RICE CRC

FINAL RESEARCH REPORT

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SUMMARY

Trials conducted as part of the Cooperative Research Centre for Sustainable Rice Production during 2003-2004 investigated alternative weed management, cultivar assessments and fertiliser strategies in order to improve the sustainability of organic rice production systems in the NSW Riverina.

Results indicated there was no immediate rice yield benefit to organic producers by applying any of the various organic fertilisers tested. Ongoing experimentation may have shown benefits to cereal or pastures which followed in the rotation, but this was not evaluated. The authors recommend that organic rice farmers carefully monitor crop yield responses to fertiliser applications and carefully consider the cost:benefit of fertiliser applications to their cropping and livestock rotation.

Whilst the yields achieved for organic rice during the experiments were low compared to district averages for ‘conventionally’ grown rice during the 2003-04 season (yields ranged from 71-86% of conventional yield), they were well above the 50-75% yield reduction cited as typical for organically produced rice compared to conventional rice.

The authors recommend that organic rice producers investigate a number of strategies to improve nutrient cycling within the rice rotation. This includes strategies to maximise symbiotic N fixation during the pasture phase such as shortening the pasture phase to two years, ensuring a high (at least 90%) legume component in pastures and improving pasture nutrition (particularly P), water use efficiency and grazing management. The value of incorporating green manuring within the farming system to increase N cycling, provide weed breaks and alternative cropping and grazing opportunities should also be investigated.

Rice establishment techniques (sowing method, fertiliser placement and flushing) may have a significant impact on N losses and rice yields. Sod-seeding rice into a legume pasture, the method commonly used by organic producers, is the preferred sowing method for preserving organic nitrogen as there is zero cultivation and hence slow plant decomposition. Organic farmers can further reduce N losses during establishment by minimising flushing and by applying organic fertilisers or composts prior to permanent water (as opposed to sowing application).

There was no statistical evidence that the application of liquid lime and molasses after sowing prevented the germination of some weeds, and that a homeopathic remedy made out of Barnyard grass seeds would decrease populations of barnyard grass over time. A field demonstration showed that harrowing could produce an effective post-emergent control for barnyard grass, providing the timing of harrowing and soil condition is optimal.

BACKGROUND TO THE PROJECT

Markets for Australian organic[1] rice have been identified domestically, in Europe, and in Asia (particularly Japan). SunRice predicted that the demand for Australian organic rice will increase from 2205 tonnes finished product (FP) in 2003 to 2640 tonnes FP in 2004, with the greatest increase in the Food Ingredients category. However, organic rice production still falls well short of both domestic and export requirements with total production in 2004 of around 1382 tonnes paddy (830 tonnes FP). Whilst water shortages account for reduced production in 2004, agronomically, the yield of organic rice is significantly lower than rice produced using conventional production methods (SunRice, 2004).

The environmental benefits of an increase in the area under organic farming systems include significant reductions in the use of soluble chemical fertilisers and a reduction in the use of agricultural chemicals used to control weeds and pests. This will lead to improvements in catchment water quality. In addition, reduced pesticide usage will prevent the build up of resistance to these sprays amongst weed and pest populations and reduce the potential for chemical residues in food products.

The social benefits identified include the increased production and availability of organically grown food to the wider community. Producers will gain a better understanding of organic production systems which will enable them to confidently manage their land in an efficient and environmentally sustainable way.

OBJECTIVES

The project proposed the benchmarking of existing organic rice production techniques and the identification of opportunities to increase the sustainability of Australian organic rice production systems.

The project supports the main objectives stated in Program 2 of the Rice CRC Strategic Plan:

Demonstrate technologies that support the drive for continued sustainability of the rice farming enterprise within the context of the ecological, economic and social environments of the region.

And the desired outcomes:

2.2.1 Improve productivity and sustainability of the organic rice-based production system, with particular emphasis on sustainable soil and crop management and pest control strategies to minimise pesticide use. A specific outcome is: soil management (particularly phosphorous and nitrogen availability) to create higher organic rice yields without loss of productive potential or environmental quality.

2.2.4 More appropriate use of fertilisers to increase production and grain quality by optimising phosphorous availability in the pasture phase and hence nitrogen fixation for the subsequent rice crop.

[1] For the purpose of this report 'organic' is used generically to encompass both organic and bio-dynamic systems of production, unless stated otherwise.

2.2.5 Minimal use of chemicals to successfully protect rice crops from insect pests, diseases and weeds by evaluating the effectiveness of existing non-chemical weed management and by investigating alternative non-chemical weed management techniques.

In addition, the project addresses the following Rice CRC Strategy:

2.3.6 Review the further potential for management, biological agents and reduced chemical use to support sustainable and profitable rice production (including organic production). Introductory technical information concerning the problem or research need

This will be achieved by conducting on-farm assessments to determine:

- the effectiveness of alternative (non-chemical) weed management techniques,
- the suitability of currently recommended rice varieties in organic production systems, and
- methods to optimise crop nutrition in organic rice production systems.

INTRODUCTORY TECHNICAL INFORMATION CONCERNING THE PROBLEM OR RESEARCH NEED

Organic rice production is primarily based on a pasture (clover, ryegrass) and livestock / rice rotation. This rotation tends to have a long pasture phase - usually 3-4 years pasture followed by 1-year rice. This is in contrast to conventional systems where a rice on rice rotation is common. The lengthened pasture and livestock phase in the organic system plays an important role in providing a weed break as well as nutrition for the subsequent rice crop. Some organic producers follow rice with a winter cereal if the soil has sufficient nutrient reserves. All crops and pastures grown in the rotation must be organically produced and all livestock managed by organic principles.

A workshop coordinated by NSW Agriculture, RIRDC and SunRice in 2002 (RIRDC, Project DAN-188A, 2002) was told that organic production has a greater risk of failure and lower yields than conventional rice production. Under current production regimes yields of organic rice are 50-75% lower than conventional rice. Crop establishment, crop nutrition and weed management were identified as key areas of management that differentiate organic and conventional systems. The workshop concluded a number of specific production constraints were limiting potential expansion of the organic rice industry. These are discussed below.

1.1 Suitability of current rice varieties

Organic producers questioned the suitability of ‘modern’ rice varieties for organic production. Existing organic producers believed that older varieties such as “Pelde” may be more suited to organic production citing better seedling vigour, less nutritional requirements, better weed competitiveness and reasonable cold-tolerance. The workshop concluded that district variety trials should be undertaken to determine the quality and yield potential of ‘new’ and ‘older’ varieties under organic management regimes.

1.2 Weed management

Weed management, particularly barnyard grass, is a significant problem in organic rice production. Since chemical controls are not an option, research into alternative methods of weed control is needed. The findings of such research would potentially have flow-on benefits for the ‘non-organic’ rice industry by reducing herbicide usage.

1.3 Rice system nutrition

The management and economic sustainability of the long pasture phase in organic rice systems requires investigation. Long pasture rotations require growers to place a greater emphasis on improving and maintaining vigour in clover pastures and maximising returns from organic livestock. In order to provide adequate rice nutrition, P availability, and hence N fixation, must be optimised during the pasture phase. What other options to the long pasture phase are available - is it possible to shorten the pasture phase and still achieve weed suppression and adequate crop nutrition without the use of artificial fertilisers and herbicides? Would this be at the expense of a profitable livestock enterprise? An improved understanding of these areas of organic rice production will potentially increase the yield, quality and economic sustainability of organic rice and encourage the conversion of more farms to organic production.

PROJECT METHODOLOGY

Introduction

A Technical Officer, Tobias Koenig, was employed to review and benchmark existing organic rice management systems and to undertake a series of experiments with particular emphasis on:

- Suitability of current rice varieties for organic production systems,
- weed management, and
- rice system nutrition.

Farmer Questionnaire

Initially, organic / bio-dynamic rice producers in the Murray and Murrumbidgee Valleys were surveyed to identify current management practices and potential strategies that could be evaluated in the field during the 2003-2004 rice season (Appendix 1). The Questionnaire focused on soil, crop and water management, weed control and crop nutrition. Five out of six of the registered organic and bio-dynamic rice farmers agreed to participate in the Questionnaire. The result of this Questionnaire was the unanimous view that the efficient control of barnyard grass (*Echinochloa* sp.) was the main production issue for organic rice farmers. Their views supported those expressed during the earlier (RIRDC, 2002) workshops.

Crop Nutrition / Cultivar Experiments

Due to uncertainty regarding irrigation water availability in the Murray Valley during the 2003-2004 production season it was decided that experiments would be confined to the Murrumbidgee Irrigation Area.

The experiments were conducted in the Murrumbidgee Irrigation Area at Bill Barnhill’s farm “Caloro” located at Wamoon. Prior to establishing the experiments the entire farm was certified ‘In-Conversion’. This area achieved full ‘Organic’ status, the top level of organic certification, prior to harvest of the 2004 crop. The experiment site had been previously planted to wheat, followed by a self-seeded non-irrigated legume-based pasture which had a high rye-grass component (90%) when cultivated. Pasture was incorporated using two cultivations with a wide tine scarifier and rice was combine-sown on 17/10/03 at a seeding rate of 150 kg/ha. Fertiliser treatments were surface applied before combine sowing, which then buried the applied fertiliser. The rice then received two flushing irrigations (28/10 and 12/11/03), prior to permanent water being applied on 29/11/03. Establishment and weed counts were taken of all plots before permanent water was applied.

Research trials were undertaken in two areas – i. Crop nutrition / cultivar trials, and ii. Weed management trials.

Two experiments evaluated crop responses to a range of fertilizers permitted under organic standards. Each fertiliser program / treatment used fertiliser manufacturer's recommendations based on a soil analysis report (Table 1- abridged summary) obtained for the site.

	Actual (ppm)	**Desirable** (for medium clay soil)
Phosphorus (P) (Bray1)	2.6	30
Sulphur (S)	11	30
Calcium (Ca)	412 (50.6% base saturation)	750
Magnesium (Mg)	200	105
Ca : Mg	1.52	6.42
Nitrogen (N) – as nitrate	27.6	13
Potassium (K)	114	75
pH (1:2 water)	5.11	6.5
CEC	14.91	14.0

Table 1: Reams and CEC Soil Analysis for selected elements - Experiment sites 1 & 2

The layout of the trial paddock is shown in Figure 2. Fertiliser treatments were applied to the rows. Variety treatments were applied to the columns for rows 1-19 and the same variety was planted for all columns for rows 22-40.

Figure 2: Paddock Layout Experiments 1 and 2

	Column 1	Column 2	Column 3	Column 4			
Row 1					Control		Varieties
Row 2					Guano		
Row 3					Alroc		Pelde
Row 4					Compost		
Row 5					BioAg		Calrose
Row 6					Control		
Row 7					Alroc		YRM54
Row 8					Guano		
Row 9					BioAg		Quest
Row 10					Compost		
Row 11					Control		
Row 12					Alroc		
Row 13					BioAg		
Row 14					Guano		
Row 15					Compost		
Row 16					Fertico 1		
Row 17					Fertico 2		
Row 18					Fertico 3		
Row 19					Control		
Row 20							
Row 21							
Row 22					Fertico 2		
Row 23					Fertico 3		
Row 24					Fertico 4		
Row 25					Control		
Row 26					Fertico 4		
Row 27					Fertico 2		
Row 28					Fertico 3		
Row 29					Fertico 1		
Row 30					Fertico 4		
Row 31					Control		
Row 32					Fertico 1		
Row 33					NGK		
Row 34							
Row 35					Control		
Row 36							
Row 37					NGK		
Row 38					Control		
Row 39							
Row 40					NGK		

Note: The activities in the paddock can be divided into three different trials. The first trial covers rows 1-15, the second trial covers rows 16-19 and the third trial covers rows 22-40.

Figure 1: Organic rice producer Bill Barnhill is pleased with results so far in rice trials conducted on his farm 'Caloro' at Murrami.

Experiment 1 (E1) The objective of this experiment was to assess the effect of the application of organic fertilisers to four rice varieties – Pelde, Calrose (older cultivars) Reiziq and Quest (new cultivars), to a range of commercial organic fertiliser treatments The trial also included a Control. There were three replicates of each variety for each treatment. The layout for Experiment 1 is shown in Figure 2

The five fertiliser treatments in Experiment 1 were:

E1T1 Control: No fertiliser
E1T2 BioAg: 1400 kg/ha aged compost (broiler litter)
800 kg/ha lime
240 kg/ha BioAgPhos
4 kg/ha zinc sulphate
4.5 l/ha Soil and Seed
E1T3 Compost: 2000 kg/ha aged compost (broiler litter)
E1T4 Alroc: 400 kg/ha Alroc Extraphos
40 kg/ha superfine micro lime as liquid lime
E1T5 Guano: 200 kg/ha Guano Gold

Figure 3: Experiment One Layout

		Column 1	Column 2	Column 3	Column 4	
Replicate 1	Row 1					Control
	Row 2					Guano
	Row 3					Alroc
	Row 4					Compost
	Row 5					BioAg
Replicate 2	Row 6					Control
	Row 7					Alroc
	Row 8					Guano
	Row 9					BioAg
	Row 10					Compost
Replicate 3	Row 11					Control
	Row 12					Alroc
	Row 13					BioAg
	Row 14					Guano
	Row 15					Compost
		Pelde	Calrose	YRM54	Quest	

The rates of key elements applied in each Treatment and their cost / ha are shown in Table 2.

	Units applied (kg / ha)				
	E1T1 (Control)	**E1T2**	**E1T3**	**E1T4**	**E1T5**
Calcium (Ca)	-	120	50	32.8	56
Sulphur (S)	-	5	6.5	0.6	-
Phosphorus (P)	-	60	28	5.6	23.2
Nitrogen (N)	-	36	50	-	-
Cost / ha	-	$166.70	$38.00	$154.00	$108.00

Table 2: Units (kg/ ha) of elements applied and cost / ha for Fertiliser Treatments in Experiment 1.

Experiment 2 (E2) This objective of this trial was to assess the effect of the application of four rates / blends of the fertiliser 'Fertico' on the variety Quest. The trial also included a Control. There were uneven replicates as follows:

- 2 replicates – Control, Fertico 1, Fertico 2, Fertico 3
- 3 replicates - Fertico 4

The layout for Experiment 2 is shown in Figure 3

Figure 4: Experiment 2 Layout

Row 1		Fertico 2
Row 2		Fertico 3
Row 3		Fertico 4
Row 4		Control
Row 5		Fertico 4
Row 6		Fertico 2
Row 7		Fertico 3
Row 8		Fertico 1
Row 9		Fertico 4
Row 10		Control
Row 11		Fertico 1

The five fertiliser treatments were***:***

E2T1 *Control:* *No fertiliser*
E2T2 *Fertico 1:* 100 kg/ha Fertico RPR
200 kg/ha Fertico FOF
E2T3 *Fertico 2:* 200 kg/ha Fertico RPR
200 kg/ha Fertico Blood & Bone*
(*applied before permanent water)
E2T4 *Fertico 3:* 100 kg/ha Fertico RPR
100 kg/ha Fertico FOF
200 kg/ha Fertico Blood and Bone
E2T5 *Fertico 4:* 200kg/ha Fertico RPR

The units (kg / ha) and cost of key elements applied in the fertiliser treatments for Experiment 2 are shown in Table 3.

	Units applied (kg / ha)				
	E2T1 (Control)	**E2T2**	**E2T3**	**E2T4**	**E2T5**
Phosphorus (P)	-	10	16	16.5	6
Sulphur (S)	-	6.4	2.8	3.9	2.8
Calcium (Ca)	-	45	94	64	70
Magnesium (Mg)	-	2.4	0.8	1.4	0.8
Nitrogen (N)	-	6	10	13	-
Potassium (K)	-	6	-	3	-
Cost / ha	-	$114.70	$183.40	$191.70	$65.40

Table 3: Units (kg / ha) of elements applied and cost/ha of Fertiliser Treatments in Experiment 2.

Weed Management Experiments

Experiment 3 (E3). During the survey, organic farmers confirmed their most problematic weed was barnyard grass (*Echinochloa spp).* Farmers provided anecdotal evidence that the application of liquid lime and molasses after sowing prevented the germination of some weeds, and that a homeopathic remedy made out of Barnyard grass seeds would decrease populations of barnyard grass over time.

This Experiment investigated the impact on weeds of applications of two different rates of liquid lime with molasses and the homoeopathic Barnyard grass remedy. Each treatment had three replicates. Establishment and weed counts were taken prior to treatments being applied and again prior to permanent flooding of rice. The Treatments were:

E3T1 Control
E3T2 6 kg/ha superfine lime
2 kg/ha molasses
In 160 l/ha water, applied after sowing
E3T3 9 kg/ha superfine lime
2 kg/ha molasses
In 160 l/ha water, applied after sowing
E3T4 Bio-dynamic barnyard grass pepper (3 applications - one application each day over 3 days)
1 ml/ha (potentised solution) in 50 l/ha water, applied before sowing.

There were three replicates of each treatment. Two samples were taken from each plot. The response variables recorded were counts of barnyard grass, clover, rice and other plants in a random quadrat. The layout of the trial is shown in Figure 4.

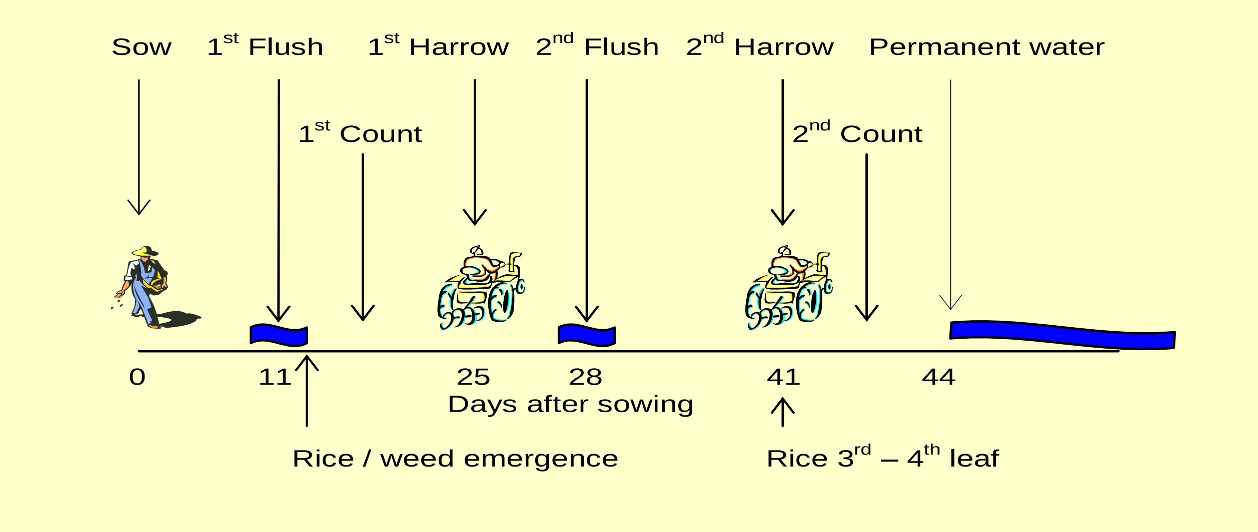
Figure 5: Trial Layout

Rep 1	lime6	Row 1
	lime9	Row 2
	pepper	Row 3
	control	Row 4
Rep 2	lime9	Row 5
	pepper	Row 6
	lime6	Row 7
	control	Row 8
Rep 3	pepper	Row 9
	lime9	Row 10
	lime6	Row 11
	control	Row 12

Demonstration 1 (D1) investigated the effect of post emergent harrowing in the rice crop on weed control. Post-emergent harrowing is a weed control method often used in organic cereal production to remove weeds that germinate following crop emergence.

An initial harrowing was conducted with a normal set of stump harrows following the first flush and when rice and weeds had emerged. A second harrowing using 'Hatzenbichler®' spring tine harrows was carried out following the second flush when the rice was in the third to fourth leaf stage. Counts of rice plants and weeds were taken before the first harrowing and again following the second harrowing (Figure5).

Figure 6. Methodology for post-emergent harrowing in Demonstration 1.



Statistical analysis

Experiment One The design of this trial is a split plot with the variety treatments representing a main plot and the fertiliser treatments being applied to the subplots.

The variety treatments have not been randomised within each replicate. The varieties have been sown in the same order in each replicate, so one column equates to one variety. Due to this arrangement the variety is confounded with column and there is no valid estimate of error for the variety main effects, or for comparisons that involve variety effects.

Due to a single variety being applied to each column the varieties were analysed separately to determine the effect of the fertiliser treatments on each variety. Each variety was analysed using a linear mixed model that had the following general form:

$$Response \sim Fixed\ Effects + Random\ Effects + Residual\ Error$$

Experimental structure was fitted as random effects, treatments were fitted as fixed effects. All models were fitted using the statistical software ASReml. The analysis of variance decomposition is given in Table 4.

Experiment 2 was a completely randomised design with unequal replicates. The analysis of variance decomposition is given in Table 5. The model was fitted using the statistical software ASReml.

Experiment 2 was analysed using a linear mixed model that had the following general form:

$$Response \sim Fixed\ Effects + Random\ Effects + Residual\ Error$$

Table 4: Analysis of Variance Decomposition Experiment 1

		Degrees of freedom	Fixed or Random
Rep		3	
	Mean	1	F
	Residual	2	R
Rep.*units*		12	
	Fertiliser treatment	4	F
	Residual	8	R

Table 5: Analysis of Variance Decomposition Experiment 2

	Degrees of freedom	Fixed or Random
Fertiliser treatment	4	F
Residual	6	R

Experiment 3 was analysed using a linear mixed model that had the following general form:

Response ~ Fixed Effects + Random Effects + Residual Error

Experimental structure was fitted as random effects, treatments were fitted as fixed effects. The experimental structure consisted of three replicates each with four plots (corresponding to treatments) and two samples taken from each plot. All models were fitted using the statistical software ASReml. The analysis of variance decomposition is given in Table 6.

Demonstration 1. Means and Standard Deviations were calculated from plant population counts (plants per quadrat metre).

Table 6: Analysis of Variance Decomposition in Experiment 3

		Degrees of freedom	Fixed or Random
Rep		3	
	Mean	1	F
	Residual	2	R
Rep.Plot		9	
	Treatment	3	F
	Residual	6	R
Rep.Plot.*units*		12	

Harvest and Quality Assessments

Experiments one and two were assessed for yield data - header cut, hand cut (one metre quadrats) and biomass - at harvest and grain quality assessments (Amylose) were conducted post-harvest.

RESULTS

The Farmer Questionnaire

The Questionnaire respondents were all certified by an AQIS accredited organic certification organisation as being either ‘organic’ or ‘bio-dynamic farmers’. The farms varied in the length of time they had been certified, ranging from 1-28 years. The average farm size was 323 hectares in the Murrumbidgee Valley and 1,120 hectares in the Murray Valley. The average area of rice planted annually on each farm was 17-22 per cent in the Murrumbidgee Valley and 5-12 per cent in the Murray Valley.

Three out of five farmers followed a three year pasture phase (subclover, ryegrass, and some phalaris and lucerne) with one year rice, followed by a winter cereal and back into pasture. The other farmers followed the same cropping sequence but implemented a four year pasture phase. All pastures were rotationally grazed either with sheep or dairy cows.

All farmers sod-seeded their rice using a triple disc seeder. Sowing rates on the organic farms varied from 120kg -185kg/ha, compared to ‘conventional’ sowing rates of 90 -130 kg/ha (depending on variety) for conventionally combine drilled grown rice. Most farmers agreed that apart from market preference, the major factor influencing variety selection was crop vigour. Only one farmer indicated they undertook regular soil testing. All farmers applied phosphorus (P) to pastures or rice (rates ranged from 8 kg/ha – 38 kg/ha total P). One producer irregularly applied gypsum at 2.5 tonnes/ha. Only one producer applied additional nitrogen (N) to rice in the form of composted cow manure (75kg/ha total actual N), the others relying on symbiotic N fixation from leguminous pastures. Four out of the five farmers utilised some form of soil or foliar microbial preparation. Two farmers direct drilled cereal crops into standing or grazed rice stubble, two cut and baled (one occasionally burning) and one mulched the rice stubble.

Weed management during the rice establishment phase used a combination of livestock grazing and mechanical removal (two farmers used harrowing and slashing), and following establishment, water depth. The time between crop flushing irrigations at establishment of the rice crop varied from 10 – 16 days, but not exceeding 20 days.

Two out of the five farmers had grown green manures (oats and vetch) for grazing and incorporation. Three farmers felt it would be possible to substitute green manures for the pasture phase as a potential source of N for the following rice crop.

Rice yields ranged from 5-8 tonnes /ha. Higher yields (7-8 tonnes/ha) were achieved where farmers practised a 3 year, as opposed to a 4 year pasture rotation, suggesting that N fixation of pastures is sub-optimal beyond 3 years if adequate rice yields are to be achieved. This is supported by the research of Beecher et al (1994) who concluded that there is no advantage to rice grain yields from a legume pasture phase of >2 years duration, provided the legume pasture is well established and maintained. Furthermore, Herridge (1982) found that N fixation in pastures declines as soil nitrate-N levels increase over time.

Detailed responses to the Questionnaire are presented in Appendix 2.

Crop Nutrition / Cultivar Experiment Results

Experiment 1 As shown in Table 7 the effect of the fertiliser treatments was not significant for yield and amylose of each variety.

Table 7: Incremental F-statistic and p value for treatment effect for Experiment One

		Treatment Effect	
Variety	**Response variable**	**Incremental F-statistic**	**p value**
Calrose	Header Cut	0.26	0.894
	Biomass	1.68	0.230
	Hand Cut	2.10	0.155
	Amylose	0.30	0.870
Pelde	Header Cut	0.82	0.546
	Biomass	1.38	0.323
	Hand Cut	1.32	0.340
	Amylose	1.40	0.303
Quest	Header Cut	1.46	0.285
	Biomass	0.38	0.818
	Hand Cut	0.38	0.820
	Amylose	1.08	0.415
YRM54	Header Cut	0.33	0.848
	Biomass	1.97	0.193
	Hand Cut	1.98	0.191
	Amylose	0.34	0.847

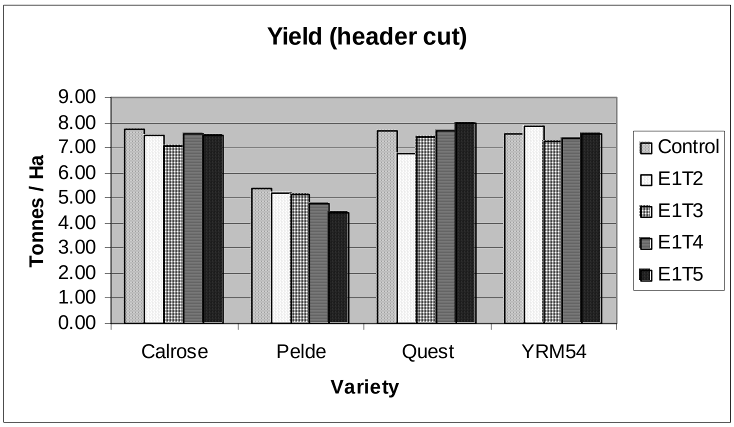


Figure 7: Effects of fertiliser treatments (Control, E1T2-E1T5) on yield (header cut) of 4 rice cultivars

Experiment 2 As shown in Table 8 the effect of the fertiliser treatments on yield and amylose was not significant.

Table 8: Incremental F-statistic and p value for treatment effect for Experiment 2

	Treatment Effect	
Response variable	**Incremental F-statistic**	**p value**
Header Cut	0.54	0.716
Biomass	1.11	0.433
Hand Cut	1.56	0.299
Amylose	0.41	0.796

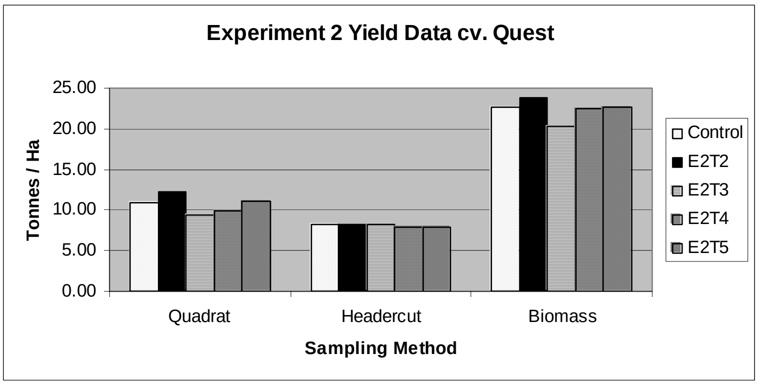


Figure 8: Effects of fertiliser treatments (Control, E2T2-E2T5) on yield – (quadrat and header) and total biomass of Quest

Weed Management Experiment Results

Experiment 3 As shown in Table 9 the effect of the treatments was not significant. However, results from E3T4 (Barnyard Grass Pepper) suggests a trend towards plant population decline in barnyard grass and rice.

Table 9: Incremental F-statistic and p value for treatment effect

	Treatment Effect	
Response variable	**Incremental F-statistic**	**p value**
Barnyard grass	0.69	0.569
Clover	1.15	0.353
Rice	1.36	0.284
Other	0.32	0.813

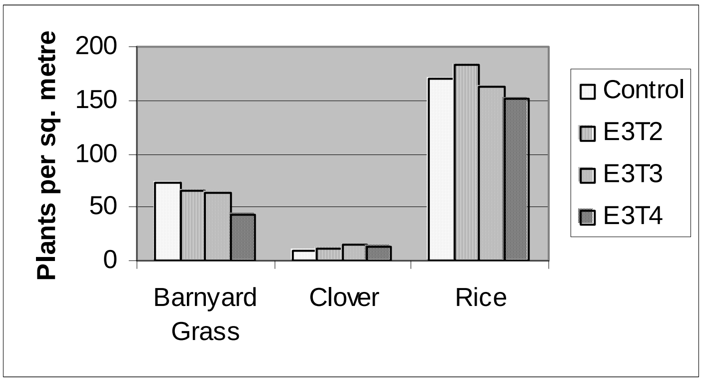


Figure 9: Effect on plant density of weed treatments in Experiment 3.

Demonstration 1. Counts of both rice and barnyard grass plant populations revealed harrowing had removed up to 98% of the barnyard grass, whilst only 3.8% of the rice was removed (Table 10).

	Plants/m^2 before harrowing		Plants/m^2 after harrowing	
	Rice	Barnyard Grass	Rice	Barnyard Grass
Mean	268.8	152.4	260.4	8.8
STDev	42.3	110.8	42.4	2.3

Table 10: Effect of harrowing on rice & barnyard grass populations

DISCUSSION OF RESULTS

The experiments were confined to the Murrumbidgee Irrigation Area due to reduced water allocations which particularly affected the Murray Valley. Experiments were limited to one season, but if the experiments had been conducted over at least one full rotation there may have been more conclusive results on the long-term effectiveness of the fertiliser and weed treatments.

Crop nutrition / cultivar experiments

There were no significant differences in yield responses to fertiliser treatments in either Experiment 1 or Experiment 2. Yields of Quest and Reiziq (YRM 54) ranged from 6.8 t/ha to 8 t/ha, which were below the industry target yield range of 10-12 t/ha for these cultivars. These results were however comparable with the district averages of conventionally produced Quest (9.3 t/ha) and Reiziq (10.3 t/ha) during 2003-04. Calrose yielded 7-7.9 t/ha, which was also below the 10.8 t/ha yield potential of conventionally grown Calrose. These results are however above the 50-75% yield reduction for organic rice cited in 2003 by SunRice.

A number of factors potentially contributed to the lack of yield response from the fertiliser treatments. These are discussed below.

Nitrogen

Nitrogen is the main nutrient which influences the yield potential of rice. Ricecheck (Anon 2004) recommends minimum fertiliser N application rates of between 60-120 kg/ha N for medium grain rice varieties growing in a soil of moderate fertility following a fair subclover /grass pasture. Clearly the yields obtained from Experiments 1 and 2 indicate that, crop N requirements had not been met by any of the fertiliser treatments. An understanding of nitrogen cycling within the rice paddy may help to explain the experimental results.

Nitrogen is present in the soil in three main forms: organic, ammonium and nitrate. The two sources of plant-available N in the early stages of growth are mineralised organic N (from legume pastures and organic matter decomposition), and fertiliser applied N. The main method to determine rice crop N level is the NIR Tissue Test at panicle initiation.

Due to the flooded conditions associated with rice production, it is necessary to use ammonium N fertiliser sources instead of using nitrates. The reason is that nitrates are lost due to denitrification / leaching under the flooded conditions. Ammonium N can be obtained from the breakdown of organic matter and organic fertilisers, or can be added to the soil as artificial fertilisers such as urea. Once dissolved, ammonium nitrogen can be tightly held within the soil and is rarely leached out.

Organic nitrogen (mainly derived from plant residues, animal manures and nitrogen fixation by legumes) must first undergo microbial digestion into simpler products and then eventually into ammonium nitrogen before it is available to rice. The rate of this process is slow and depends on the type of organic matter in the soil (the higher the C:N ratio the slower the decomposition), the microbial activity, soil pH, aeration, moisture and temperature.

In drill sown rice production, the flooding and draining (flushing) during establishment induces varying aerobic and anaerobic environments which varies N cycling in soils. Mineralization of organic nitrogen occurs slower in flooded (anaerobic) soils maintaining residual N supplies, and faster in non-flooded (aerobic) soils exposing N to potential losses. By supplying oxygen (an aerobic condition) via draining, NH_4^+ conversion to NO_3^- (nitrification) and organic matter breakdown is accelerated. Re-flooding then imposes an anaerobic condition where the newly-formed NO_3^- is lost through denitrification and leaching.

To determine how much N-fertiliser to apply to a crop it is necessary to know the amount of N supplied through soil N mineralisation (Angus *et al.* 1994). In the experimental site the pre-planting soil test indicated a reservoir of 33 kg/ha mineral N (27.6 mg/kg nitrate N x 1.2)[(2)]. However, due to the abovementioned losses, not all of this mineralised N will be recovered by the crop. Angus *et al*. suggest that the recovery rates of mineralised N by a rice crop may be as high as 97%, however, Beecher *et al.* (1994) reports a much lower recovery of 70%. Losses would be expected to be greater in a cultivated versus sod-seeded (pasture) seed bed. Assuming therefore that up to 30% of the mineralised N may have been lost in the trial site during rice establishment, the quantity of soil N remaining for crop growth would be around 23 kg/ha mineral N.

Various researchers have reported that the recovery of fertiliser N by rice is much lower than that of soil N. Humphries *et al* (1987) reports the plant recovery of fertiliser N at sowing was only 3%, with 80% unaccounted for, the majority being lost from the top 20cm of soil due to the rapid rates of nitrification and denitrification during the flushing period. Plant recoveries of fertiliser N surface applied before permanent flood (after flushing) have tended to be higher than from application at sowing (before flushing), usually falling in the range 25-40%, with losses around 40% (Patrick & Reddy 1976; Reddy & Patrick 1976, 1978). IRRI (1983) reported that intermittent flooding in the field increased losses by 150% over continuous flooding.

Whilst these studies reflect the bioavailability of readily available chemical fertilisers such as urea, organic fertilisers such as manures must first undergo conversion by soil micro-organisms into ammonium nitrogen (NH_4^+) before becoming available, the timing of release dependent on factors such as the C:N ratio of the organic matter, microbial activity, soil pH, aeration, moisture and temperature.

Clearly, timing of fertiliser application is a critical issue for rice yield. Humphries *et al* (1987) estimated that the agronomic efficiency (56 kg grain per kg applied N) of surface applied fertiliser N was greatest when applied just prior to permanent flooding in a combine-sown rice crop. This compared to an agronomic efficiency of 8.2 kg grain per kg N when fertiliser N was applied at sowing.

Analysis of the method used to establish the rice in these experiments reveals a number of avenues of potential soil N loss. Soil disturbance during ground preparation and combine sowing increases the extent of N mineralisation especially in high clay soils (Craswell and Waring, 1972). As a result, nitrate levels at sowing are normally higher in cultivated than in undisturbed soils, leading to increased losses during flushing and permanent flooding due to denitrification. Sod-seeding rice into a legume pasture, the method commonly used by organic producers, is the preferred sowing method for preserving organic nitrogen as there is a minimum of cultivation and hence plant decomposition. Because little air remains in the soil after flooding to assist breakdown, plant

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[2]Calculated using the following formula: kg N/ha = $\frac{\text{Soil test value (a) x soil bulk density BD (b) x sample depth (c)}}{10}$

Where: a = 27.6 mg/kg nitrate N; b = 1.2 g/cc; c = 10cm decomposition to ammonium nitrogen is very slow and nitrogen becomes slowly available over the rice growing season. This then provides an ideal release pattern of nitrogen for the nutrient responsive growth stages of rice. (Anon, 1984)

These experiments have indicated there are no yield benefits to be obtained, at least in the short-term, from additional application of fertiliser applied N. However, there may be some long-term benefit to be obtained from repeated applications of some organic fertilisers. For example, long-term repeated applications of composted cattle manure and various other kinds of compost have been shown to slowly increase the level of mineralized nitrogen, although the pattern of increase is different for each material (Figure 10).

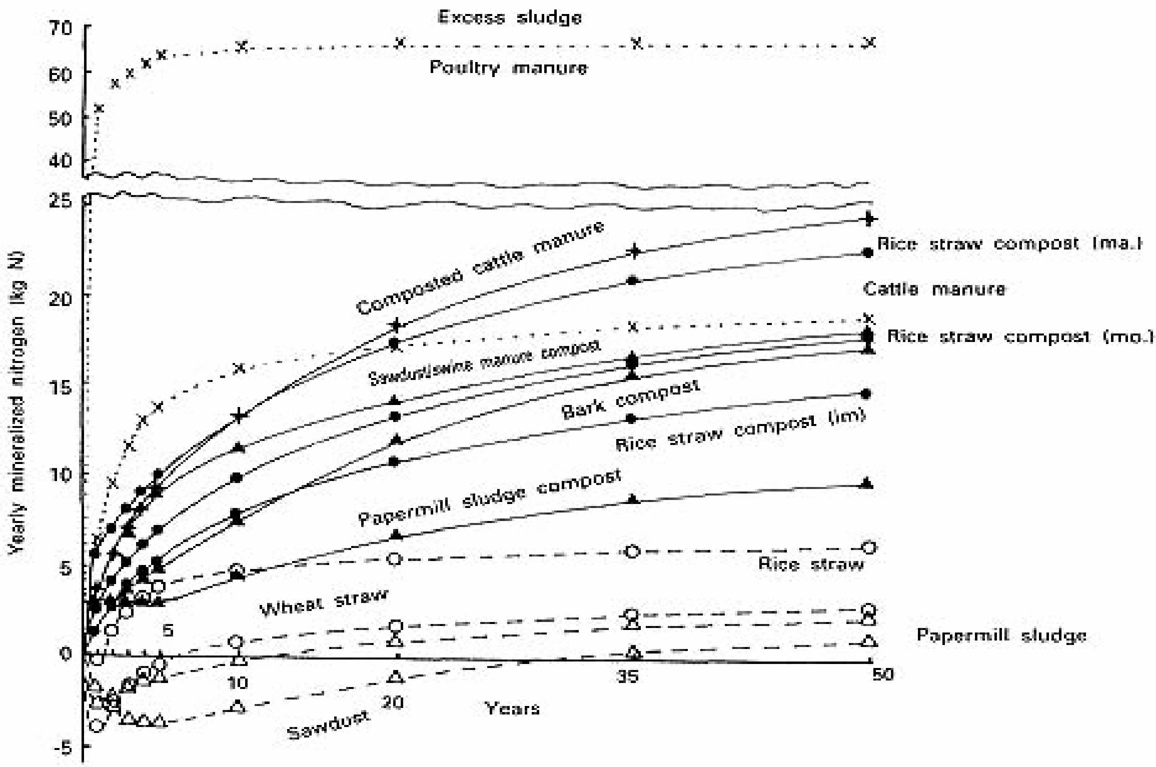

Figure 10: Changes in the amount of nitrogen mineralized each year in temperate rice culture, derived from successive applications of 1 mt (on a dry matter basis) of organic materials for 50 years. (Notes: ma.: mature; mo.: moderately mature; im.: immature) Source: Shiga *et al.* 1985

The solution to improved rice crop N nutrition in organic rice production systems is to ensure adequate N is provided from symbiotic fixation of legumes and through the timely addition of organic fertilisers. Under current production systems, organic rice nutrition depends largely on the symbiotic fixation of nitrogen by legume pastures prior to the rice phase of the rotation. Under optimal conditions the proportion of N fixed by mixed pastures with a largely legume (sub clover) component could be expected to be around 100kgN/ha. However, this reduces significantly with pasture age and as legume percentage declines.

The health of a legume pasture is a key factor in determining the quantity of N fixed. Factors influencing N fixation include pasture nutrition, water use efficiency and grazing pressure. Symbiotic N fixation of legumes is highly sensitive to soil water deficiency. (Zahran, H.H.1999). Farmers surveyed in this project agreed that water availability was likely to impact on future rotation options. The farmers interviewed in the survey currently allocate very little water to pasture production. Under-watering of pastures is therefore likely to be leading to reduced N fixation.

Green manures as an alternative source of nitrogen

All the organic farmers surveyed expressed an interest in trialling green manuring. Leguminous green-manure crops can supply 30 to 50 percent of the nitrogen needs of high-yielding rice varieties. The availability of green-manure nitrogen depends on the quantity, quality, and type of green-manure crop; the time and method of application; soil fertility; and cropping method. (Westcott and Mikkelsen 1988)

Other benefits of green manure crops include improved soil tilth, and the addition of organic matter leading to an enhancement of soil structure due to increased soil pore space, microbial activity, and increased cation exchange sites for nutrients. The use of high density legumes as green manures has been shown to provide opportunities within a crop rotation for improving soil nitrogen, breaking cereal disease cycles, weed management, and as a source of grazing or conserved fodder (Bowcher, A and Condon, 2004).

Green manuring has been successfully used in Californian rice production. The aim being to replace legume pastures with green manures in the rice rotation as the major source of N. N cycling within the farming system would be enhanced due to a greater frequency in the incorporation of organic matter and mineralisation of symbiotically fixed N.

Californian organic rice farmers utilise the following approach with green manuring:

> ‘The Lundbergs of Richvale, California, are large-scale organic rice producers who use a purple vetch green-manure crop as their nitrogen source. They mow the vetch in spring to 6 inches and drill rice seed directly into the vetch mulch. Following planting, they flood the field to kill the vetch and germinate the rice seed. Following germination, they drain the field and allow it to dry, and then the field is re-flooded for the season.’ (Sullivan, P. 2003)

The development of short season rice varieties may facilitate the use of green manures by allowing more time for plough down and decomposition prior to rice seedbed preparation. Incorporation of green manures would need to coincide (as near as possible) with the sowing of the following ‘catch’ crop in order to avoid N losses through leaching. Alternatively, grazing or mowing of green manures, followed by disc drilling of rice would further reduce N losses.

Phosphorus

Preliminary soil analysis of the trial site revealed low levels of available P (Bray 1 = 2.6 mg/kg; 30 mg/kg is desirable). P recommendations for rice production in Southern NSW are 20kg/ha actual P. P applications in the applied organic fertiliser treatments ranged from 5.6 – 60.0 kg/ha. Treatments 2, 3, and 5 clearly meet the recommended rate for applied P, and a response to at least some of the Treatments compared to the Control should have been expected.

The apparent lack of P response in the trials is perhaps due to the fact that the majority of the crop’s requirements for P could have been met as a result of natural soil chemical processes which occurred during permanent flooding. This is discussed below.

A major benefit of growing rice under flooded conditions is that the resulting soil reactions increase the availability of phosphorus (Patrick and Mahapatra 1968; Ponnamperuma 1972). This occurs under the rice paddy’s anaerobic (submerged) conditions where the reduction of iron phosphate results in increasing P availability. The reduction of paddy soils during permanent flooding is also accompanied by an elevation in soil pH, which stabilises around 6.5. This rise in pH further enhances P availability by increasing the solubility of iron phosphate and aluminium phosphate by a factor of 10 times per unit rise in pH (Kyuma, K. 1995). Small quantities of organic P are also released during the decomposition of organic matter. Rice therefore rarely suffers from phosphorus deficiencies. This is supported by the findings of Yadvinder-Singh *et al.* (2000) and Kawasaki (1953) (cited in Kyuma, K. 1995). Yadvinder-Singh *et al.* found that P application to rice increased P accumulation by rice, but it did not consistently increase rice yields because flooding decreased soil P sorption and increased P diffusion resulting in a higher P supply to rice. Kawasaki found that even when P was not applied, the yield decline was only 5% of the complete (fertilised) plot for rice, whereas it was as severe as 31% for wheat and barley. This means that in paddy soils, the mechanisms outlined above maintained the P status at a high enough level, even when no P had been applied. Any beneficial P response is more likely to be to cereal crops or pastures which may follow rice in the rotation. Unfortunately, post harvest soil analysis of the experimental site was not undertaken so determination of residual soil P was not possible.

Phosphorus and legume productivity

The major limiting factor for pasture legume growth (and hence, nitrogen fixation) is considered to be phosphorus It is recommended that sub-clover pasture receives 13.5kg/ha actual P. The residual effect of P fertilizer application can persist for several years, and management must emphasize the build-up and maintenance of adequate soil-available P levels to ensure that P supply does not limit crop growth and N use efficiency.

A number of contributing factors may influence P availability in legume pastures. The P in mineral fertilizers such as rock phosphate is largely insoluble in water as well as in citric acid. They are suitable in strongly acid soils or organic soils. The phosphorus is slowly released by the action of microbes and remains in the soil over a longer period of time. Hence, in organic systems P application has to be considered well in advance of requirements. Researchers investigating the availability of organic fertilisers have suggested that soil analysis should include organic P, which is likely to be an important source of P in organically farmed soils. (NOAG, 1999)

Calcium

All fertilisers supplied by manufacturers were high in calcium (32.8-120 kg/ha). The preliminary soil analysis reveals a calcium level of 412 ppm (Morgan Extract). Exchangeable calcium was 7.55 $cmol^+$/kg, and the CEC was 14.91 $cmol^+$/kg (Ca saturation was 50.64% of the CEC). Ca:Mg ratio was 1.52 (Percent Base Saturation). Dobermann and Fairhurst (2000) report Ca deficiency in rice is likely to occur when soil exchangeable Ca is <1 $cmol^+$/kg or when the Ca saturation is <8% of the CEC. For optimum growth, Ca saturation of the CEC should be >20%. Clearly the trial site should have provided adequate calcium for crop growth. However, for optimum growth, the ratio of Ca:Mg should be > 3-4:1 for exchangeable soil forms, suggesting Mg is in excess. It can only be assumed that by raising Ca levels, manufacturers aimed to raise the Ca:Mg ratio to the desirable level. It is arguable if this would significantly impact on rice yields but may benefit subsequent legume pastures.

Weed management trials

There was no statistical evidence to suggest that ‘anecdotal’ weed treatments had any impact on weed numbers or species. However, results from E3T4 (Barnyard Grass Pepper) does suggest a trend towards plant population declines in barnyard grass and rice. This could suggest an allelopathic interaction against grass species and further trials in this area are warranted. Note that clover populations did not exhibit a similar decline in population due to this treatment.

Results from D1 showed that the harrowing could produce an effective post-emergent control for barnyard grass, providing the timing of harrowing and soil condition is optimal. Whilst some crop stand thinning did occur this could be compensated for by increasing sowing rate by 3-5%.

IMPLICATIONS AND RECOMMENDATIONS

Organic rice farmers establish their crops by direct drilling into a well grazed pasture, which is then flushed on at least two occasions prior to permanent water being applied. Typically, N is supplied to organic rice crops through mineralisation of rhizobial N provided by legume pastures.

These experiments relied on crop N supplied through soil mineral N and fertiliser N. Soil mineral N at the start of the trial was low, most likely from the grass dominant pasture which preceded in the rotation as well as the crop establishment techniques which may have facilitated denitrification. The experiments failed to show any response to the organic fertilisers applied in any of the treatments.

The augmentation of rhizobial N provided by a good subclover pasture (90%+ legume component) with smaller quantities of fertiliser applied nitrogen could be considered by farmers, however, these trials have not indicated any short-term cost benefit of such a decision. A totally dominant legume pasture may however conflict with the organic philosophy of providing a mixed diet (grasses, herbs and legumes) for livestock.

Despite the fertiliser / cultivar trials failing to show significant differences between the treatments and controls, they did highlight the need for a more rigorous and accurate assessment of nutrient flows within organic rice rotations. Experiments ideally should be carried out over a minimum of two full rotations (4-6 years) to asses any cummulative benefits from fertiliser applications.

Whilst sod-seeding provides the best method to optimise N availability to rice, farmers need to carefully consider how to manage N availability from legume pasture and organic fertilisers to avoid environmental losses. In order to optimise nitrogen availability to rice it is recommended that organic farmers aim to:

1. Maximise symbiotic N fixation during the pasture phase by;
   - ensuring a high (at least 90%) legume component in pastures
   - shortening the pasture phase to 2 years
   - improve pasture nutrition (particularly P), water use efficiency and grazing management;
   - investigating the value of green manuring within the farming system to increase N cycling, provide weed breaks and alternative cropping and grazing opportunities.

2. Minimise N losses during rice establishment by:

If direct drilling:

- drilling rice into heavily grazed irrigated pasture, minimise flushing and apply permanent water as soon as possible to prevent denitrification;
- apply organic fertilisers or composts to the rice crop prior to permanent water to minimise N losses;

If combine sowing:

- incorporating pastures as near to rice sowing as practical to minimise the potential for denitrifcation;
- incorporate organic fertilisers in the top 10cm of soil (in combine sown crops) to reduce N losses;

Applications of composted manures or organic fertilisers based should be based on crop requirements and soil analysis of ‘available’ nutrients and from the NIR Tissue Test results from previous rice crops. Organic farmers should carefully monitor crop yield responses to fertiliser applications and consider the cost benefit of fertiliser applications.

These trials demonstrated that organic rice farmers can significantly reduce weed competition during crop establishment in combine-sown rice by implementing strategic post-emergent harrowing, without significant crop damage. Results showed that rice establishment losses due to post-emergent harrowing could be compensated for by increasing rice seeding rate by 3 - 5%. Harrowing should be done on a dry, warm, sunny day for the most effective weed kill and to reduce seedling damage and the spread of disease. Flushing or permanent flood should be applied at least 3-4 days after harrowing to allow time for the weeds to die and for rice plants that were covered during harrowing to re-emerge. Harrowing damp or wet plants should be avoided as this increases crop damage and may also increase the spread of diseases. Harrowing should only be considered when the seed has been placed below the depth of harrowing to avoid disturbing the seed and the primary root system. Precautions to reduce the risk of crop injury include the use of tine or flexible harrows (such as Hatzenbichler® harrows), reduced ground speed, cross harrowing and a reduced angle of harrow tines.

Figure 11: Post-emergent harrowing using Hatzenbichler® harrows in D1.

The critical time for weed competition in rice is within the first 20-30 days after seeding, so early rice seedling vigour is important in determining the competitive outcome. Calrose, Quest and Reiziq are known to have greater seedling vigour than Pelde (Lewin, L., pers com. 2005). Observations from these trials did not show any obvious seedling vigour in Calrose, however this may have been due to the fact that the seed used had been stored which reduced its viability. This highlights to organic farmers the importance of utilising fresh, well stored seed for sowing, and is perhaps one argument against choosing older varieties, where obtaining fresh seed is often difficult. Farmers cite their preference for Pelde in organic systems is largely due to the cultivars lower N requirements. However these lower N requirements are relative to yield performance. Ultimately, market preference for newer cultivars will most likely always be the determining factor governing variety selection in organic rice production. Rice breeding efforts which focus on enhancing cultivar seedling vigour and improving N use efficiency can only serve to improve the performance of organic rice production. Shortening the rotation to include crops such as green manures could provide additional cultural opportunities to enhance weed control in rice and provide alternative cropping opportunities. However choice of alternative crops may be partly limited on heavy clay and salt-prone soils which may be unsuitable for most other crops.

FUTURE RESEARCH

The authors recommend that future research investigate different organic management systems and their effect on crop yield (rice, cereal and legume dominant pasture), N and P uptake, and weed populations, for example: (i.) pasture, direct drill, +/- fertiliser (various rates and application times); (ii) incorporated pasture, combine sown, +/- fertiliser (various rates and application times); (iii) green manure, mown, direct drill, +/- fertiliser (various rates and application times); (iv) incorporated green manure, combine sown, +/- fertiliser (various rates and application times).

Whilst further trials are needed to evaluate the effect of long-term management practices on weed populations, the harrowing demonstration showed that organic rice farmers could reduce weed competition during crop establishment in combine-sown rice by implementing strategic post-emergent harrowing, without significant crop damage. Rice establishment losses due to post-emergent harrowing were minimal and could be compensated for by increasing rice seeding rate by 3 - 5%. Research should be undertaken to further evaluate this method as a control for Barnyard grass and other weeds during crop establishment.

PUBLICATIONS/ACTIVITIES UNDERTAKEN AS A RESULT OF THIS PROJECT

Overviews of the project and preliminary results of the studies were presented at organic industry forums, in publications, the print media and at a field day.

Conference presentations/papers

Neeson, R and Koenig, T. (2003). "Facilitating Conversion of Organic Rice and Soybean Production in the NSW Riverina." Presentation at: Organic Futures for Australia. 2nd National Organic Conference Adelaide October 2-3, 2003. In: OFA, (2003). *Organic Futures for Australia.* 2nd National Organic Conference Adelaide October 2-3 2003. Record of Proceedings. Organic Federation of Australia, 2003.

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Neeson, R. (2005). Improving system sustainability in Riverina organic rice production – fertilisers & weed control. Presentation at 2005 Rice Research & Extension Meeting. Yanco Agricultural Institute, July 25, 2005.

Neeson, R. (2005). Aspects of organic rice production. Presentation at RIRDC Rice Research & Development Committee Rice R&D Workshop. Yanco Agricultural Institute, August 1-2, 2005.

Paper accepted to be presented at International Federation of Organic Agricultural Movements World Congress in Adelaide (September, 2005). Paper title: "Improving system sustainability in Riverina organic rice production."

Publications

Neeson, R. and Koenig, T. (2004). "Improving yields of organic rice." In: *IREC Farmers Newsletter*. 60th Anniversary Edition. No. 167, winter 2004. IREC, 2004.

Koenig, T. & Neeson, R (2004) , "Organic Rice: Rice CRC explores productivity solutions".

In: *Organic News*, NSW DPI Electronic Newsletter February 2004. ISSN 1449-325X http://www.agric.nsw.gov.au/reader/news-organic

Print media

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Field days

Pre-harvest field day on Murrami trial site in March 26, 2004.

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Figure 12: Discussing progress with organic rice trials are (from left): organic farmer Bill Barnhill, project managers Tobias Koenig & Robyn Neeson, & Rice CRC Director, Dr. Laurie Lewin.

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APPENDIX 1

Questionnaire of Organic/Bio-Dynamic Rice Grower Practices

Name (optional)

Certification
Organic / Bio-Dynamic since:
Certification organisation and level:

Farm Details
Farm total area (Ha):
Area suitable for rice (Ha):
Area of rice per year (Ha):
Area of laser levelled land (Ha):

Soil
Soil type:
Is salinity a problem in your area?
Is salinity a problem on your farm?
Soil tests:
Use of consultants:

Rotations
Years of pasture phase:
Green manure crops:
Could green manure crops be substituted for pasture phase?
Management of green manures:
Other crops grown:
Management of pastures:
Composition of pastures:
Nodulation:
Livestock:
Rotational grazing:
Pasture spelling periods:
Number of paddocks:

Water
Water source:
Water license:
Water management:
Water use ML/Ha (Rice):
Water use ML/Ha (Pasture):

Land Management:
Re-establishment of pasture:
Stubble management:

Inputs
Fertilisers:
Biologicals (EM etc.):
Bio-Dynamics:
Use of foliar sprays:

Sowing
Seeding rate and depth:
Seed treatment:
Sowing method:
Pre-germinate seed?
Date of sowing / delayed sowing used:
Cultivars used:
Preferred cultivars:

Weed management
What are the main weed problems?
Summer fallow:
Grazing – critical stocking rate:
Mechanical:
Water:
Time between water flushing:
Weed management in channels:
Peppering of weeds:
Nutrition – impact on weeds:

Insect / other pest management:

Harvest/Yield:
Delaying harvest:
On-farm grain storage:
Yield:
Yield penalty:

Cost of production:

APPENDIX 2

Farmer responses to organic/bio-dynamic rice questionnaire

	Producer 1	Producer 2	Producer 3	Producer 4	Producer 5
Certification					
Organisation & level	NASAA 'Organic'	NASAA 'In-conversion Organic'	BDRI 'Bio-dynamic'	BDRI 'Bio-dynamic'	NASAA 'Organic'
Certified since	1994	2003	1988	1976	
Farm area (Ha)					
Total	525	270	2083	753	375
Suitable for rice	460		625	243	
Rice per year	61	40-50 (depending on water availability)	146	41	83
Laser levelled	53	No response	1667	1440	None
Biodiversity					
Tree planting & native vegetation	30 Ha remnant bushland	Tree shelter belts planted	Yes	Not much	No response
Soil					
Soil types	Heavy red and grey clays & sandy loams.	Red clay loam to grey lignum country	Heavy clay - sandy	Clay-Loam	Self-mulching clay, Coree clay loam
Is salinity a problem in your area?	Yes	No response	Yes	Yes	No response
Is salinity a problem on your farm?	No	No response	Yes, addressed by drainage recycling, trees	Yes. Areas affected are manageable	No response
Soil tests	Yes	Not yet, this year	Yes	No	No response
Use of consultants	Yes	No	Once	No	No response
Rotations					
Years of pasture phase	4	3 year pasture, rice, oats direct drilled into stubble,	3 years pasture followed by 1 year rice	3-4 Pasture-rice-wheat	3 years subclover, followed by rice then

Green manures (grms) Management of grm's Other crops	No but would like to grow N/A Oats, barley	then pasture again No N/A Oats	oats/vetch for grazing No response Wheat or barley	Oats / vetch for feed No response Barley	oats No N/A Oats
Pasture management Pasture composition Nodulation Could green manure crops be a substitute for pasture phase? Livestock Rotational grazing Pasture spelling Number of paddocks	Subclover & ryegrass good Yes 90 goats, 270 sheep, sheep agistment Yes Yes 16	Subclover & ryegrass No response No response 350 1st X ewes. Poll Dorset rams Yes Yes No response	Subclover & ryegrass Good Yes Merino crossbred lambs Yes Yes No response	Subclover, ryegrass, lucerne Good Yes 330 Holstein Friesian / Jersey cross Yes Not adequate No response	40% clover, ryegrass, phalaris No response No response 400 X bred Dorper ram Yes Yes No response
Water Source License Management Rice water use (ML/Ha) Pasture use (ML/Ha)	Murray 870 ML Border check/contour & laser landformed 11 None unless big year	Murrumbidgee 1450 ML Contour, laser landformed 12-15 No response	Murray 2700 ML Contour District average 2-3	Murray 800 ML Contour 12-15 3	Murrumbidgee 2000ML Contour flood 13 No response
Land preparation Do you re-establish pasture	Yes	Sod sowing rice into	Volunteer or re-	Under-sow	None

		pasture	seeded		
Stubble management	Mulching	Direct drill oats into stubble	Bale rice straw, burn	Bale rice straw	Direct drilling oats
Inputs					
Fertilisers	Bio Ag Phos 200kg/Ha to pasture & rice	BioAg Phos 200 kg/Ha, Rockdale compost 2.5 t/Ha	RRP 50kg/Ha Sometimes gypsum 2.5 t/Ha	RPR 65kg/Ha	Guano 125 kg/Ha
Biologicals (eg EM)	BioAg Soil & Seed. BioAg Digest	No	No	No	EM – 3 applications
Bio-Dynamics	No	No	BD500	BD500	No
Foliar sprays	Yes	No	No	No	No
Sowing					
Seeding rate & depth	185 kg/Ha, 2.5cm (even depth a problem)	150 kg/Ha	120 kg/Ha, 2cm	165kg/Ha 1-1.5cm	130 kg/Ha
Seed treatment	BioAg Soil & Seed	No	No	No	No
Sowing method	Triple disc sod seeder	Disc sod seeder	Triple disc sod seeder	Triple Disc – not happy as depth variable	Sod sown
Pre-germinate seed?	No	No	No	No	No
Date of sowing/delayed sowing used	2-3 weeks later than conventional	No delayed sowing	End of September	Whenever can sow into moisture	Yes
Cultivars used	Koshi	Short grain	Amaroo, Quest	Quest	Koshi
Preferred cultivars	Langi if fertility good	More vigorous ones	Vigorous ones	No preference	Pelde would be good
Weed management					
What are your main weed problems?	Barley grass, millet	Barnyard grass,	Barnyard grass, pin rushes	Barnyard grass	Barnyard grass
Summer fallow	No	Rotation	Yes, after rice	No response	No response
Grazing	Yes	Yes – sheep		Yes – as many stock	Yes

				as it takes to keep weeds down	
Mechanical	No	Harrowing	No response	Slashing	No
Water	Yes	Sceptical about benefit for weed management	No	Yes	Yes, timing
Time between flushing	14-16 days. Tries to stretch it out but not over 20 days	14 days	10 days	Depending on sowing equipment 10-15 days	No response
Management in channels	Weed cutter (home made)	No response	Rotary hoe & disc excavator	Rotary hoes or excavator	No response
Peppering	No, but would look at.	No response	Would consider	Yes if it works	No response
Nutrition – weed impact	Yes	Yes, important part of weed management	Yes	Could be	No response
Insect / other pests	None	None	Leaf miner – drains water for a week to control	No insect problems. Slime can be a problem	None
Harvest/Yield					
Delaying harvest	Yes better threshing	No	Contractor to harvest. No delayed harvest.	No	Harvests own crop
On-farm grain storage	No, straight to silo	No response	No, straight to silo	Yes	No response
Yield	5.7-5.9 tonnes/Ha	7 tonnes/Ha	5 (new farm)-7.5 tonne/Ha	5 tonne/Ha	7-8 tonnes/Ha
Yield penalty	No	30-40%	No response	No response	No response
Cost of production	No response	50% of gross income	No response	No response	No response