



**RICE CRC**  
**FINAL RESEARCH REPORT**

*P1204(B)FR06/05*

*ISBN 1 876903 23 6*

<b>Title of Project :</b>	<b>Strategies for improving the water use efficiency of rice</b>
<b>Project Reference number :</b>	<b>1204(B)</b>
<b>Research Organisation Name :</b>	<b>NSW Department of Primary Industries</b>
<b>Principal Investigator Details</b>	
<b>Name :</b>	<b>J A Thompson</b>
<b>Address :</b>	<b>PO Box 736, Deniliquin, 2710</b>
<b>Telephone contact :</b>	<b>03 5881 9928</b>

# **STRATEGIES FOR IMPROVING THE WATER USE EFFICIENCY OF RICE**

John Thompson <sup>1,2</sup>, Don Griffin <sup>1,2</sup>

<sup>1</sup>Cooperative Research Centre for Sustainable Rice Production  
C/- Yanco Agricultural Institute  
PMB Yanco 2703  
<http://www.ricecrc.org>

<sup>2</sup>NSW Department of Primary Industries  
PO Box 736, Deniliquin, 2710

Rice CRC Final Report – Project No: 1204(B)

## TABLE OF CONTENTS

NON-TECHNICAL SUMMARY .....	1
ABSTRACT.....	2
BACKGROUND .....	3
1. OBJECTIVES .....	4
2. METHODOLOGY .....	4
2.1 Plot size and replication.....	4
2.2 Crop agronomy .....	4
2.3 Measurements.....	5
2.4 Site specific experimental details .....	5
3. RESULTS .....	7
3.1 Experiment 1 (2001/2002).....	7
3.2 Experiment 2 (2002/2003).....	10
3.3 Experiment 3 (2002/2003).....	12
3.4 Experiment 4 (2003/2004).....	14
4. DISCUSSION .....	17
4.1 Experiment 1 .....	17
4.2 Experiment 2 .....	17
4.3 Experiment 4 .....	17
4.4 General discussion.....	18
5. IMPLICATIONS AND RECOMMENDATIONS .....	20
6. INTELLECTUAL PROPERTY .....	20
7. ACKNOWLEDGEMENTS .....	20
8. REFERENCES .....	20

## **NON-TECHNICAL SUMMARY**

This project further explores opportunities to improve the water use efficiency of the rice crop. It continues on from Project 1204(A), 'Improving the water use efficiency of rice', which investigated growing rice on a raised bed layout.

Field experiments were conducted to evaluate two approaches that may increase the water use efficiency of the rice crop. One approach was to delay flooding (the application of permanent water) until approximately ten days before panicle initiation. Intermittent irrigations were applied, as required by the establishing crop, until the application of the permanent flood. Two experiments included both aerial and combine sown plots.

The second approach was a water management strategy termed mid-season 'drain'. This involves removing surface water from the crop for about seven days towards the end of tillering. The rice plants experience visible moisture stress before the flood water is re-applied. This technique is recommended practice in the Philippines and regions of China.

Water use was quantified and agronomic performance of the rice crop was monitored.

Plots grown with delayed flooding produced equivalent yields to the fully ponded control. Water use was reduced by 8-18%; thus water use efficiency was increased.

Mid-season drain increased grain yields by 6, 10 and 9% for the three growing seasons covered in this report. Whilst none of these yield increases were statistically significant there is sufficient evidence of an increase in grain yield to warrant further investigation. Water use efficiency was increased.

Results from this project and from Project 1204(A) indicate that where water use is the total water balance ie. includes rainfall and change of storage in the profile, water use efficiency of a fully ponded crop is unlikely to exceed 7.5 kg/ha/mm (0.75 t/ML).

## Abstract

The cost of irrigation water accounts for 30-38% of the total variable costs of rice production in the Murray and Murrumbidgee Valleys. Rice production consumes a substantial proportion of the available supply of irrigation water. Any water management practice that has the potential to reduce water use and/or increase water use efficiency should be investigated.

This project evaluated two approaches that may increase water use efficiency of rice – delayed flooding and a water management strategy termed mid-season ‘drain’. Water use was quantified and agronomic performance of the rice crop monitored.

Delayed flooding involves intermittent irrigation of the crop until about ten days prior to panicle initiation. The scheduling (and number) of intermittent irrigations will be determined by the growing season temperatures. In the experiments reported here the combine sown treatments received eight irrigations as well as the first flush which initiated germination. The aerial sown treatments received three or four irrigations once the crop had established. The time taken for establishment (3-4 leaves) ranged from 34-43 days.

Mid-season ‘drain’ involved removing surface water from the crop for about seven days towards the end of tillering. The rice plants experience visible moisture stress before the flood is re-applied.

Plots grown with delayed flooding produced equivalent yields to the fully ponded control. Water use was reduced by 8-18%; thus water use efficiency was increased.

Mid season ‘drain’ increased grain yields by 6, 10, and 9% for the three growing seasons covered in this report. Whilst none of these increases in yield were statistically significant there is sufficient evidence of an increase in grain yield when the crop experienced a mid-season ‘drain’ to warrant further investigation.

In commercial crops, when mid-season ‘drain’ is practised, a reduction in water use of about 50 mm (0.5 ML/ha) could be expected.

Results from this project and from project 1204(A) indicate that where water use is the total water balance ie. includes rainfall and change of storage in the soil profile, water use efficiency from a fully ponded crop is unlikely to exceed 7.5 kg/ha/mm (0.75 t/ML).

**NB:** Throughout this document “*water use efficiency*” = “*water productivity*”

## BACKGROUND

The cost of irrigation water accounts for 30-38% of the total variable costs of rice production in the Murrumbidgee and Murray Valleys (2004/2005 water prices: Singh and Fleming, 2004). This is an increase from the 20-30% reported for 1995/1996 in a previous Final Report (Project 1204A) of the CRC for Sustainable Rice Production (Thompson et al, 2003).

Project 1204(A) examined the water use of rice grown on a raised bed layout (Thompson et al, 2003). Maintaining water in the furrows all season reduced water use by 14% compared with the conventional fully ponded flat layout. However, grain yield was 10% lower resulting in little improvement in water use efficiency.

Two other approaches to increase water use efficiency are delayed flooding (application of permanent water) and a water management strategy termed mid-season 'drain'.

**Delayed flooding.** Delayed flooding (intermittent irrigation until about ten days before panicle initiation (PI)), as a strategy to reduce the water requirement of the rice crop, was evaluated at Yanco in the early 1980's. This work involved the variety Calrose as the benchmark variety. Current varieties have a much higher yield potential and should be evaluated under delayed flooding. The Yanco experiments indicated water savings of 20-25% (Heenan and Thompson, 1984a; Heenan and Thompson, 1984b) however, there was substantial deep drainage at the Yanco site which made computation of actual water use difficult and perhaps the results are misleading. The proposed site at Deniliquin should have much reduced drainage below the rootzone. The Yanco work was conducted with combine sown rice. Aerial sowing will also be included at Deniliquin.

**Mid-season 'drain'.** A treatment that involved removing surface water from the crop for about seven days towards the end of tillering (long enough for the rice plants to experience visible moisture stress) will also be evaluated. In 2000/2001 the Hatty family (ricegrowers located between Finley and Tocumwal) grew seven crops of rice. Two of these crops were unintentionally exposed to mid-season 'draining' ('problems' with water supply). The grain yields were 13.4 and 12.4 t/ha. The remaining five crops averaged 10.4 t/ha.

In the 1970's, allowing the soil to drain and to experience moderate drying, was being recommended in the Philippines (Lindsay Evans, personal communication). They recommended drying the soil during the lag vegetative phase – late tillering but before PI. It is also employed in a number of regions in China.

# 1. OBJECTIVES

This project is an extension of Project 1204(A) and aims to investigate additional opportunities to improve the water use efficiency of the rice crop.

This project will evaluate the effect of delayed flooding and mid-season 'draining' on grain yield and water use.

Water use will be quantified and agronomic performance of the rice will be monitored.

# 2. METHODOLOGY

Four replicated field experiments were conducted over three growing seasons - 2001/2002 to 2003/2004. All four experiments were conducted at NSW Agriculture's Murray Valley Field Station, Deniliquin.

## 2.1 Plot size and replication

All plots were approximately 12 m in width. Plot length was approximately 40 m in 2001/2002 and 2002/2003 and 45 m in 2003/2004. An additional experiment in 2002/2003 (Experiment 3) had a plot length of 65 m.

A randomised block design was used for all experiments. Experiments 1, 2 and 4 had four replications (severe damage from ducks at establishment reduced Experiment 2 to three). Experiment 3 had three replicates.

All treatments in all experiments were grown on a 'flat' layout.

## 2.2 Crop agronomy

### 2.2.1 *Sowing rate*

The sowing rate was as recommended in NSW Agriculture's Ricecheck publication (approximately 140 kg/ha).

### 2.2.2 *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

## 2.3 Measurements

### 2.3.1 *Water use*

Water use was measured by change in bay water level. 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.

### 2.3.2 *Crop phenology*

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

### 2.3.4 *Dry matter production*

Samples for dry matter production were taken at PI, flowering and physiological maturity. Some treatments were also sampled at 'times of interest' before PI. The sample size was 1 m<sup>2</sup> (0.25 m<sup>2</sup> before PI). All samples were dried at 80°C until constant weight was achieved.

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

### 2.3.5 *Grain yield*

Grain yields were obtained using a 'small plot' header. Header width was 1.8m and there were two strips approximately 10 m in length (18 m for experiment 3) 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.

## 2.4 Site specific experimental details

### 2.4.1 *Experiment 1 (2001/2002)*

Soil type: transitional red-brown earth.

Variety: Amaroo and Illabong (split plot).

Sowing date: combine sown – 3<sup>rd</sup> October; aerial sown – 17<sup>th</sup> October

Nitrogen fertiliser rate: 150 kg N/ha (as urea) pre-plant for aerial sown treatments; 50 kg N/ha pre-plant plus 100 kg N/ha before permanent flood. Topdressing at PI was not required.



Water management: all treatments were ponded (some re-ponded) by ten days before PI and then kept ponded for the remainder of the growing season. All treatments had 'deep' water during the early pollen microspore growth stage (for protection against cold night temperatures).

#### Treatments

1. Aerial sown; ponded all season (control).
2. Aerial sown; mid-season 'drain'. No surface water for 80 mm of cumulative ETo.
3. Aerial sown; intermittent irrigation once established (40 days after sowing (D40)) until ten days before PI. Irrigations were scheduled at 50-60 mm of cumulative ETo. There were four intermittent irrigations.
4. Combine sown; permanent flood at 3 leaf stage.
5. Combine sown; intermittent irrigation until ten days before PI. Irrigations scheduled as for T3. There were eight intermittent irrigations after the first flush which initiated germination.

#### 2.4.2 Experiment 2 (2002/2003)

Soil type: transitional red brown earth

Variety: Amaroo and Illabong (split plot)

Sowing date: combine sown – 1<sup>st</sup> October; aerial sown – 16<sup>th</sup> October

Nitrogen fertiliser rate: 18 kg N/ha (as DAP) plus 132 kg N/ha (as urea) pre-plant for aerial sown treatments; 18 kg N/ha (as DAP) plus 31 kg N/ha (as urea) plus 100 kg N/ha (as urea) prior to permanent flood. Topdressing at PI was not required.

Water management: all treatments were ponded (T2 re-ponded) by ten days before PI and then kept ponded for the remainder of the growing season. All treatments had 'deep' water during the early pollen microspore growth stage.

#### Treatments

1. Aerial sown; ponded all season (control).
2. Aerial sown; intermittent irrigation once established (D43) until ten days before PI. Irrigations were scheduled at 55-60 mm ETo. There were three intermittent irrigations.
3. Combine sown; permanent flood at 3 leaf stage.
4. Combine sown; intermittent irrigation until ten days before PI. Irrigations scheduled as for T2. There were eight intermittent irrigations after the first flush which initiated germination.

#### 2.4.3 Experiment 3 (2002/2003)

Soil type: transitional red-brown earth

Variety: Amaroo

Sowing date: 16<sup>th</sup> October.

Nitrogen fertiliser rate: 18kg N/ha (as DAP) plus 132 kg N/ha (as urea) pre-plant. Topdressing at PI was not required.

Water management: all treatments were ponded (T2 and T3 re-ponded) by ten days before PI and then kept ponded for the remainder of the growing season. All treatments had 'deep' water during the early pollen microspore growth stage.

#### Treatments

1. Aerial sown; ponded all season (control)
2. Aerial sown; mid-season 'drain'. No surface water for 90 mm of cumulative ETo
3. Aerial sown; mid-season 'drain'. No surface water for 130 mm of cumulative ETo

#### 2.4.4 Experiment 4 (2003/2004)

Soil type: red-brown earth

Variety: Amaroo and Quest (split plot)

Sowing date: 22<sup>nd</sup> October

Nitrogen fertiliser rate: 132 kg N/ha (as urea) pre-plant. Topdressing at PI was not required.

Water management: all treatments were ponded (T2 and T3 re-ponded) by ten days before PI and then kept ponded for the remainder of the growing season. All treatments had 'deep' water during the early pollen microspore growth stage.

#### Treatments

1. Aerial sown; ponded all season (control).
2. Aerial sown; intermittent irrigation once established (D34) until ten days before PI. Irrigations were scheduled at approximately 55 mm of cumulative ETo. There were three intermittent irrigations.
3. Aerial sown; intermittent irrigation once established (D34) until ten days before PI. Water remained ponded between every second irrigation of T2.
4. Aerial sown; mid-season 'drain'. No surface water for 80 mm of cumulative ETo.
5. Aerial sown; mid-season 'drain'. No surface water for 120 mm of cumulative ETo.

## 3. RESULTS

### 3.1 Experiment 1 (2001/2002)

All results are for Amaroo unless there is a specific reference to Illabong.

#### 3.1.1 Crop phenology

Illabong reached PI on the 17<sup>th</sup> January (D93) four days before Amaroo (T1). All plots had reached physiological maturity by 2<sup>nd</sup> April (D168 for aerial sowing).

### 3.1.2 Plant height

Plant height was not significantly influenced by water management.

### 3.1.3 Dry matter production

At the time of re-ponding for the intermittent aerial sown treatment (T3; D74) it had produced 80% of the ponded control (T1) (575 g/m<sup>2</sup> v 460 g/m<sup>2</sup>). At PI, the advantage for the control was similar but had decreased to (87%) at flowering (from Table 1). The difference was similar at physiological maturity.

Production from the aerial sown mid-season ‘drain’ treatment (T2) was similar to the control at each time of harvest (Table 1).

**TABLE 1**

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

Treatment	Panicle initiation (g/m <sup>2</sup> )	Flowering (g/m <sup>2</sup> )	Physiological maturity (g/m <sup>2</sup> )
Aerial sown; ponded (control) (T1)	955	1820	2335
Aerial sown; mid-season ‘drain’ – no surface water for 80 mm of cumulative ETo (T2)	985	1810	2385
Aerial sown ; intermittent irrigation once established; re-ponded ten days before PI (T3)	750	1575	2040
Combine sown; permanent flood at 3 leaf stage (T4)	770	1790	2165
Combine sown; intermittent irrigation until ten days before PI (T5)	600	1335	1945
lsd (P = 0.05)	140	230	240

The combine sown intermittently irrigated treatment (T5) produced 78% and 75% of the combine sown control (T4) at PI and flowering respectively (Table 1). At physiological maturity this had increased to 90%.

At flowering, there was no significant difference in dry matter production between the three aerial sown treatments (Table 1). The combine sown treatments (T4 and T5) had produced significantly less but there was no difference between them (Table 1).

The same comments apply to dry matter production at physiological maturity (Table 1).

### 3.1.4 Panicle number

Counts from the 1 m<sup>2</sup> quadrats taken at flowering, indicated that mid-season ‘draining’ (T2) resulted in fewer panicles than the ponded control (T1) – 840 v 925/m<sup>2</sup>. The two combine sown treatments produced 715 and 745 panicles per m<sup>2</sup> for T4 and T5 respectively.

### 3.1.5 Grain yield

Although there was no significant differences in grain yield the highest grain yield for Amaroo was produced by the mid-season ‘drain’ treatment (T2; Table 2). The highest yield for Illabong was also from T2. The advantage for the drained treatment was 5% and 7% for Amaroo and Illabong respectively. If replicate 3, which produced a yield reduction, is excluded than the advantage increases to 14% and 12% for Amaroo and Illabong respectively.

Illabong yielded substantially higher than Amaroo for all treatments – 32,33,20,25, and 19% for T1 to T5 respectively.

**TABLE 2**

**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. 5.6 kg/ha /mm = 0.56 t/ML). As the plots were split for variety, the grain yield used to calculate water use efficiency is the mean of Amaroo and Illabong.

Treatment	Grain yield (t/ha)	Water use (mm)	Water use efficiency (kg/ha/mm)
Aerial sown; ponded (control) (T1)	9.5	1695	5.6
Aerial sown; mid-season ‘drain’ – no surface water for 80 mm of cumulative ETo (T2)	10.0	1485	6.7
Aerial sown; intermittent irrigation once established; re-ponded ten days before PI (T3)	9.2	1395	6.6
Combine sown; permanent flood at 3 leaf stage (T4)	8.7	1570	5.5
Combine sown; intermittent irrigation until ten days before PI (T5)	8.8	1295	6.8
lsd (P = 0.05)	n.s.	125	

For both varieties, the yield from the intermittently irrigated treatments (T2, T5) was similar to their ponded counterparts (T1, T4 respectively; Table 2).

### 3.1.6 *Harvest index*

Water management had little effect on harvest index (mean 0.39 for Amaroo). Although not statistically significant ( $P = 0.053$ ), the combine sown treatments (T4, T5) had a higher harvest index (mean of 0.41) than the aerial sown treatments (T1, T2, T3) (mean of 0.38). Illabong had a much higher harvest index (mean of 0.50) than Amaroo.

### 3.1.7 *Water use*

The aerial sown control (T1) recorded the highest water use (1695 mm; Table 2). Both intermittent treatments used significantly less water (18%) than their fully ponded counterpart (T3 v T1; T5 v T4).

### 3.1.8 *Water use efficiency*

The mid-season 'drain' treatment (T2) recorded the highest water use efficiency (7.9 kg/mm/ha) (Table2). In comparison with the fully ponded control (T1), both higher yield and decreased water use contributed to this result.

Intermittent irrigation treatments(T3, T5) were more efficient than their ponded counterparts (T1,T4; Table2). Grain yield was maintained whilst less water was used.

## **3.2 Experiment 2 (2002/2003)**

### 3.2.1 *Crop phenology*

The combine sown treatments reached PI approximately ten days before the aerial sowings (sown 16 days earlier). At flowering (D130 for the aerial sown control (T1)) and at physiological maturity (D164), the difference was reduced to only 3-4 days and two days respectively. Intermittent irrigation did not delay maturity.

### 3.2.2 *Plant height*

There was no effect of water management on plant height.

### 3.2.3 *Dry matter production*

Plant establishment of the aerial sown treatments was severely affected by duck damage in this experiment. Any measurement of production before flowering was considered to be meaningless. I consider that samples taken at flowering and physiological maturity have produced valid results as, by this time, the crop had compensated for the initial variable plant stand.

At flowering, the intermittent aerial sown treatment (T2) had produced 87% of the ponded control (T1). At physiological maturity, dry matter production was similar for all for treatments (mean 2020 g/m<sup>2</sup>; Table 3).

#### 3.2.4 Grain yield

Grain yield was not influenced by water management (no significant difference; Table 4). Although not statistically different, grain yield from the combine sown intermittently irrigated treatment (T4) was 10% lower than the corresponding treatment that was ponded from the 3 leaf stage (T3).

The grain yield from Illabong was similar to Amaroo.

**TABLE 3**

**DRY MATTER PRODUCTION AT FLOWERING AND PHYSIOLOGICAL MATURITY IN EXPERIMENT 2**

Treatment	Flowering g/m <sup>2</sup>	Physiological maturity g/m <sup>2</sup>
Aerial sown; ponded (control) (T1)	1850	2135
Aerial sown; intermittent irrigation once established; re-ponded ten days before PI (T2)	1690	2185
Combine sown; permanent flood at 3 leaf stage (T3)	Not measured	2050
Combine sown; intermittent irrigation until ten days before PI (T4)	Not measured	2115
lsd (P = 0.05)		n.s.

#### 3.2.5 Harvest index

There was no effect of water management on harvest index. The mean of all four treatments was 0.46 for Amaroo and 0.51 for Illabong.

**TABLE 4****GRAIN YIELD, WATER USE AND WATER USE EFFICIENCY IN EXPERIMENT 2**

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. 6.1 kg/ha/mm = 0.61 t/ML). As the plots were split for variety, the grain yield used to calculate water use efficiency is the mean of Amaroo and Illabong.

Treatment	Grain yield (t/ha)	Water use (mm)	Water use efficiency (kg/ha/mm)
Aerial sown; ponded (control) (T1)	11.2	1835	6.1
Aerial sown; intermittent irrigation once established; re-ponded ten days before PI (T2)	11.2	1670	6.7
Combine sown; permanent flood at 3 leaf stage (T3)	11.5	1655	7.0
Combine sown; intermittent irrigation until ten days before PI (T4)	10.3	1525	6.8
lsd (P = 0.05)	n.s.	90	

**3.2.6 Water use**

The aerial sown ponded treatment (T1) had the highest water use (1835 mm; Table 1). Both intermittently irrigated treatments (T2, T4) used significantly less water than their ponded counterparts (T1, T3) (Table 4).

**3.2.7 Water use efficiency**

The aerial sown ponded control (T1) recorded the lowest water use efficiency (Table 1). The aerial sown intermittently irrigated treatment recorded a higher water use efficiency than the ponded control. In contrast, the combine sown intermittently irrigated treatment (T4) was less efficient than the fully ponded comparison (T3). Water use was significantly lower but grain yield was also lower precluding an improvement in water use efficiency.

**3.3 Experiment 3 (2002/2003)**

This experiment also experienced considerable damage from ducks at establishment with consequent variation in plant arrangement. There was no attempt to measure any production parameters until flowering. Water use was not measured in this experiment.

### 3.3.1 Crop phenology

Surface water was drained from the plots exposed to the mid-season ‘drain’ treatments on 23<sup>rd</sup> December (D69). Water was re-ponded on D75 for T2 and D82 for T3 (20 mm of rainfall on D75 delayed re-ponding for this treatment by approximately three days). PI was recorded on 20<sup>th</sup> January (D98).

### 3.3.2 Plant height

Although not statistically significant, T2, the mid-season ‘drain’ treatment without surface water for 80 mm ETo, was taller than the ponded control (T1) (82 cm v 78 cm).

### 3.3.3 Dry matter production

The 7 % reduction in dry matter production at flowering for T3 (without surface water for 130 mm ETo) was not statistically different from the other treatments (Table 5). The reduction at physiological maturity (16%) was significant (Table 5).

### 3.3.4 Grain yield

Treatment 2 (no surface water for 90 mm ETo) produced the highest grain yield (12.2 t/ha; Table 5). Although the grain yield was 10% higher than the control treatment, it was not significantly (statistically) higher. The grain yield from T3 (no surface water for 130 mm of ETo) was significantly less than T2 but not from the control (T1) (Table 5).

### 3.3.5 Harvest index

Harvest index was similar for all treatments. The ponded control treatment (T1) produced a harvest index of 0.46.

**TABLE 5**  
**DRY MATTER PRODUCTION AND GRAIN YIELD FOR EXPERIMENT 3**

Treatment	Dry matter at flowering (g/m <sup>2</sup> )	Dry matter at physiological maturity (g/m <sup>2</sup> )	Grain yield (t/ha)
Aerial sown; ponded (control) (T1)	1665	2355	11.1
Aerial sown; mid-season ‘drain’ – no surface water for 90 mm of cumulative ETo (T2)	1620	2510	12.2
Aerial sown; mid-season ‘drain’ – no surface water for 130 mm of cumulative ETo (T3)	1535	2050	9.1
lsd (P = 0.05)	n.s.	235	2.2



### 3.4 Experiment 4 (2003/2004)

All results are for Amaroo unless there is a specific reference to Quest.

#### 3.4.1 *Crop phenology*

The aerial sown control (T1) reached PI on 13<sup>th</sup> January (D83), flowered on 17<sup>th</sup> February (D118) and was physiologically mature on 31<sup>st</sup> March (D161). Mid-season 'draining' (no surface water for 80 mm ETo; T4) delayed PI, flowering and physiological maturity by six, four, and two days respectively.

Quest, sown on the same day as Amaroo, reached PI ten days earlier and physiological maturity 15 days earlier.

#### 3.4.2 *Plant height*

At flowering T4 (mid-season 'drain'; 80 mm ETo) was significantly taller (5 cm) than all other treatments (89 cm v 84).

#### 3.4.3 *Dry matter production*

By 30<sup>th</sup> December (D70) the aerial sown control (T1) had produced 27% more dry matter than the treatment that was intermittently irrigated (T2) (795 g/m<sup>2</sup> v 580). The plants were also substantially taller (58 v 34 cm). At PI, the difference had increased to 34% (1045 g/m<sup>2</sup> v 695; Table 6). However, at flowering and at physiological maturity the intermittently irrigated treatment had similar levels of production to the ponded control (Table 6).

At PI, production of T4 (mid-season 'drain'; no surface water for 80 mm of cumulative ETo) was not significantly less than T1 (Table 6) however, T5 (no surface water for 120 mm of cumulative ETo) had produced significantly less dry matter than T1 and T4. At flowering the two mid-season 'drain' treatments (T4, T5) had the highest production (mean of 2135 g/m<sup>2</sup>), significantly higher than the fully ponded control (T1) (1875 g/m<sup>2</sup>; Table 6). The two intermittently irrigated treatments (T2, T3) had produced similar quantities to T1 (Table 6). The differences measured at flowering were maintained at physiological maturity (Table 6).

**TABLE 6****DRY MATTER PRODUCTION AT PANICLE INITIATION, FLOWERING, AND PHYSIOLOGICAL MATURITY IN EXPERIMENT 4**

Treatment	Panicle initiation (g/m <sup>2</sup> )	Flowering (g/m <sup>2</sup> )	Physiological maturity (g/m <sup>2</sup> )
Aerial sown; ponded (control) (T1)	1045	1875	2980
Aerial sown; intermittent irrigation once established; re-ponded ten days before PI (T2)	695	1760	2785
Aerial sown; water ponded between every second irrigation of T2 (T3)	825	1875	2890
Aerial sown; mid-season 'drain' – no surface water for 80 mm of cumulative ETo (T4)	950	2215	3240
Aerial sown; mid-season 'drain' – no surface water for 120 mm of cumulative ETo (T5)	755	2055	3170
lsd (P = 0.05)	115	190	210

Between PI and flowering, T4 produced 383 kg/ha/day considerably more than T1 (237 kg/ha/day). Treatment 5 also had a higher growth rate (342 kg/ha/day) than T1.

#### 3.4.4 Panicle number and sterility

Counts of panicle numbers (from one 0.2 m<sup>2</sup> ring per plot) indicated no significant difference at flowering (mean of 940 per m<sup>2</sup>).

Percent fertile florets (from 50 randomly selected panicles per plot) for T1, T4 and T5 were 76, 76, and 80% respectively. T4 (mid-season 'drain' – 80 mm) produced ten more grains (fertile florets) per panicle than the fully ponded control (T1).

#### 3.3.5 Grain yield

Intermittent irrigation (T2) produced significantly more grain yield than the ponded control (T1) (Table 7). Where the water was left ponded between every second irrigation (T3) grain yield was intermediate between T2 and T1 (Table 7)

The highest grain yield was produced from T5 (no surface water for 120 mm of cumulative ETo). Although T4 (no surface water for 80 mm of cumulative ETo) yielded 9% higher than the ponded control (T1) the advantage was not statistically significant (Table 7).

Grain yield of Quest was lower than Amaroo for all treatments (mean of 6%).

**TABLE 7****GRAIN YIELD, WATER USE, AND WATER USE EFFICIENCY IN EXPERIMENT 4**

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. 7.5 kg/ha/mm = 0.75 t/ML). As the plots were split for variety, the grain yield used to calculate water use efficiency is the mean of Amaroo and Quest.

Treatment	Grain yield (t/ha)	Water use (mm)	Water use efficiency (kg/ha/mm)
Aerial sown; ponded (control) (T1)	11.3	1505	7.5
Aerial sown; intermittent irrigation once established; re-ponded ten days before PI (T2)	12.8	1310	9.8
Aerial sown; water ponded between every second irrigation of T2 (T3)	11.8	na	na
Aerial sown; mid-season 'drain' – no surface water for 80 mm of cumulative ETo (T4)	12.3	1400	8.8
Aerial sown; mid-season 'drain' – no surface water for 120 mm of cumulative ETo (T5)	13.4	1455	9.2
lsd (P = 0.05)	1.1	120	

*3.3.6 Harvest index*

The two intermittently irrigated treatments (T2, T3) produced a higher harvest index (mean of 0.46) than the remaining treatments (mean of 0.42).

*3.3.7 Water use*

The fully ponded control (T1) used the most water (1505 mm; Table 7). Although the mid-season 'drain' treatments used less water the difference was not statistically different. Intermittent irrigation (T2) had a significantly lower water use (1310 mm) than the ponded treatment (Table 7).

### 3.3.8 *Water use efficiency*

Intermittent irrigation (T2) produced the highest water use efficiency (Table 7). Higher grain yield and reduced water use both contributed to the increase when compared with the fully ponded control (T1).

## **4. DISCUSSION**

### **4.1 Experiment 1**

Surface water was kept off one plot from the mid-season 'drain' treatment for 125 mm of cumulative ETo (compared with 80 mm). Yield from this plot was reduced by 15% compared with the ponded control suggesting that this degree of moisture stress reduced grain yield.

Water use of T1 (aerial sown ponded control) was 1695 mm. This was 400 mm (4 ML/ ha) higher than ETo minus rainfall and would have been drainage below the rootzone (there was no surface drainage). Two of the four plots in this treatment had relatively low EM 31 readings (associated with higher water use), thus the measured 1695 mm is probably excessive. Water use from the combine sown ponded treatment was 1570 mm; the aerial sown treatment should have used a similar amount. Also the drainage below the rootzone for the same treatment in experiments 2 and 4 recorded values of 245 and 205 mm respectively.

### **4.2 Experiment 2**

Although not statistically significant, the grain yield from T4 (combine sown; intermittent irrigation) was 10% less than the fully ponded T3. There was a reduction in all three replicates. This difference contrasts with results from earlier work at Yanco and experiment 1 in this project where equivalent grain yields were obtained. The 2003/2004 season experienced especially high temperatures and ETo which probably reduced vegetative growth whilst T4 was being grown with intermittent irrigation.

### **4.3 Experiment 4**

Based on results from experiments 1 (for only one replicate) and 3 it was expected that T5 (no surface water for 114 mm of cumulative ETo) would have produced a lower grain yield than T4 (no surface water for 80 mm of cumulative ETo). However, T5 outyielded T4 by 9% (Table 7). The difference was consistent for all replicates. Treatment 5 reached PI only one day later than T4 however it flowered six days later and reached physiological maturity 11 days later. Thus the duration of grainfilling was five days longer for T5. Both treatments should have been exposed to similar minimum temperatures during the cold temperature sensitive early pollen microspore stage of crop development. Examination of both temperature data and solar radiation during grainfilling cannot explain this unexpected yield increase. Treatments 1, 4 and

5 experienced similar temperatures (growing degree days) and solar radiation during their respective grainfilling periods.

Quest, because of its earlier maturity, was exposed to cooler minimum temperatures (an average of 4°C for the relevant 10 days) during early pollen microspore than Amaroo. This probably would have increased floret sterility (not measured) and thus reduced grain yield when compared to Amaroo.

Entries for water use and water use efficiency for T3 are not included in Table 7. One of plots of this treatment had an extraordinary high water use thus the mean water use is misleading.

## 4.4 General discussion

### 4.4.1 Grain yield

Intermittent irrigation cf. fully ponded. There was no significant difference in grain yield in four of the five comparisons within this project. In experiment 4 there was a significant advantage from intermittent irrigation. Although consistent for all replicates this result is considered anomalous.

Mid-season 'drain'. Although mid-season 'drain' (no surface water for 80 or 90 mm of cumulative ETo) produced increases in grain yield of 5, 10 and 9% for experiments 1, 3 and 4 respectively none of these increases were statistically significant. If replicate 3 is excluded from experiment 1 the advantage increases to 14%. Experiment 3 only involved three replicates, a total of nine plots (only eight degrees of freedom for the statistical analysis). In experiment 4 the grain yield advantage was 1 t/ha and was approaching statistical significance (lsd  $P = 0.05$ ; 1.1 t/ha). Treatment 5 which had no surface water for 114 mm of cumulative ETo realised an increased grain yield of 2.1 t/ha or 19%. This increase was statistically significant.

Despite the lack of statistical significance, there is sufficient evidence of an increase in grain yield when the crop experienced a mid-season 'drain' to warrant further investigation.

### 4.4.2 Water use

Intermittent irrigation cf. fully ponded. Where the crop was combine sown water use was lower (18% and 8% for experiment 1 and 2 respectively), than for the fully ponded control. This reduction was less than the 20-25% recorded at Yanco in the early 1980's. As indicated above experiment 2 experienced especially high temperatures and ETo which affected early crop growth and presumably water use.

Where the crop was aerial sown and subjected to intermittent irrigations once the crop was established (four, three and three irrigations for experiments 1, 2 and 4 respectively) the reduction in water use was 11, 9 and 13%.

Adopting intermittent irrigation is likely to reduce crop water use by about 10%. The 'saving' should be higher where the crop is combine sown as there are more days when the water is not ponded; evaporation from the soil surface is lower than from the water surface..

Whilst there was no problem with additional weed growth in these experiments, this may not be the situation in commercial crops.

Mid-season 'drain'. The mid-season 'drain' treatment used less water (210 and 105 mm for experiments 1 and 4 respectively) than the fully ponded control. As indicated above (section 4.1) the measured water use for the fully ponded treatment in experiment 1 was probably higher than would be expected. Commercially, there will be some reduction in water use. The crop is without surface water for 80-100 mm ETo and following re-ponding there are several days when lack of green leaf will reduce actual ET. Although crop duration is several days longer however daily ETo is much lower in late March than in late December. A reduction in water use of about 50 mm (0.5 ML/ha) would be expected.

Considerable plot to plot variation within the same treatment was observed in these experiments and also in the previous work described in Project 1204A This should encourage caution when attempting conclusions about water use. Lateral seepage was minimal and there was no surface runoff thus the differences can all be attributed to differences in drainage below the rootzone of the rice.

#### 4.4.3 *Water use efficiency*

Values calculated for water use efficiency ranged from 5.6 to 9.8 kg/ha/mm of water used. In each of the three experiments where water use was measured the fully ponded treatment (T1) recorded the lowest value.

All other treatments had higher water use efficiencies from either reduced water use (treatments involving intermittent irrigations) or both reduced water use and higher grain yield (mid-season 'drain').

Results from this project and from Project 1204(A) indicate that where water use includes the total water balance ie. rainfall and change of storage in the soil profile, water use efficiency from a fully ponded crop is unlikely to exceed 7.5 kg/ha/mm (0.75 t/ML).

## **5. IMPLICATIONS AND RECOMMENDATIONS**

Results from this project show that rice grain yields can be maintained whilst using intermittent irrigations during the period of vegetative growth. Water use will be reduced by 10-15%. There may be issues with weed control in commercial crops, especially if combine sown.

Although not statistically significant, there is sufficient evidence of an increase in grain yield in response to a mid-season 'drain' to warrant further investigation. Growers should be encouraged to trial one or two bays of their crops.

## **6. 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.

## **7. ACKNOWLEDGEMENTS**

We thank Jim Small for assistance at the Murray Valley Field Station, especially with sowing of the experiments and with water management throughout the growing season. John Smith also assisted at sowing and with the measurement of grain yield (harvest with 'small plot' header).

## **8. REFERENCES**

NSW Agriculture (2001, 2002, 2003) Ricecheck Recommendations. NSW Agriculture and RIRDC Rice Research & Development Committee.

Singh R.P, and Fleming, M. (2004) Summer Crop Budgets – Southern Irrigated Zone.

Heenan, D.P, and Thompson, J.A. (1984a) Growth, grain yield, and water use of rice grown under restricted water supply in New South Wales. *Australian Journal of Experimental Agriculture* 24: 104-109.

Heenan, D.P, and Thompson, J.A. (1984b) Managing rice to increase water use efficiency in New South Wales. In: Muirhead WA, Humphreys E, editors. *Rootzone limitations to crop production on clay soils*. Symposium of the Riverina Branch of the Australian Society of Soil Science. Griffith. 25-27 September 1984. p 264-267

Thompson, J.A, Griffin, D, and North, S. (2003) *Improving the Water Use Efficiency of Rice*. Rice CRC Final Report Project 1204(A) Cooperative Research Centre for Sustainable Rice Production, Yanco, NSW, Australia.17.