1. Flat layout; aerial sown; ponded (control).
2. Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at the 3 leaf stage and then maintained in furrow for the remainder of the season.
3. Raised bed layout; combine sown. This treatment was abandoned, as establishment was extremely poor (less than 20 plants/m^2; inclement weather, galahs etc).

3.4.5 Experiment 5 (2000/2001)

Location: ‘Zennor’, Jerilderie. Nick Elwood.
Soil type: transitional red-brown earth.
Variety: Illabong

Sowing date: combine sown – 3rd November (into rainfed moisture).
Weed control: Gramoxone/Magister by ground 'rig'.
Nitrogen fertiliser rate: 83 kg N/ha (as urea) broadcast just before the first irrigation (6 days after sowing). An additional 70 kg N/ha (as urea) before permanent flood – end December.

Treatments
1. Raised bed layout; combine sown into moisture; flushed five times and then water maintained in the furrows for the remainder of the season.
2. Raised bed layout; combine sown into moisture; flushed five times and then water maintained in the furrows; ponded just prior to PI.

4 RESULTS

Where the result is expressed per unit area (eg. m^2, ha) the area of the full width of the bed ie. from furrow to furrow, has been used in the calculation.

4.1 Experiment 1 (1997/1998 Deniliquin)

4.1.1 Crop phenology

All treatments reached PI within three days of each other. The aerial sown ponded treatment (control) was the earliest. There was a ten day 'spread' in flowering dates with the aerial sown ponded treatment (control) being the earliest. The three treatments where water was maintained in the furrows (not ponded) were the latest to reach flowering. The aerial sown ponded treatment was the first to reach physiological maturity (156 days after sowing (D156)). All treatments were at physiological maturity within eight days of the control.

4.1.2 Plant height at flowering

TABLE 1

PLANT HEIGHT AT FLOWERING IN EXPERIMENT 1

Treatment	Plant height (cm)
Flat layout; aerial sown; ponded (control) (**T1**)	70
Flat layout; combine sown; ponded at 3 leaf stage (**T2**)	75
Raised bed layout; combine sown; water in furrows all season (**T3**)	66
Raised bed layout; combine sown; water in furrows then ponded at PI (**T4**)	76
Raised bed layout; aerial sown; water level lowered to 'in furrow' at 3 leaf (**T5**)	65
Raised bed; aerial ; water level lowered to furrow at 3 leaf; ponded at PI (**T6**)	72
Flat layout; aerial sown (late); ponded (**T7**)	79
Raised bed layout; aerial sown (late); water level lowered to 'in furrow' at 3 leaf (**T8**)	74
lsd (P = 0.05)	3.3

The late aerial sown ponded treatment (variety Jarrah) produced the tallest crop (Table 1). The three treatments on raised beds, where the water was maintained in the furrows, were significantly shorter than their corresponding ponded treatment (Table 1).

4.1.3 Dry matter production

By the 27th November (D55 for combine sown treatments; D43 for aerial sown treatments) the aerial sown treatments had produced 350 g/m^2, 287% greater than the combine sown treatments (120 g/m^2).

Fourteen days later the advantage of the aerial sown treatments had been reduced to 80% (Table 2). The aerial sown treatments had produced an average of 550 g/m^2; the combine sown 310 g/m^2 (from Table 2). The two late sown treatments had only produced 90 g/m^2.

TABLE 2

DRY MATTER PRODUCTION ON THE 11TH DECEMBER IN EXPERIMENT 1

The 11th December corresponds to D69 for the combine sown treatments; D57 for the aerial sown treatments; and D29 for the two late sown treatments.

Treatment	Dry matter (g/m^2)
Flat layout; aerial sown; ponded (control) (**T1**)	525
Flat layout; combine sown; ponded at 3 leaf stage (**T2**)	310
Raised bed layout; combine sown; water in furrows all season (**T3**)	350
Raised bed layout; combine sown; water in furrows then ponded at PI (**T4**)	265
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf (**T5**)	505
Raised bed; aerial ; water level lowered to furrow at 3 leaf; ponded at PI (**T6**)	625
Flat layout; aerial sown (late); ponded (**T7**)	90
Raised bed layout; aerial sown (late); water level lowered to ‘in furrow’ at 3 leaf (**T8**)	90
lsd (P = 0.05)	100

At PI the aerial sown control (T1) had produced the highest dry matter (Table 3). Production from the aerial sown treatments (T1,T5 and T6) was still significantly higher than all other treatments. The combine sown treatment, whilst still producing significantly less was ‘bridging the gap’. Production, where water was maintained in the furrows (T3 and T4; mean 570 g/m^2), was only 60 % of that produced under ponding (T1, T2, T5 and T6; mean 955 g/m^2).

The aerial sown control (T1; 2140 g/m^2) maintained its statistically significant advantage at flowering (Table 3). The combine sown control treatment (T2) produced the second highest amount, but this was not greater than T5 or T6. At flowering, the raised bed layout where water was maintained in the furrows all season (T3), had produced 84% of the flat layout with ponded water (T2). The increase in dry matter production from PI to flowering ranged from 855 g/m^2 (T5) to 1165 g/m^2 (T7) and averaged 1020 g/m^2 for all treatments.

At physiological maturity, the dry matter production from the combine sown ‘control’ (T2) and the late sown ponded treatment (T7) was statistically similar to aerial sown control (T1) (Table 3). The two raised bed layouts that had been aerial sown (T5 and T6) had a similar production (not statistically inferior) to T1. The production from the raised bed layout where water was maintained in the furrows all season (T3) was 78% of the flat layout with ponded water, a similar result to that recorded at flowering. For the late sown treatments, T7 where the water was ponded in the furrows only produced 87% of the ponded treatment.

TABLE 3

DRY MATTER PRODUCTION AT PANICLE INITIATION, FLOWERING, AND PHYSIOLOGICAL MATURITY IN EXPERIMENT 1

Treatment	Panicle initiation (g/m^2)	Flowering (g/m^2)	Physiological maturity (g/m^2)
Flat layout; aerial sown; ponded (control) (**T1**)	1040	2140	2585
Flat layout; combine sown; ponded at 3 leaf stage (**T2**)	885	1960	2610
Raised bed layout; combine sown; water in furrows all season (**T3**)	580	1645	2035
Raised bed layout; combine sown; water in furrows then ponded at PI (**T4**)	555	1515	2190
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf (**T5**)	955	1810	2315
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf; ponded at PI (**T6**)	945	1850	2305
Flat layout; aerial sown (late); ponded (**T7**)	615	1780	2335
Raised bed layout; aerial sown (late); water level lowered to in ‘furrow’ at 3 leaf (**T8**)	480	1500	2025
lsd ($P = 0.05$)	90	155	280

4.1.4 Grain yield

The highest yield (12 t/ha) was produced from T6 where the rice was aerial sown on the raised bed layout (Table 4). In this treatment the ponded water was lowered into the furrows at the 3 leaf stage and then ponded again at PI. The other three treatments where water was ponded from at least PI to maturity (T1, T2 and T4) produced grain yields that were not significantly below T6. Although not significantly different (at P = 0.05), maintaining water in the furrows all season (T3) reduced grain yield by 11% compared to the combine sown ‘control’ (T2).

Treatment 5, where water was maintained in the furrows for most of the growing season produced 35% less than T6 where water was ponded again at PI (Table 4).

Both late sown treatments yielded substantially less than the corresponding treatments that were sown at the ‘normal’ time. Maintaining the water in the furrow all season only produced 63% of the treatment where water was ponded (T7).

4.1.5 Harvest index

Treatments 4 and 6, where water was ponded from PI to maturity following an initial period with water in the furrows, had the highest harvest index – 0.46. The aerial sown ponded ‘control’ treatment recorded a harvest index of 0.33. The three treatments, where water was maintained in the furrows for most of the growing season, produced a harvest index lower than their corresponding ponded treatment.

4.1.6 Water use

The aerial sown control (T1) recorded the highest water use (1710 mm; Table 4; see discussion). The water used by the other two treatments where water was also ponded all season (T2 and T7) was not significantly less than T1.

TABLE 4

GRAIN YIELD, WATER USE AND WATER USE EFFICIENCY IN EXPERIMENT 1

The value for water use includes effective rainfall and change in soil stored moisture. Water use efficiency is the quantity of grain in kg/ha (@ 14 % moisture) produced per mm of water used (to convert this value to tonnes/ ML of water divide by 10 eg. 6.8 kg/ha/mm = 0.68 T/ML).

Treatment	Grain yield (t/ha)	Water use (mm)	Water use efficiency (kg/ha/mm)
Flat layout; aerial sown; ponded (control) (**T1**)	11.7	1710	6.8
Flat layout; combine sown; ponded at 3 leaf stage (**T2**)	11.4	1535	7.4
Raised bed layout; combine sown; water in furrows all season (**T3**)	10.2	1255	8.1
Raised bed layout; combine sown; water in furrows then ponded at PI (**T4**)	11.1	1455	7.6
Raised bed layout; aerial sown; water level lowered to 'in furrow' at 3 leaf (**T5**)	7.8	1285	6.1
Raised bed layout; aerial sown; water level lowered to 'in furrow' at 3 leaf; ponded at PI (**T6**)	12.0	1410	8.5
Flat layout; aerial sown (late); ponded (**T7**)	8.9	1515	5.9
Raised bed layout; aerial sown (late); water level lowered to 'in furrow' at 3 leaf (**T8**)	5.6	1350	4.2
lsd ($P = 0.05$)	1.3	225	

The raised bed layout (combine sown) where the water was maintained in the furrows all season (T3) had the lowest water use (1255 mm), but this was not significantly less than the remaining four treatments (T4, T6, T8 and T5) (Table 4).

4.1.6 Water use efficiency

The treatment with the highest grain yield (T6) also recorded the highest water use efficiency (Table 4). Treatment 3 was the next most efficient treatment. The late sown treatments, especially where the water was maintained in the furrows (T8) measured the lowest water use efficiency.

4.2 1998/1999 Deniliquin

4.2.1 Crop phenology

Millin sown on the 28th September (T4) flowered on 2nd February and reached physiological maturity by the 25th February.

Namaga, sown on the 16th October on a flat layout and water ponded (T1), was at PI on the 6th January, flowered on the 18th February, and was physiologically mature by the 25th March. When sown on the raised bed layout and with water maintained in the furrows (T2) flowering was delayed by 13 days. On the raised bed layout where water was ponded again at PI (T3) the delay was reduced to nine days.

4.2.2 Dry matter production

At physiological maturity, the aerial sown ponded treatment (control; T1) had produced significantly higher dry matter than the other three treatments (Table 5). Production from these three was statistically similar (Table 5).

4.2.3 Grain yield

Grain yield from all treatments was similar (mean of 10.5 t/ha; Table 5). However P = 0.07, indicating that differences were approaching significance. The raised bed crop, where water was maintained in the furrows all season (T2), produced 7% less than the fully ponded control (T1).

4.2.4 Harvest index

The highest harvest index (0.59) was produced from the early sown Millin (T4) (Table 5). For Namaga, where water was ponded for all or most of the growing season the harvest index was 0.5. Maintaining water in the furrows all season lowered the harvest index to 0.44.

4.2.5 Water use

There was no significant difference in water use (Table 5).

TABLE 5

PRODUCTION AND WATER USE PARAMETERS IN EXPERIMENT 2

Harvest index is displayed in the column headed ‘HI’. The value for water use includes effective rainfall and change in soil stored moisture. Water use efficiency is the quantity of grain in kg/ha (@ 14% moisture) produced per mm of water used.

Treatment	Dry matter (g/m^2)	Grain yield (t/ha)	HI	Water use (mm)	Water use effic. (kg/ha/mm)
Flat layout; aerial sown; ponded (control) (**T1**)	2430	11.1	0.51	1480	7.5
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf (**T2**)	2125	10.3	0.44	1450	7.1
Raised bed layout; aerial sown; water level lowered to in furrow at 3 leaf; ponded at PI (**T3**)	2170	10.8	0.50	1640	6.6
Flat layout; aerial sown; ponded; early sowing (variety Millin) (**T4**)	2020	9.8	0.59	1585	6.2
lsd (P = 0.05)	150	n.s.	0.002	n.s.	

4.2.6 Water use efficiency

Early sown Millin had the lowest water use efficiency (Table 5). The aerial sown ponded ‘control’ treatment was the highest.

4.3 1999/2000 ‘Old Coree’ Jerilderie

4.3.1 Crop phenology

Opus sown on the 31st October was at PI on the 19th January, flowered on the 18th February, and was physiologically mature by 28th March.

4.3.2 Dry matter production

The three treatments produced similar amounts of dry matter at all three times of sampling (Table 6). There was also no effect on tiller numbers at PI (1395 per/m^2).

TABLE 6

DRY MATTER PRODUCTION AT PANICLE INITIATION, FLOWERING, AND PHYSIOLOGICAL MATURITY IN EXPERIMENT 3

Treatment	Panicle initiation (g/m^2)	Flowering (g/m^2)	Physiological maturity (g/m^2)
Flat layout; aerial sown ; ponded (control) (**T1**)	660	1525	2350
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf (**T2**)	595	1500	2330
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf; ponded at PI (**T3**)	575	1410	2330

lsd (P = 0.05)	n.s.	n.s.	n.s.

4.3.3 Grain yield

Grain yield from all three treatments was similar (mean of 11.1 t/ha; Table 7). However, as for experiment 2, a P value of 0.08, indicates that the differences were approaching significance. The raised bed crop, where water was maintained in the furrows all season (T2), produced 10% less than the fully ponded control (T1).

4.3.4 Harvest index

Harvest index was higher (0.44) where water was ponded for most of the growing season (T1 and T3) than where water was maintained in the furrows all season (0.37) (Table 7).

4.3.5 Water use

Water use was significantly lower where water was maintained in the furrows all season (Table 7). Water use for individual plots (bays) where water was ponded for most of the season ranged from 1470 to 1790 mm (mean of 1595).

4.3.6 Water use efficiency

The highest water use efficiency (8 kg/ha/mm) was recorded where the water was maintained in the furrows all season (Table 7).

TABLE 7

PRODUCTION AND WATER USE PARAMETERS IN EXPERIMENT 3

Harvest index is displayed in the column headed ‘HI’. The value for water use includes effective rainfall and change in soil stored moisture. Water use efficiency is the quantity of grain in kg/ha (@ 14% moisture) produced per mm water used.

Treatment	Grain yield (t/ha)	HI	Water use (mm)	Water use effic. (kg/ha/mm)
Flat layout; aerial sown; ponded (control) (**T1**)	11.8	0.43	1595	7.4
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf (**T2**)	10.4	0.37	1295	8.0
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf; ponded at PI (**T3**)	11.1	0.45	1700	6.5
lsd (P = 0.05)	P=0.08		235	

4.4 2000/2001 'Old Coree' Jerilderie

4.4.1 Crop phenology

The Amaroo crop sown on 19th October, reached PI on 11th January and physiological maturity on 20th March. As indicated in the methods (section 3) the combine sown treatment was abandoned, leaving only the two treatments common to all four seasons.

4.4.2 Dry matter production

The weather at establishment was unfavourable for good crop growth. Although both treatments were aerial sown into ponded water, the ponded control had 20% more tillers at PI. At flowering the ponded control had produced 2040 g/m^2 compared with 1520 g/m^2 for raised bed layout where water was lowered to 'in furrow' at the 3 leaf stage. At physiological maturity advantage to the control was still substantial (2720 g/m^2 cf. 1850 g/m^2).

4.4.3 Grain yield

The grain yield where water was maintained in the furrows for most of the season was 20% lower than the ponded control treatment (Table 8).

4.4.4 Harvest index

The harvest index of both treatments was similar (Table 8).

4.4.5 Water use

Water use was high in this experiment (2280 mm for the ponded control; Table 8). The previous season, on the same site, this treatment recorded 1595 mm. Water use, where water was ponded only in the furrows for most of the growing season, was 7% lower than the ponded control (Table 8).

4.4.6 Water use efficiency

Water use efficiency was considerably lower than that recorded in the previous experiments. This was primarily due to the high water use. The ponded control was more efficient than where water was maintained in the furrows for most of the growing season (Table 8).

TABLE 8

PRODUCTION AND WATER USE PARAMETERS IN EXPERIMENT 4

Harvest index is displayed in the column headed ‘HI’. The value for water use includes effective rainfall and change in soil stored moisture. Water use efficiency is the quantity of grain in kg/ha (@ 14 % moisture) produced per mm of water used.

Treatment	Grain yield (t/ha)	HI	Water use (mm)	Water use effic. (kg/ha/mm)
Flat layout; aerial sown; ponded (control) (**T1**)	11.9	0.44	2280	5.2
Raised bed layout; aerial sown; water level lowered to ‘in furrow’ at 3 leaf (**T2**)	9.4	0.45	2115	4.2

4.5 2000/2001 ‘Zennor’ Jerilderie

In 2000/2001, Nick Elwood, ‘Zennor’ Jerilderie grew four hectares of rice on the raised bed layout. The raised beds were constructed across the relative flat slope of 1 in 2000 within a conventional rectangular landformed rice bay. The bed width was 1.8 m from furrow to furrow. The opportunity was taken to monitor crop growth in detail (with assistance from Matthew Tubb, a summer student from the University of New England, Armidale).

The crop was combine sown into rainfed moisture on the 3rd November. Plant emergence was rapid and uniform. There were seven rows spaced at 22 cm on the ’top of the bed’. The outside rows were virtually on the bed shoulder and emergence was not as uniform as the centre five rows.

4.5.1 Water management

The first ‘in furrow’ irrigation was applied on 8th November, five days after sowing. This timing was required as the rainfall utilised to sow the crop had not penetrated much below the sowing depth. Water was maintained in the furrow until it had ‘subbed’ to the centre of the bed (2-3 days) and was than allowed to evapotranspire or soak away (not drained). A further four ‘in furrow’ irrigations were applied. Following the final ‘in furrow’ irrigation (28th December; 55 DAS) the water was maintained in the furrows. Several days after PI (PI occurred about the 15th January) the water level was raised to approximately 10 cm above the ‘top of the bed’. The flood was maintained until draining in preparation for harvest.

A small area (six beds by 30 m) was not ponded but had the water maintained ‘in furrow’ throughout the reproductive growth period of the crop. Under these conditions a ‘perched’ watertable was created about 12 cm below the bed surface. This arrangement enabled a comparison of crop growth where water only ‘subbed’ from the furrows into the bed and where the water was ponded over the beds.

4.5.2 Dry matter production.

The crop had produced 600 g/m^2 at PI, 1190 g m^2 at flowering and 2150 g/m^2 at physiological maturity. There was no advantage from ponding the water.

4.5.3 Grain yield and harvest index

Grain yield from quadrats (one metre of row by seven rows) was 1080 g/m^2 (10.8 t/ha). There was no difference due to water management. The 'commercial' yield was 10 t/ha from the four hectare bay. Harvest index was 0.52 from both systems of water management.

5 DISCUSSION

5.1 Experiment 1

There was considerable variation in water use between plots with the same water management treatment despite a 'conventional' soil survey undertaken when the Field Station was acquired indicating little variation in soil type across the site chosen for the experiment. An EM 31 survey undertaken after the conduct of experiment one indicated that the variation in water use was related to 'soil properties', as measured by the EM readings across the experimental site. Based on the survey data, one plot with a substantially lower EM reading (higher water use; Beecher et al, 2002) from treatments one, two, four, five and eight was treated as a 'missing plot' for parameters involving water use (water use and water use efficiency). Unfortunately, treatment one included a second plot that recorded a low EM. This plot has been retained in the water use measurements. If it had also been excluded, reducing four replications to only two, than the value shown in Table 4 for water use would be lower (1560 mm in lieu of 1710 mm) and for water use efficiency higher (7.2 in lieu of 6.8).

The 20 plots required for experiment two, were positioned on the area with the highest EM values thus reducing the variability experienced in experiment 1 (32 plots).

Grain yield from treatment five (raised bed layout; aerial sown; water level lowered to 'in furrow' at 3 leaf) was much lower than all the other treatments sown at the same time. A high number of tillers (1500 m^2) together with water not 'subbing' to the centre of the bed resulted in a lot of panicles, especially in the centre of the bed, having a high level of sterility.

5.2 Experiment 2

Maintaining water in the furrows all season (T2) delayed flowering by 13 days. This delay was longer than that recorded in the other three seasons where any delay was only a few days. Ponding the water prior to PI reduced the delay to nine days. Delays of this magnitude are unlikely to be an issue in commercial crops.

Maintaining water only in the furrows during experiment 1 did not prevent moisture stress in the centre of the bed. Water did not 'sub' to the centre of the bed and plants growing in the centre rows often displayed visual signs of drought stress. Thus yield was reduced and water use would also have been lower than if subbing had been satisfactory. To maintain water in the furrows and to measure the quantity applied, water was added to the plots three times per week. Often by Monday morning (water added the previous Friday) the furrows would have no surface water left in them. Presumably these treatments would have used more water if it had been possible to maintain water in the furrow throughout the additional day involved with the weekend.

To alleviate this water deficit in experiment two, sufficient water was added to the plots on Fridays to cover the surface of the beds (shallow – 10-20 mm). This ensured that water was available to 'sub' into the bed through to the next water application on Mondays. Table 5 indicates that there was no reduction in water use compared with the ponded control treatment. Although not statistically significant (P=0.08), grain yield was still reduced.

5.3 Experiment 4

Water use in experiment four was particularly high (2280 mm or 23 ML; Table 8). This crop was 'rice on rice' and the soil profile would have been virtually 'full; saturated' for the whole growing season. This contrasted with experiment three, the first crop on this site, where the profile had to wet up whilst the crop was growing. Accessions below the root zone are controlled by the hydraulic conductivity of the soil. Hydraulic conductivity is much higher at saturation than at field capacity (Lyle et al, 1986). The soil type at 'Old Coree' is a texturally-uniform clay to depth and is known to require more water for ponded rice than the other soil types used for rice production on the Riverine Plain (van der Lelij et al, 1978). No 'throttle' effect (Loveday et al, 1978; van der Lelij, 1978) develops in this soil type.

5.3 Experiment 5

Approximately 15% of the bay was heavily infested with barnyard grass and a yield monitor on the header indicated a yield as low as 3 t/ha from this area. Thus the yield from the remainder of the bay was higher than the 10 t/ha recorded for the whole bay.

5.4 General discussion

5.4.1 Grain yield

Maintaining water in the furrows all season reduced grain yield by 11, 7, 10 and 20% for experiments 1 – 4 respectively (this treatment in experiment 4, despite the application of 100 kg N/ha appeared to be lacking nitrogen up until PI. Two substantial falls of rain, both 30 mm, during early establishment may have contributed to N losses. Rainfall would not have affected the nitrogen dynamics of the ponded control).

Cool night temperatures during the early pollen microspore stage of crop development may reduce grain yields through increased sterility and deep ponded water is recommended to alleviate this effect. Temperatures experienced during this project were not considered to be conducive to cold damage. Although sterility was not measured, no affected panicles were observed.

In three of the four experiments harvest index was lower where water was maintained only in the furrows. Moisture stress during panicle development and grain filling may have contributed to this result.

Three of the five experiments included a treatment where water was ponded at PI, following a period of time where water was only in the furrows. On each occasion this treatment produced a grain yield equivalent to that obtained from the ponded control (Tables 4, 5 and 7).

5.4.2 Water use - where water was maintained in the furrows

Water use by the crop, where water was maintained in the furrows, was reduced by 18, 18 and 7% for experiments 1, 3 and 4 respectively. This is lower than the 32% recorded in Queensland (Borrell, 1997). As discussed above for experiment one, water use from treatments where water was maintained in the furrows (not ponded) would have been higher if water supply from the furrow had not been exhausted by the beginning of most weeks. Thus the reduction in water use from growing rice on the raised bed layout with water maintained in furrow would have been less than was recorded under the experimental conditions imposed here

In Queensland, Borrell recorded a water use of 1400 mm. As potential evapotranspiration was approximately 650 mm deep drainage was substantial (approximately 7 mm per day). Although described as a grey clay, particle size analysis measured 10% coarse sand, 37% fine sand and 37% clay.

5.4.3 Water use - plot to plot variation

Variation in water use from plots under the same water management has already been discussed for experiment 1 (5.1 above). At ‘Old Coree’, an EM 31 survey indicated that the area chosen for experiments 3 and 4 was relatively uniform. In experiment 3, the ponded control plots recorded a water use of 1595 mm with a range from 1470 to 1790 mm. Although the combine sown treatment was abandoned in experiment 4 the plots were reseeded and treated as for the ponded control. The six ponded plots recorded an average water use of 2205 mm with a range from 1860 to 2465 mm. Thus when attempting to measure water use in ‘small plots’ it is recommended that there be a minimum of four replications and/or that differences in water management between treatments be substantial.

5.4.4 Water use efficiency

Where water was maintained in the furrows, water use efficiency was higher in experiments 1 and 3 but lower in experiment 2, then for the ponded control treatment (experiment 4 is not included in this discussion because of suspected nitrogen limitations to grain yield – 5.4.1 above). Ponding water just prior to PI, following a period where it was maintained in the furrows, further reduced water use efficiency in all three experiments despite an increase in grain yield. Water use was increased proportionately more than grain yield.

Sowing later (experiment one) or earlier (experiment two), both with quicker maturing varieties, resulted in a reduction in water use efficiency. Grain yield was reduced more than water use. Shortening the growing season (reducing the time that the water is ponded) will only improve water use efficiency if grain yield is maintained.

5.1 Research outcomes compared with project objectives

The project evaluated water use efficiency of rice grown on raised beds on two of the principal soil types used for rice production. The opportunity to explore water management options on the raised bed layout was undertaken in three of the four growing seasons.

The water use of short season varieties was examined in the first two experiments. In experiment one, Jarrah was sown four weeks later than the mid-season control and in experiment two Millin was sown eighteen days earlier than the mid-season control. In both situations water use was not significantly reduced.

5.1.1 New releases from the breeding program

New varieties (eg. Quest; 2003) are continually being released and grown by the rice industry. Where the rice is aerial sown and water is ponded for the whole season, the variation in growing season (as determined by data collected during evaluation by the rice breeders) should be sufficient to provide a guide to comparative water use (by relating growing season to long term average potential evapotranspiration). Because of variation in growing season climate (temperature, wind run and solar radiation) and the variability from plot to plot evident from this project (presumably due to differences in drainage below the root zone) more detailed evaluation of water use of the new cultivars is unlikely to be warranted.

6 IMPLICATIONS AND RECOMMENDATIONS

This project demonstrated that rice can be successfully grown on the raised bed layout. Reductions in water use (at least on soils approved as suitable for rice production) will not be as substantial as those reported from Queensland.

Maintaining water in the furrows all season will probably reduce grain yield by 10%. To supply the crop with its water requirement water will need to ‘sub’ readily to the centre of the raised bed. From PI to flowering, crop growth rates are as high as 250-300 kg/ha/day, thus requiring a nonlimiting supply of water to the rootzone of the crop. If water is ponded before PI (10 days) than grain yield reduction may be minimal.

If commercial crops are grown on the raised bed layout than any opportunity to monitor the crop growth and water use should be taken

7 INTELLECTUAL PROPERTY

There is no tangible intellectual property arising from this project. However, potential improvements to water use efficiency of the rice crop are detailed in this report. The report will be published in the public domain, providing the opportunity to extend any benefits to growers through established networks.

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